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CORN AND SOYBEAN MARKETING STRATEGY EVALUATION FOR SOUTHWEST INDIANA FARMS

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Abstract

Various corn and soybean marketing strategies' historical performance were examined from the 2004/2005 to 2022/2023 crop years. Strategies included combinations of pre-harvest sales, harvest sales, and sales from on-farm storage later in the marketing year. Strategy evaluation explicitly included on-farm storage costs based upon financial records from a commercial scale southwest Indiana farm in addition to the opportunity costs of storing corn and soybeans post-harvest. Cash prices from southwest Indiana markets near the Ohio River were used to generate historical returns. Results indicate that storing corn and soybeans after harvest generated, on average, higher corn and soybean returns compared to grain sold at harvest. Strategies that included pre-harvest sales made in May using hedges placed in December CBT corn futures for corn and November CBT soybean futures for soybeans also provided higher average net returns than strategies that relied solely upon harvest and post-harvest sales. Combining pre-harvest sales of corn and soybeans made using futures market hedges with unhedged storage following harvest generated the highest net returns, on average, for both corn and soybeans. Results provide evidence that producers should include pre-harvest spring sales and sales from on-farm storage following harvest as part of their crop marketing strategies.

Key Words: grain storage strategies, hedging, pre-harvest sales

Introduction

Corn and soybean production and sales dominate agriculture in the United States of America (U.S.). According to the U.S. Department of Agriculture (USDA) in 2023 the combined harvested area of corn, soybeans, wheat, hay, cotton, sorghum, and rice totaled nearly 111.3 million hectares with 32 and 30 percent, respectively, of land area devoted to corn and soybean production. Related calculations by USDA indicate that 35 and 23 percent, respectively, of the value added to the U.S. economy by crop production was attributable to feed grains and oil crops. Given the importance of the corn and soybean sectors to U.S. agriculture, it is important to research how U.S. farmers might reduce their risk exposure and improve their farms' income by examining strategies used to price and market corn and soybean production.

Corn and soybean prices in the United States respond to shifting world supply and demand both across crop years and within a single crop marketing year. Corn and soybean futures contracts useful for price risk management are traded on the Chicago Board of Trade (CBT) futures exchange. Harvest of corn and soybeans in the U.S. primarily takes place in the fall and the first CBT futures contract expirations following harvest are November and December for soybeans and corn, respectively. Although both the December corn and November soybean contracts begin trading four years prior to their respective expiration dates, trading volume and open interest remain very low until about one year prior to expiration and increase as contract expiration approaches. For example, on January 2, 2024, daily volume in the December 2024 corn futures contract was equivalent to about 1 percent, and open interest about 6 percent, of USDA's estimated 2024 crop size. By May 1, 2024, both daily volume and open interest doubled suggesting that use of the contracts to manage price risk increased as the spring planting season approached, and that contract liquidity also improved. Research by Edwards *et al* (2020) indicated that CBT corn and soybean futures prices rise seasonally in the spring, making it potentially advantageous to do some pricing of both crops in spring. For that reason, along with the improvement in contract liquidity that takes place in the late winter and early spring, this study examines pricing strategies that commence in May. Since many U.S. corn and soybean farms have on-farm storage facilities this study also examines marketing strategies that store corn and soybeans until June of the year following harvest which is near the end of the storage season making it possible to capture seasonal price strength.

Corn and soybean prices can vary substantially from May of one year through June of the following year. For example, reviewing the 19 years (2004-2023) of Chicago Board of Trade (CBT) corn futures prices used in this study indicates that December corn futures contract prices varied as much as $4.00/cwt from May to October and the July corn futures contract prices varied as much as $5.50/cwt from October to June of the following year. Over the same period, CBT November soybean contract futures prices varied as much as $6.00/cwt from May to October and the July soybean futures contract prices varied as much as $8.00/cwt from October to June of the following year. Variations in corn and soybean prices are a large source of risk for U.S. corn and soybean farm operations. As a result, U.S. farms would benefit from the identification of marketing strategies for both corn and soybeans that would help reduce their risk exposure without unduly limiting net returns.

This research builds upon research conducted by Edwards *et al.* (2020) who evaluated the use of grain storage and hedging strategies for Indiana farm operations using 30 years of historical data. Edwards' study included three grain storage marketing strategies: unhedged grain storage; a basic storage hedge where grain is placed in storage and simultaneously hedged in a deferred futures contract; and a hedge and roll strategy where the futures hedge is initially placed in a nearby futures contract and then subsequently rolled to a deferred contract combined with physical storage of the corn or soybeans. Results indicated that, on average, the hedge and roll strategy provided the highest net returns to storage for corn and the second highest for soybeans. However, in 2 of the 30 years studied, the hedge and roll strategy provided significant negative returns to storage due to an inverted futures market. The unhedged storage strategy on average provided the highest net returns to storage for soybeans and the second highest returns for corn. While the unhedged strategy on average provided high returns to storage, it was heavily influenced by the presence of just a few years of exceptionally high returns to storage during the 30 years studied. Finally, Edwards concluded that a basic storage hedge, where corn or soybeans are placed in storage at harvest and simultaneously hedged in the deferred futures contract, provided the lowest average net returns for both corn and soybeans.

Farmers who choose to store corn or soybeans instead of selling at harvest incur costs referred to as a carrying charge. Edwards' study included a carrying charge of approximately \$0.02/cwt/month for storing grain which was comprised of the opportunity cost on money invested in the grain inventory combined with an estimate of variable on-farm storage costs. To estimate the opportunity cost of money invested in the grain inventory, Edwards used a flat 6% APR interest rate even though interest rates varied substantially throughout the 30 years examined. Additionally, Edwards used average Indiana state-level cash price data reported by USDA which might not be representative of cash prices (and basis levels) available in different regions of the state.

This study improves upon and extends Edwards research in several ways. First, a pre-harvest marketing strategy that has the potential to capture seasonal strength in corn and soybean futures prices is included with results from a total of six possible corn and soybean marketing strategies examined in the study. Second, farm records from a southwestern Indiana commercial scale farm operation are used to estimate actual on-farm storage costs. Third, cash prices for the southwest Indiana region are used instead of state level averages to ensure that strategy selection is applicable to farms in that region of Indiana. Fourth, instead of using a single interest rate for the life of the study to estimate the opportunity cost of storage, historical interest rates for corn and soybean storage loans from the USDA's Farm Service Agency (FSA) are used. U.S. producers who participate in USDA farm programs are eligible to obtain loans from FSA using corn and soybeans as collateral. Interest rates available for this program are below commercial loan rates with the resulting calculations providing a lower bound for the opportunity cost of storage.

Methods

Historical data used in this study begin with price data for the corn and soybean crops harvested in the fall of 2004 and conclude with the crops harvested in the fall of 2022. To better understand the impact of regional crop prices and the cost of storing grain on an Indiana farm, this study uses data specific to a commercial scale corn and soybean farm located in Posey County, Indiana, near Mount Vernon along the Ohio river (figure 1). Outlets for corn and soybeans in southwest Indiana include export-oriented elevators on the Ohio River, a soybean processing facility, and two nearby ethanol plants.

Figure 1. County Map of State of Indiana.

All historical cash price and futures price data are obtained from DTN's ProphetX (2023) database which limited the study to 19 years of recent price data since cash prices prior to 2004 are not available. Cash prices from grain elevators in the Mount Vernon, Indiana area are used to simulate sales from a southwest Indiana farm. Futures prices are for Chicago Board of Trade corn and soybean futures contracts. To take advantage of available on-farm storage it is assumed that if corn and soybeans are placed in storage, they are stored until June of the year following harvest. Daily price data are used to compute monthly averages by year for both cash price and futures price data. October cash price averages are used to simulate sales made at harvest and to calculate opportunity costs of storage until June. Pre-harvest corn and soybeans sales are simulated using an average of daily May futures settlement prices for December CBT corn futures and November CBT soybean futures prices, respectively, and then offset using October averages for the same futures contracts. Hedges for corn and soybeans stored from October to June are placed each year using October monthly averages for July CBT corn and soybean futures contracts, respectively, and then offset using June averages for the same contracts. June monthly average cash prices are used to simulate cash market sales for corn and soybeans in storage.

The study assumes an existing on-farm storage facility is used to store corn and soybeans and that grain quality is maintained throughout the storage season. Utility and repair costs from 2022 and 2023 for a southwest Indiana farm's grain storage facilities are used to estimate variable costs per cwt. stored. The cost of repairs and utilities for the entire eight-month storage season averaged $0.09/cwt for both corn and soybeans. The opportunity cost of having capital invested in corn and soybean inventories is calculated using the USDA's FSA Commodity Credit Corporation's borrowing rate for each year. Since U.S. farmers can obtain low-cost financing of inventories from USDA, it represents a lower bound for the opportunity cost of having dollars invested in inventories. The storage season evaluated is limited to an eight-month season from harvest in October to delivery in June for all the storage strategies. The Commodity Credit Corporation's average interest rates for each year are divided by 12 to obtain a monthly interest rate and then multiplied by eight to cover the eight-month storage period, October to June. The total carrying charge is computed by adding the opportunity cost of capital to the repairs and utilities cost. The total carrying charge is subtracted from the four corn and soybeans storage strategies sales prices to obtain net sales prices.

Six possible marketing strategies are evaluated for both corn and soybeans. Strategies 1 and 2 assume corn and soybeans will be sold in October while Strategies 3-6 assume an eight-month storage season with cash sales made in June. October is a key harvest month for both corn and soybeans in southwest Indiana and June crop sales take advantage of a seasonal tendency for prices to rise in the spring and are also near the end of the storage season for many farms in the region. Strategies 2-5 utilize futures market hedges where the sale of CBT futures is used as a temporary substitute for a cash market sale that will take place at a later date. At the time of delivery, the hedge is offset in the corresponding futures market. The study assumes unlimited futures margins are available to fund futures margin accounts.

Strategies 1 and 2 do not utilize grain storage. In strategy #1, *Fall Cash Sale,* the commodities are sold during harvest in October at the October average cash price. In strategy #2, *Spring Hedge, No Storage*, a short hedge is placed in May in December CBT futures for corn and November CBT futures for soybeans then offset in October. In October, the grain is sold at the October average cash price. The net sale price includes the gain or loss on the hedge plus the October cash price.

Strategy #3, *Spring Hedge & Roll, Storage*, places a short hedge in May using the December CBT contract for corn and the November CBT contract for soybeans and then offsets this initial hedge in October. The futures market hedge is rolled forward by selling July CBT futures contracts in October for both commodities and the corn and soybeans are placed in storage. Finally, the corn and soybeans are sold at the June average cash price and hedges are offset at the same time. The net sale price is a combination of the gains or losses on the hedges and the June cash price, less the total carrying charge.

Strategy #4, *Spring Hedge, Store Unhedged*, places a short hedge in May during planting and then offsets the hedge in October using the December CBT contract for corn and the November CBT contract for soybeans. The grain is placed in storage in October until delivery at the June average cash price. Strategy #4 uses a hedge during the growing season but stores the grain unhedged during the October-June storage season. The net sale price is a combination of the gain or loss on the hedge and the June cash price, less the total carrying charge.

Strategy #5, *Fall Hedge & Storage*, places a short hedge during harvest in October using the July futures and simultaneously places the grain in storage. The corn and soybeans are sold in June at the average cash price and the July CBT futures hedges are offset at the same time. In this strategy, corn and soybean sales are not hedged during the growing season but are hedged during the storage season. The net sale price is a combination of the gain or loss on the hedge and the June cash price, less the total carrying charge.

Strategy #6, *Unhedged & Storage*, places grain in storage at harvest in October. In June, the grain is delivered for the cash price. This strategy does not use the futures market to hedge sales. The net sale price is the average June cash price, less the total carrying charge.

Data

Tables 1 and 2 provide the average October and June corn and soybean cash prices from 2004-2022. Futures contract prices for each month are calculated by averaging all the daily settlement prices for that entire month. Cash prices for each month are also calculated by averaging daily cash prices posted in the DTN database following that day's futures market close. The two tables also include the average price change, along with their respective standard deviations, from October through the following June. Although the average price change during the October-June storage period is positive for both commodities, there is considerable variation around the average suggesting that storing unpriced corn and soybeans carries some downside risk.

Table 1. Average Corn Cash Prices in October and June in Southwest Indiana, 2004-2022.

Corn			
	Average ($/cwt)	Minimum ($/cwt)	Maximum ($/cwt)
October Cash Price	7.46 (2.66)*	3.15	13.40
June Cash Price	8.84 (3.07)*	3.06	14.31
Range (June – October)	1.39 (1.92)*	-0.91	5.48

* standard deviation.

Table 2. Average Soybean Cash Prices in October and June in Southwest Indiana, 2004-2022.

Soybeans			
	Average ($/cwt)	Minimum ($/cwt)	Maximum ($/cwt)
October Cash Price	16.46 (4.34)*	8.80	25.73
June Cash Price	19.37 (5.42)*	9.73	28.95
Range (June – October)	2.91 (2.83)*	-0.83	8.55

* standard deviation.

Tables 3 and 4 examine the average change in CBT futures contract prices from May to October. Once again, the average futures contract price change is positive for both commodities, but there is a lot of variability around the average.

Table 3. Average Change in December CBT Corn Futures Prices from May to October, 2004-2022.

Corn			
	Average ($/cwt)	Minimum ($/cwt)	Maximum ($/cwt)
Dec Futures Price in May	7.94 (2.33)*	4.11	13.11
Dec Futures Price in Oct.	7.55 (2.55)*	3.61	13.39
Range (May – October)	0.39 (1.69)*	-4.04	3.75

* standard deviation.

Table 4. Average Change in November CBT Soybean Futures Prices from May to October, 2004-2022.

Soybeans			
	Average ($/cwt)	Minimum ($/cwt)	Maximum ($/cwt)
Nov Futures Price in May	17.27 (4.26)*	10.30	25.00
Nov Futures Price in Oct.	16.68 (4.30)*	8.77	25.65
Range (May – October)	0.59 (2.70)*	-3.95	6.17

* standard deviation.

Results

The four corn storage strategies generated higher net sale prices than the two strategies without storage. Strategy #4 produced the highest net sale price among the storage strategies at $9.08/cwt while strategy #1 provided the lowest net sale price at $7.46/cwt.

Table 5. Corn Marketing Strategies Average Net Sale Prices, 2004-2022 Crop Years.

Corn	
Strategy	Average Price Received ($/cwt)
#1 Fall Cash Sale	7.46
#2 Spring Hedge, No Storage	7.85
#3 Spring Hedge & Roll, Storage	8.51
#4 Spring Hedge, Store Unhedged	9.08
#5 Fall Hedge & Storage	8.12
#6 Unhedged & Storage	8.69

#2 *Spring Hedge, No Storage* corn strategy generated an average price of $7.85/cwt. while #1 *Fall Cash Sale* strategy's average net sale price was $7.46/cwt. Looking more closely at the strategies without storage, #2 provided the highest net sale price in 14 out of 19 marketing years and, on average, provided a net sale price that was $0.39/cwt. higher than unhedged fall delivery.

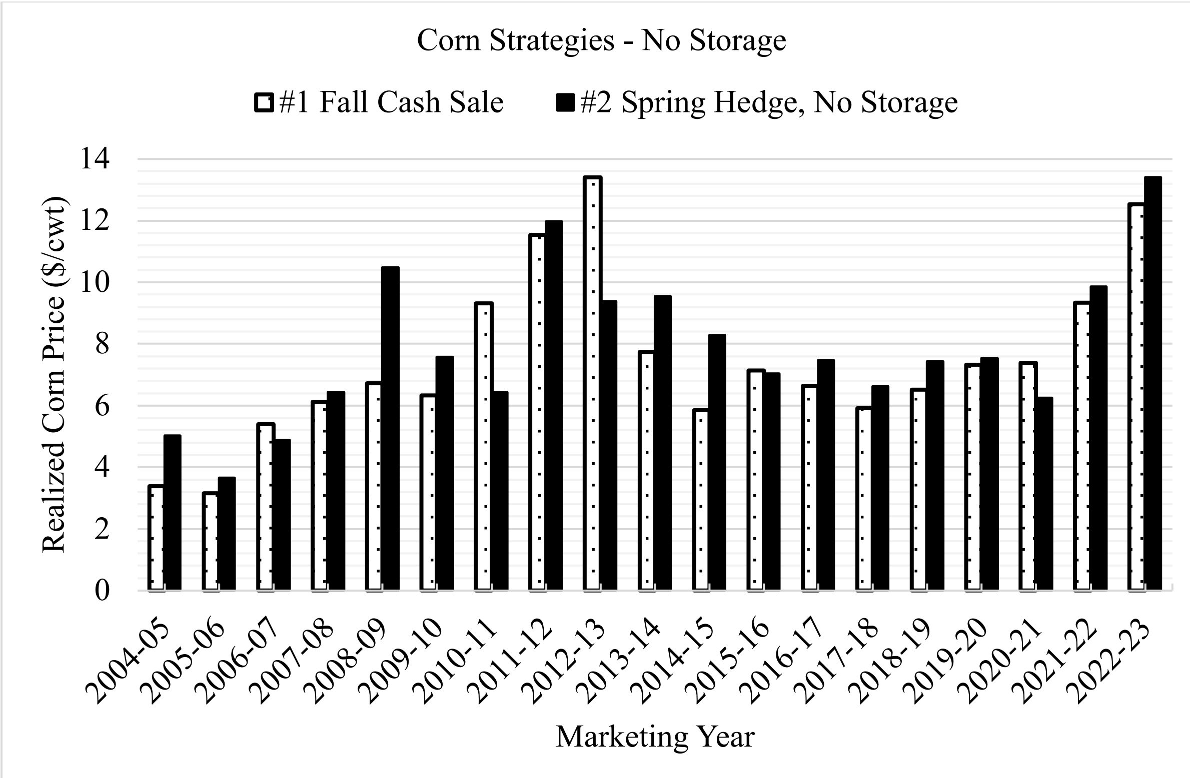

Figure 1. Net Sales Prices for Corn Marketing Strategies Without Storage, Southwest Indiana, 2004-2022.

The three corn storage strategies that produced the highest average net sale price from 2004 through 2022 are compared in Figure 2. Strategy #4 *Spring Hedge, Store Unhedged* provided the highest net sale price at $9.08/cwt but was only the top strategy in 4 out of 19 years. Strategy #3 *Spring Hedge & Roll, Storage* generated the lowest average net sale price among these three strategies but produced the highest net sale price in 9 out of 19 years and tied for the top net sale price with strategy #4 once. Strategy #6 provided an average net sale price of $8.69/cwt. and had the highest net sale price in 5 of 19 years.

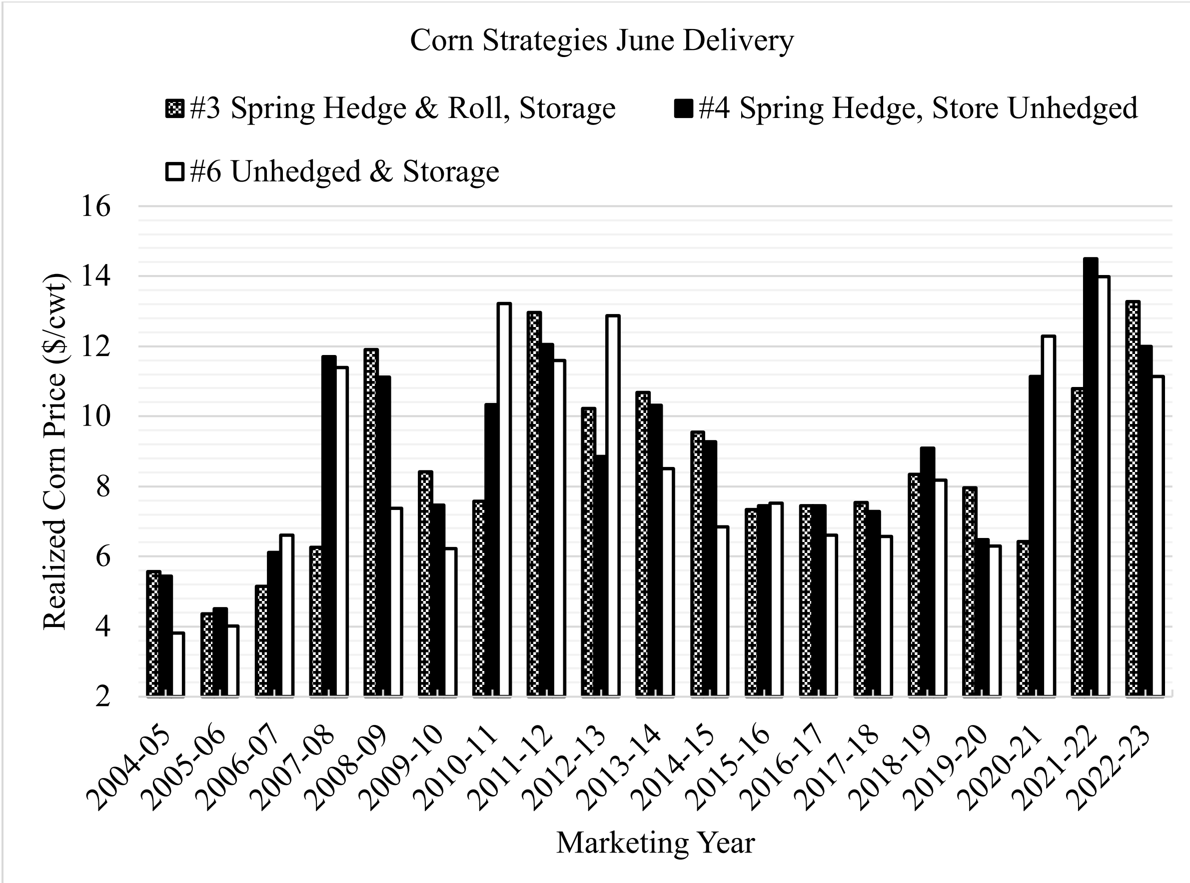

Figure 2. Net Sale Prices for Corn Marketing Strategies With Storage, Southwest Indiana, 2004-2022.

For soybeans, the four storage strategies produced higher net sale prices than the strategies without storage. Strategy #4 produced the highest average net sale price at $19.73/cwt while strategy #1 provided the lowest average net sale price of $16.46/cwt.

Table 6. Soybean Marketing Strategy Average Net Sale Prices, Southwest Indiana, 2004-2022.

Soybeans	
Strategy	Average Net Sale Price ($/cwt)
#1 Fall Cash Sale	16.46
#2 Spring Hedge, No Storage	17.06
#3 Spring Hedge & Roll, Storage	17.59
#4 Spring Hedge, Store Unhedged	19.73
#5 Fall Hedge & Storage	17.00
#6 Unhedged & Storage	19.14

Examining the two soybean strategies without storage reveals that Strategy #2 *Spring Hedge, No Storage* averaged a net sale price of $17.06/cwt while Strategy #1 *Fall Cash Sale* averaged a net sale price of $16.46/cwt. Among the two soybean sales strategies without storage, #2 provided the highest net sale price in 12 out of 19 marketing years in addition to generating an average net sale price that was, on average, $0.60/cwt higher than the *Fall Cash Sale* strategy.

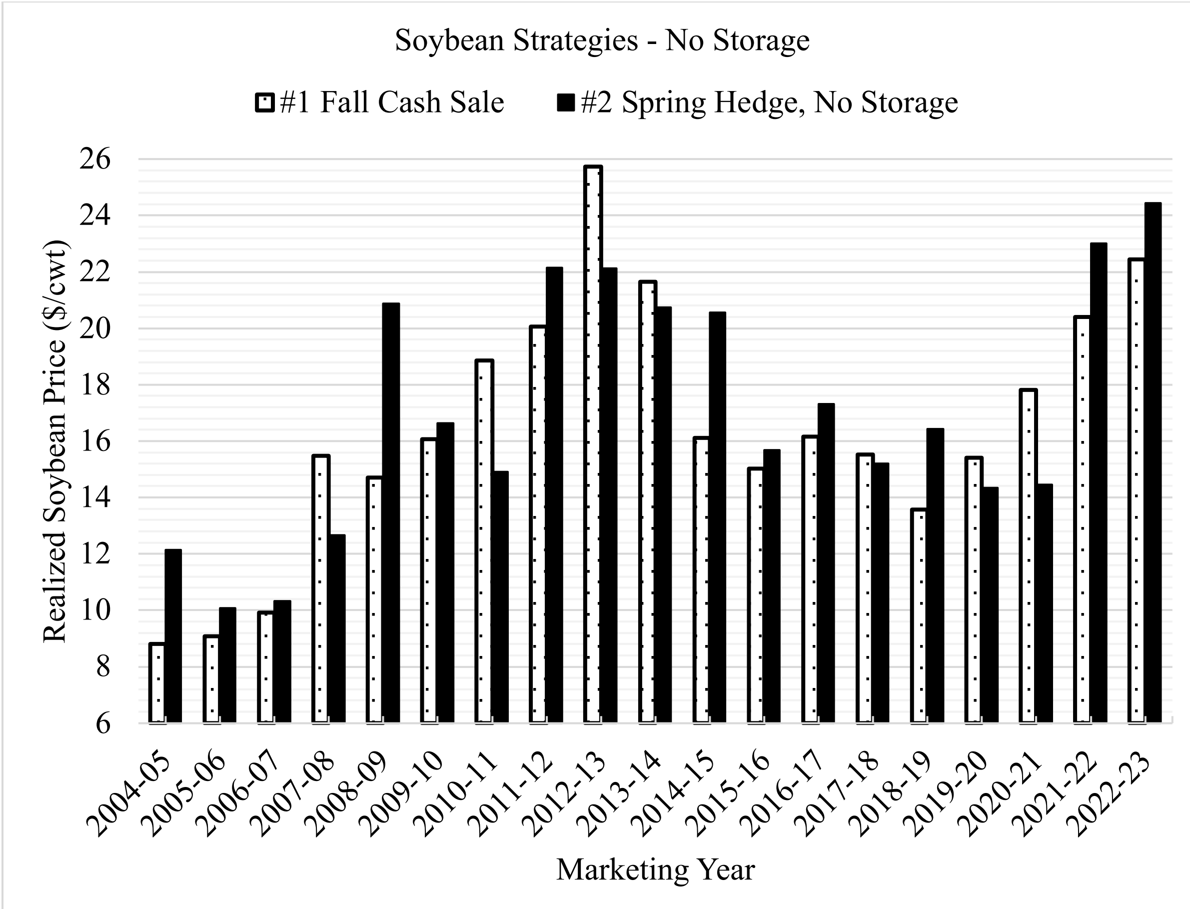

Figure 3. Net Sale Prices for Soybean Marketing Strategies Without Storage, Southwest Indiana, 2004-2022.

The three soybean storage strategies providing the highest net sale prices from 2004 through 2022 are compared in Figure 4. Strategy #4 *Spring Hedge, Store Unhedged* provided the highest average net sale price of $19.73/cwt and provided the highest net sale price in 7 out of 19 years. Strategy #6 *Unhedged & Storage* generated an average price received of $19.14/cwt, which was just $0.59/cwt lower than Strategy #4 over the 19 years examined.

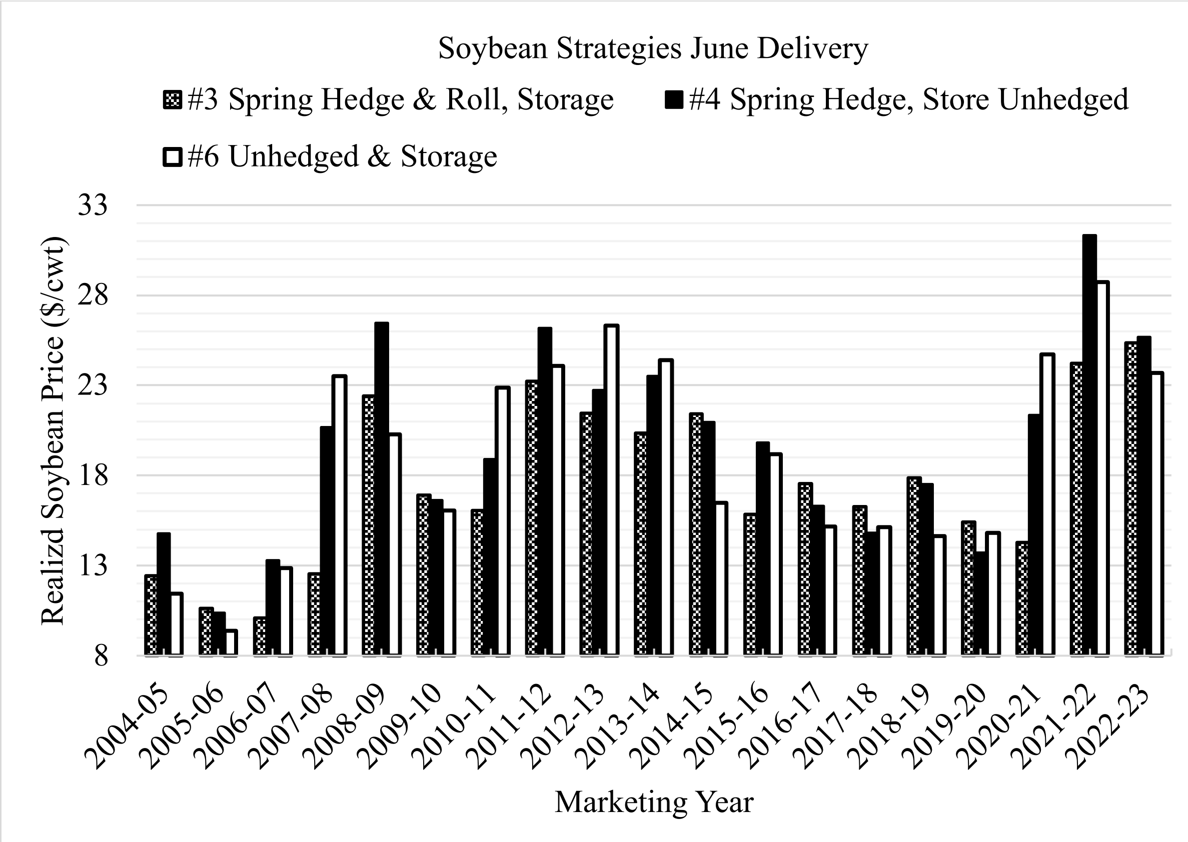

Figure 4. Net Sale Prices for Soybean Marketing Strategies With Storage, Southwest Indiana, 2004-2022.

Discussion

No single marketing strategy generated the highest net sales price for either corn or soybeans every year. Strategy #4 provided the highest average net sale prices for corn and soybeans over the 19 years of data, but it did not produce the highest net sale price strategy every year. The storage strategies all resulted in higher average net sales prices than the strategies without storage, but again this was not the case every year. Since no single strategy was a clear winner, a risk analysis technique known as stochastic dominance (SD) was used to try and identify a preferred marketing strategy. Using stochastic dominance, it's possible to compare the probability distribution of outcomes from the 6 marketing strategies and determine which strategy dominated the other strategies over the 2004-2022 time frame. Two forms of SD were used: 1) first degree; and 2) second degree. First degree SD assumes that more is preferred to less and only occurs when one distribution of outcomes lies entirely above another distribution of outcomes. For this to occur in our study, the net sales price for one strategy would need to be higher than the net sales price for another strategy for every year in the analysis. Second degree SD, which is more discriminating than first degree SD, assumes that a farmer is risk averse. Results from the SD analysis revealed that, for both corn and soybeans, strategy #4 was dominant for all risk averse producers. In other words, strategy #4 is preferred by all producers who are concerned about variability of outcomes and/or outcomes below a specified target (i.e., downside risk).

Conclusion

Results from 6 corn and soybean sales strategies for southwest Indiana corn and soybean farms from 2004 to 2022 were examined. Strategies that took advantage of 1) seasonal price strength in the spring and 2) the seasonal tendency for cash prices to rise following harvest provided the highest net sale prices, on average, from 2004 through 2022. Strategy #4, which included pricing corn and soybeans in May using futures market hedges and then storing both commodities unhedged until June, provided the highest average net sale price over the 19 years reviewed. However, strategy #4 did not provide the highest net sale price every year. To learn more about which strategy provided the best results overall, first- and second-degree stochastic dominance analysis was performed on the results. Strategy #4 was second-degree dominant indicating that it was an optimal strategy for all risk averse producers.

There are two key points for corn and soybean producers in southwest Indiana to consider. First, pricing at least a portion of anticipated corn and soybean production in the spring when prices exhibit some seasonal price strength should be given serious consideration as part of a farm's marketing plan. Second, storing unpriced corn and soybeans following harvest to take advantage of the seasonal improvement in cash prices that occurs in southwest Indiana from fall harvest into the spring should also be considered for inclusion in a farm marketing plan.

Although this research helps identify pricing strategies to consider for southwest Indiana corn and soybean farms, it still leaves important questions unanswered. First, uncertainty about anticipated production precludes pricing all of a farm's production in the spring. Second, storing both corn and soybeans unhedged or unpriced over the winter and into the spring could entail taking on more risk than some farm operators are willing to assume. The question of what percentage of anticipated production to price in the spring and what percentage of actual production should be stored into the following spring is not addressed in this research and should be examined in future research. Given these constraints, producers are faced with a quandary regarding how best to combine the use of strategy #4 with other strategies examined in this research. Future research should consider identifying a portfolio of marketing strategies that could be employed by farm operators to reduce risk and improve returns.

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IFMA24: Resilience through Innovation

BUILDING FARM RESILIENCE THROUGH THE AGPLAN BUSINESS PLANNING SOFTWARE

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Abstract

Every business wants to succeed, but what sets apart a successful, resilient business from one that is not? We utilize a survey of producers who created a business plan using a business planning software, AgPlan, to examine how they use their business plans, the benefits they perceive from creating a business plan in AgPlan, and the challenges they face when writing a business plan in AgPlan. We discuss how using AgPlan promotes successful, resilient businesses. Educators can use the results of this survey to better serve producers during the business planning process and promote successful, resilient businesses by encouraging and supporting producers in writing a business plan using the AgPlan software.

Keywords: business planning, software, business success, AgPlan

Introduction

Every person that owns a business wants it to succeed. But what sets apart a successful, resilient business from other businesses that fail? Research has shown that one tool business owners can use to be more successful and resilient is a business plan. Practically, a business owner who writes a business plan demonstrates that they have carefully thought through all aspects of their business, including potential opportunities or challenges that can impact the business. For start-up businesses, having a written business plan results in faster and higher annual average growth compared to start-up businesses without a written business plan, and results in a positive impact on firm success (Brinckmann, Grichnik and Kapsa, 2010; Burke, Fraser and Greene, 2010). Start-up businesses are not the only types of businesses that benefit from business planning. Established businesses can use a business plan to obtain funding, or as a risk management strategy. Business planning is even more pertinent in agriculture, where net farm income ratios have been as narrow as 5% in recent years (*FINBIN*, 2024).

Given the importance of business planning to agricultural businesses, the Center for Farm Financial Management (CFFM) of the University of Minnesota developed an online business planning software in 2008, geared especially toward agricultural production businesses. The software, AgPlan, has since been used to create over 100,000 business plans (‘AgPlan’, 2024).

AgPlan has been used worldwide and has received outstanding praise for helping agricultural businesses. As the AgPlan creators, we’ve begun to wonder – specifically how helpful is this tool? How have business plans created with AgPlan been used, and how does AgPlan support resilient businesses? To help answer those questions, we utilize a survey of AgPlan users to identify the benefits and challenges of business planning using AgPlan. This information will help educational efforts of educators, lenders, and consultants who can utilize AgPlan and the results of this study to help producers create resilient businesses through business planning.

Material Studied / Area Description / Methods

AgPlan assists users by allowing them to select a business plan template based on the type of agricultural business they operate. Templates are available for commodity producers, value-added producers, agritourism operators, and farms transitioning from conventional to organic production. There is also a template for personal or career development, and a template for small businesses, even if they are not farm-based. Lastly, AgPlan provides a short-term operating template, available for situations when the main business operator is unable to operate the farm for a certain time, such as due to illness or military deployment.

AgPlan segments business plans into six main sections: Executive Summary, Description, Operations, Marketing, Management and Organization, and Financial. Additionally, there are several subheadings under each of these sections. For each section and subheading, the software includes tips, resources, and samples specific to each template. The tips and samples inspire and assist AgPlan users in creating their own business plan. The resources provide additional insight if users want a deeper understanding of what to include in each topic.

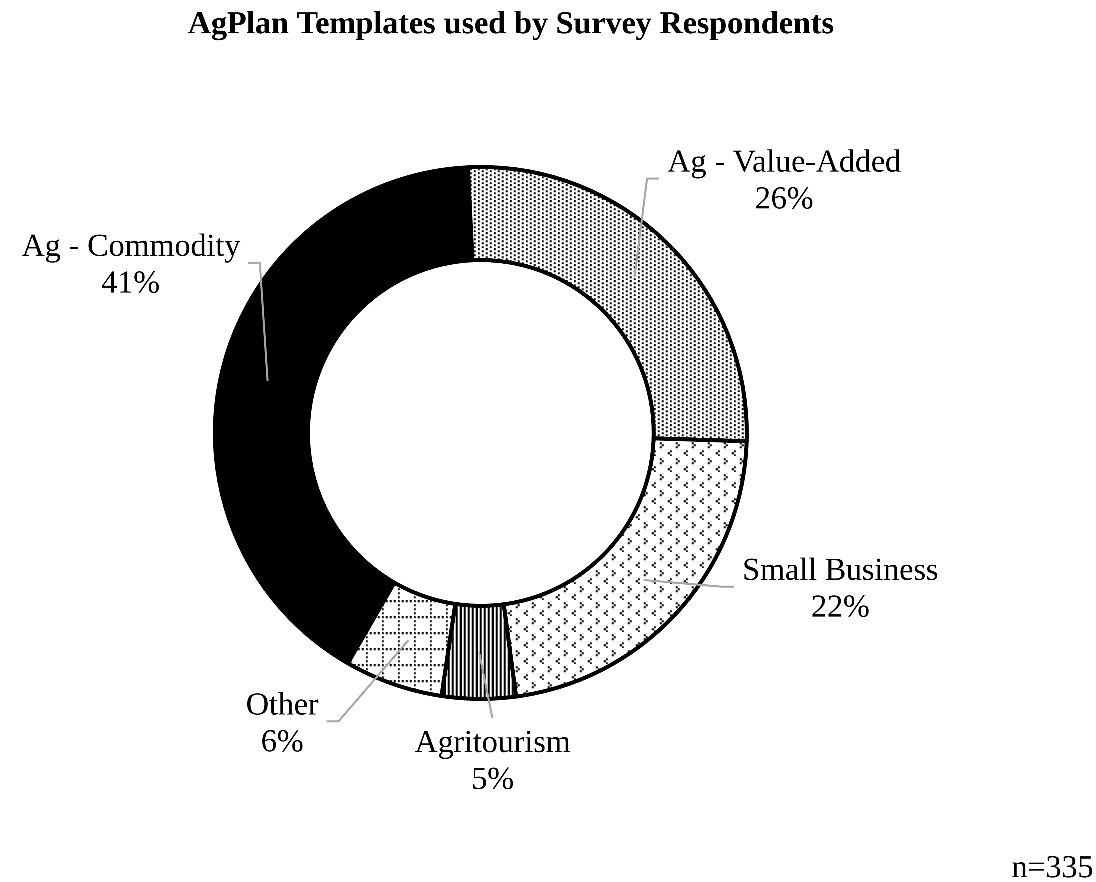
A Qualtrics survey was launched in February 2024 to gather information directly from AgPlan users regarding their perception of business planning, if and how they have used their business plans, and the overall usefulness of the AgPlan tool. The survey was created by the Center for Farm Financial Management's evaluation specialist, in conjunction with CFFM extension economists. Specific questions were tailored toward agricultural producers and business owners who have used AgPlan. The survey was sent to all AgPlan accounts that have been accessed between March 2021 and March 2024. Three reminders were sent to non-respondents of the survey before it closed in March 2024. Just under 350 responses were gathered from producers and business owners, and the results are discussed below[1].

Results

The survey results show that the AgPlan software is used by a plethora of business types. Survey respondent emails were matched with the AgPlan database summarizing user emails and plan types created in AgPlan[2]. For users who have multiple plans, the plan that was accessed most recently was considered for the summary of information in Figure 1. Of the template types within AgPlan, the most common templates used were commodity, value-added, and small business (Figure 1). Templates that were used less frequently include the organic transition plan, agritourism plan, personal plan, short-term operating plan, and a retired template for commercial fishing.

[1] Survey respondents were not required to answer all questions of the survey. Where appropriate, sample sizes for questions are given in parentheses.
[2] For clarification, business plans within AgPlan are not accessible to anyone besides the plan creator and any reviewers they have shared the plan with. CFFM only has summary information including user email and plan type created.

Figure 1: AgPlan Templates Used by Survey Respondents



*Other includes organic transition, personal, short-term operating, and commercial fishing plans.

Producer survey respondents communicated a multitude of benefits to using the AgPlan business planning software. It is often assumed that the main way in which business plans are used is for the business to either obtain financing or for internal planning. The results of the survey verified this assumption in Table 1, with approximately 33% of respondents (n=268) indicating one of the ways they used their AgPlan business plan was for start-up business planning, 15% used their business plan for general business planning, and 25% used their business plan to obtain financing.

Table 1: Top Ten Ways in Which Business Plans made in AgPlan Were Used

Way plan was used	n (%)	Sample quote
Business planning for startups, transitioning, and expanding businesses	88 (33%)	"I used AgPlan for start-up farm business planning. We used the tool to identify which crops and livestock we could incorporate to monetize our farm."
Apply for financing (grants, loans, etc.)	66 (25%)	"I originally used my plan to approach USDA for financial backing to start our peony farm."
General business planning and management	41 (15%)	"We use our business plan for financing, strategic planning, internal business management, startup business planning, figuring out if another direction is needed, and tweaking the current direction."
Strategic planning and thinking	26 (10%)	"It was a tool that encouraged me to actually do strategic thinking. It helped me shape an idea or a dream into concrete actions."
Organize thoughts and ideas	18 (7%)	"I have used it as a framework to put my thoughts to paper and structure my business concept/idea."
Develop and monitor business goals	12 (4%)	"I have used the plan to hold me accountable for accomplishing my goals."
As a communication, collaboration, or educational tool	12 (4%)	"I used it for starting a new business and as a part of my presentation for investors."
To plan for the future	9 (3%)	"Helping to organize my business thoughts and plan for the property I will have in the future."
Financial planning	9 (3%)	"I used the plan for planning and financing."
Develop marketing plans	7 (3%)	"(I used it to)…clarify my thoughts on ideal customers and markets."

Start-up planning and general business planning are critical to the success of a business, largely because business planning increases a business owner's overall understanding of their business. According to the survey, 90.7% of respondents either strongly agree or agree that writing a business plan in AgPlan gave them a more complete understanding of the various aspects of their business (Figure 2). Moreover, survey respondents indicated certain business practices were improved because of writing a business plan in AgPlan. These results are presented in Figure 3 with an overwhelming majority of respondents (93%) strongly agreed or agreed that writing a business plan in AgPlan clarified their operation's mission and vision. Additionally, most respondents either strongly agreed or agreed that writing a business plan using AgPlan resulted in improved financial practices (75% of respondents), improved personnel management practices (76% of respondents), improved marketing practices (73% of respondents), and improved production practices (72% of respondents).

Figure 2: Extent to which respondents agree with the statement: "Writing your business plan using AgPlan gave you a more complete understanding of the various parts of your business."

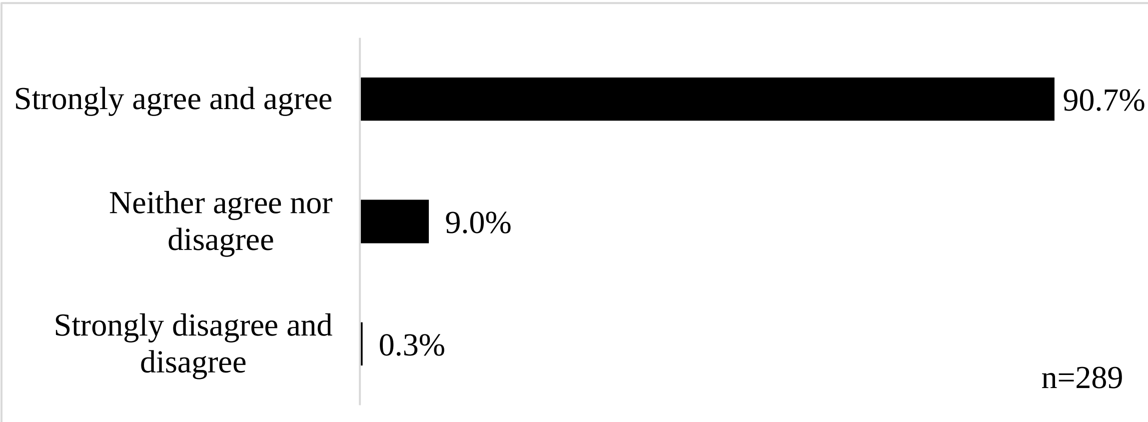
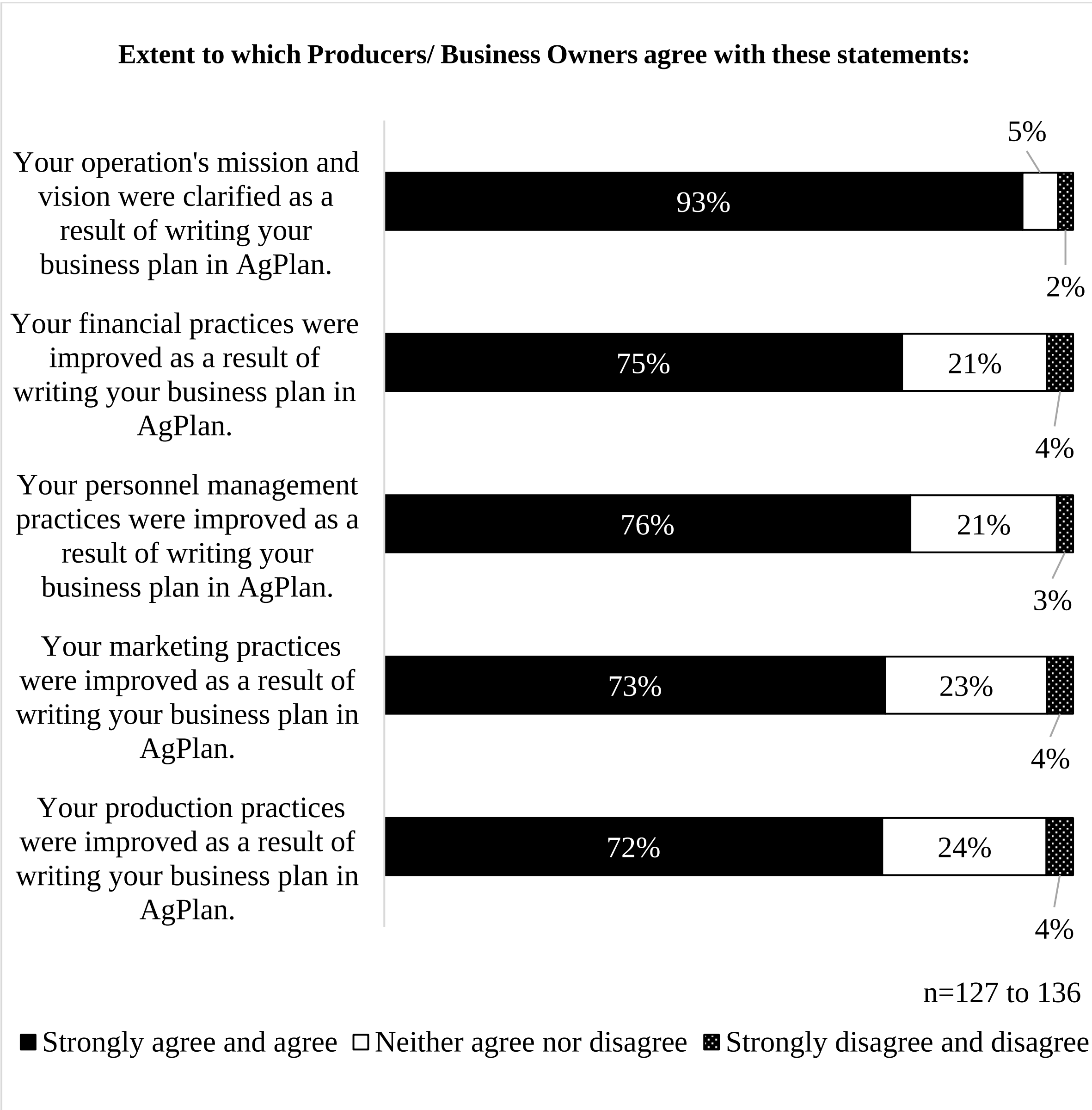


Figure 3: Percentage of Respondents Who Agreed or Disagreed Business Practices Improved as a Result of Writing a Business Plan in AgPlan



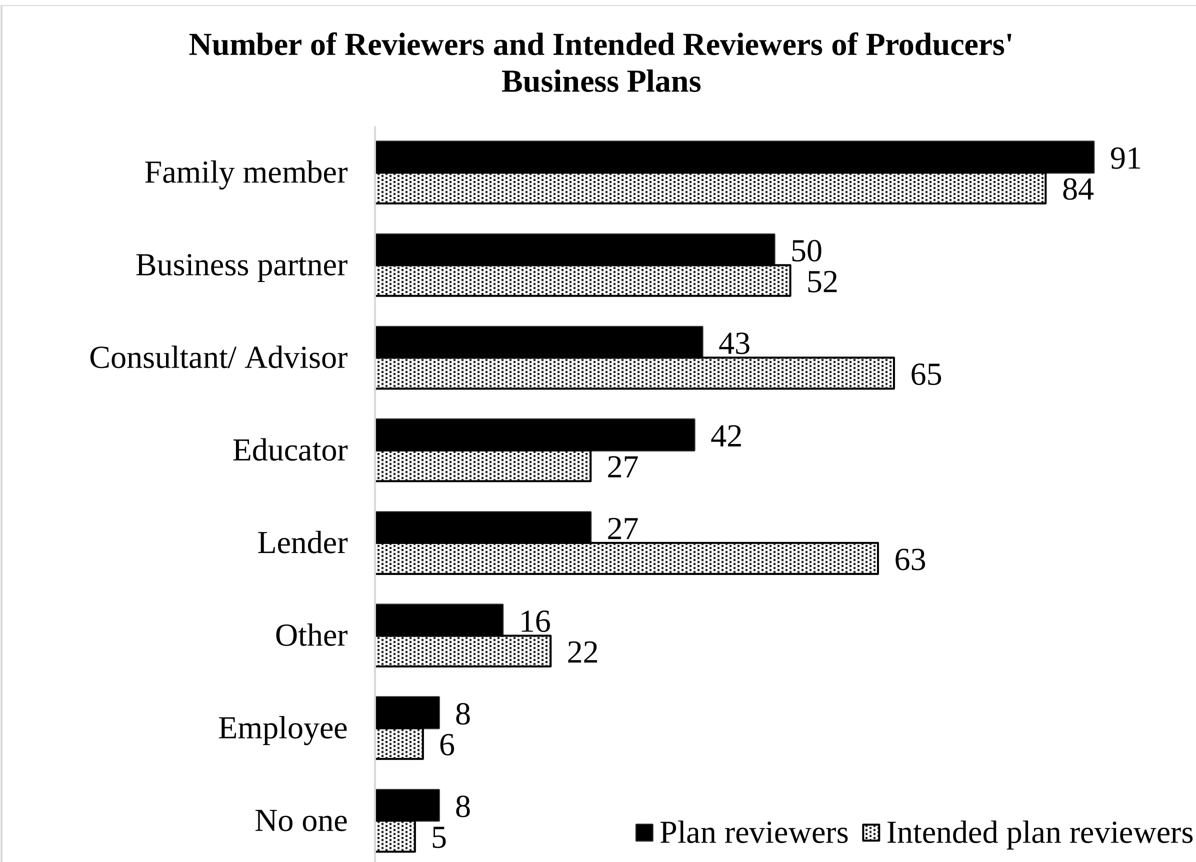
Although helpful to a business, completing a business plan can be challenging for a multitude of reasons. According to the 237 respondents who answered, the most difficult aspect of using AgPlan to write a business plan is the financial aspect (Table 2). Other challenges included the time-consuming nature of writing a business plan, needing to research and gather information, and not knowing how or where to begin the business planning process.

Table 2: Top Ten Most Challenging Aspects of Writing a Business Plan in AgPlan

Challenges to writing business plans	n (%)	Sample quotes
Financial section: Respondents said they struggled to come up with things like cash flow, expenditures, enterprise budgets, revenue, growth percentages, financial projections, etc.	31 (13%)	"Delving into the financial aspects of the ranch and farm was quite challenging. The day-to-day accounting is difficult for me."
Finding time	26 (11%)	"Finding the time to make a detailed plan was the biggest hurdle."
Accurately researching and gathering all the information needed	16 (7%)	"Doing research and having the correct information."
Deciding what to include in each section: Some respondents found it difficult to determine how specific or detailed they needed to be.	18 (8%)	"Delineating between the different sections' specifics without crossing over the descriptions or purposes (of other sections)."
Articulating thoughts and ideas	13 (5%)	"Actually, putting my thoughts into words to make a plan is harder than I thought."
Marketing section	12 (5%)	"Doing the research for marketing in my area of the country. Specifically, the cost of doing business and putting that in my business plan."
Making projections	11 (5%)	"Financial projections take time and expertise."
Getting started	9 (4%)	"Getting started and all of the unknowns."
Developing a mission and vision	8 (3%)	"Clearly defining mission and goals and developing a budget that sustains the mission and goals."
Unavailable information for new businesses: New businesses have many unknowns, which makes it challenging to complete all sections of a plan.	8 (3%)	"It's challenging to document action items or goals that depend on assets or other resources that you don't have. For example, planning to run a small direct-to-consumer beef enterprise when you don't have acreage or the faculties to raise cattle. How can you move to "step 2" when you haven't completed "step 1" (acquire land)? The challenge is not directly related to AgPlan itself, but it is an overall challenge of writing my business plan with so many unknowns."

To overcome some of the challenges of writing a business plan, AgPlan allows users to add reviewers to their business plan to increase the strength of each section of the plan and to provide accountability through the writing process. Figure 4 displays the type of people respondents have had review their business plan, or the type of people they plan to have review their business plan sometime in the future. Approximately 94% of the 142 business owner survey respondents who have completed a business plan in AgPlan indicated they had someone review their plan. The most common reviewer was a family member or business partner. Of the 152 business owners who have not yet completed their business plan, 97% indicate they plan to have someone review their plan.

Figure 4: Types of Reviewers for Business Plans in AgPlan



Discussion

This study allows insight into how producers and business owners are using the AgPlan business planning software, the benefits they have found from using the software, and the ongoing challenges they face in business planning.

The survey results from business owners that describe how their business plans are used make it clear that business plans developed in AgPlan serve a multitude of purposes. Most commonly, AgPlan business plans are used as planning guides for start-ups and general business planning. Most survey respondents agreed or strongly agreed that because they had written a business plan in AgPlan, their practices in the four mentioned aspects of their business improved. When producers use AgPlan to create a business plan, they are forced to think through all aspects of their business, including production, marketing, personnel management, and finances. In fact, research shows that intuition can mislead small firm managers on the question of how to best deal with competitive pressures and environmental conditions (Covin and Covin, 1990). Developing a formal business plan forces the business owner to participate in a process that leads to a better understanding of their product, market, and operational requirements for their business (Zinger and LeBrasseur, 2003).

Business planning with the AgPlan software can also provide a stronger understanding of the business mission and vision. Survey respondents indicated that their business mission and vision were clarified as a result of writing their business plan in AgPlan. Strong mission and vision statements can be helpful to businesses in several ways, according to research. For example, mission statements have been linked to organizational performance (Bart and Hupfer, 2004; Taghi Alavi and Karami, 2009). Vision statements have also been linked to performance, but benefits can be negated if a vision statement is not implemented in day-to-day running of the business (Lucas, 1998). Overall, vision and mission statements help communicate direction and give motivation to those involved with the business (Ehmke *et al.*, 2004).

It is also clear from the survey that AgPlan users utilize business planning to obtain financing. Respondents indicated their AgPlan business plans were used to obtain financing from traditional banks, grants, or from USDA/FSA. A good business plan alongside adequate financials is crucial in successfully accessing capital (Leoveanu, 2016; Owusu, 2017). Respondents also indicated that the business plan they created in AgPlan was used for strategic planning. Research shows that strategic planning is positively associated with business profitability and performance (Baker, Addams and Davis, 1993; Skokan, Pawliczek and Piszczur, 2013). While we do not have financial performance metrics of the businesses that utilize AgPlan, the research discussed supports the fact that businesses with a written business plan have a better chance of accessing capital and succeeding financially than businesses with no business plan. Educators can stress these benefits to producers who are unsure of the worth of a written business plan. If a farm wants to be a resilient farm business, one tool they should utilize is a well thought out business plan. AgPlan can serve as a helpful resource for farms to create a business plan.

While users indicated many benefits to completing a business plan in AgPlan, they also detailed the challenges of creating a business plan within the software. Some challenges educators may not be able to help with, such as finding the time to complete a plan, organizing the producers' thoughts, or just getting the producers to use the tool. However, with other issues educators are perfectly positioned to assist producers. Knowing these issues, educators can be proactive in their approach to business planning and be prepared to offer more education and technical assistance in the areas of the business plan producers struggle to write. For instance, two areas producers struggled with most in AgPlan were the financial and marketing aspects of their business plan. Producers also struggled with researching and gathering information for their business plan. It is likely that farmers are not sure where to find information about prices, yields, costs, etc., which in turn makes creating a financial and marketing plan more challenging. Educators need to teach both *what* goes into a financial or marketing plan, and *how* to find relevant information about price, yield, costs, etc. when creating a business plan. AgPlan provides users with tips and resources to help alleviate this challenge. Additionally, in the United States, FarmAnswers.org and the United States Department of Agriculture are great resources for producers to gather some of this information.

One feature AgPlan producers utilize is the ability to add reviewers to their business plan. Reviewers can see and make comments on business plans. In some cases, if the plan owner allows, reviewers may also edit business plans. Educators can work alongside business owners to ensure that they have a clear, concisely written business plan. Having an advisor that is familiar with the business and the industry can be helpful to point out the weaknesses of the plan, answer questions the producer may have while writing the plan, or point to sources for price, yield, cost, etc. if applicable.

Conclusion

We utilized a survey of business owners who have used AgPlan, an online business planning software, to examine the benefits and challenges of using AgPlan to create a business plan. Survey respondents mentioned how they used the business plan they created in AgPlan. Responses included obtaining financing, to start a business, for business and strategic planning, and communicating their business with others. Respondents also indicated many benefits to utilizing AgPlan, such as a better understanding of the aspects of their business and a clarified business mission/vision. The challenges of using AgPlan for business planning included creating the financial and marketing sections of the plan, as well as researching and finding the information needed to complete the plan. Lastly, most respondents indicated that they have had or planned to have someone review their business plan in AgPlan.

Educators can use the information from this survey to better support producers who have a business plan, or producers who wish to create a business plan. Research supports many benefits to business planning, and educators can reiterate these benefits to producers to encourage them to create a business plan. Additionally, educators can use the results of this survey to address challenges producers may face while writing their business plan. Two ways to support producers in writing their business plan is to encourage the use of AgPlan, and to be a reviewer of the plan. While building a business plan with AgPlan is not an automatic guarantee to success or resilience, it is one tool producers can utilize to increase their chances of profitability, longevity, sound decision making, and resiliency in the long run.

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Sub theme: Production/Farm Management

ECONOMIC POTENTIAL OF FIELD PEAS AS AN ALTERNATIVE TO CORN DRIED DISTILLERS GRAIN WITH SOLUBLES (DDGS) IN BEEF HEIFER GROWING DIETS

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ABSTRACT

The objectives were to determine economic potential of field peas relative to corn DDGS in diets of growing heifers, and to determine price points for competitive utilization of field peas as an alternative to corn DDGS. Animal performance data from 324 heifers were generated from a completely randomized design feeding trial replicated over two years. Mixed effects regression models revealed total gain was not influenced ($P > 0.05$) by dietary treatment allowing for a comparative ration cost analysis. Base-case ration costs were calculated using prices of \$325 MT^{-1} and \$366 MT^{-1} for corn DDGS and field peas, respectively. Sensitivity analysis was conducted to determine how sensitive the relative total ration cost is for price combinations of DDGS and field peas ranging from ± 50% of the base-case prices. Base-case results indicate the ration with field peas cost \$6.89 $head^{-1}$ more than the ration with DDGS. The breakeven price of field peas is \$231.15 MT, 71% of the price of DDGS; the breakeven price of DDGS was \$514.59 MT^{-1}, 141% of the price of field peas. Results will help pea processors and feed supply dealers develop a reliable supply chain for a beef cattle quality field pea source of feed.

Key words: corn DDGS, economic feasibility, feed rations, field peas, beef heifers

INTRODUCTION

Feed costs account for 60 to 70% of the total costs of a beef operation (Kaliel and Kotowich, 2002). Thus, reducing feed costs while optimizing animal production is essential for maintaining a profitable operation. Feed costs can be reduced through the use of cost-effective ingredients in mixed rations fed to cattle. Corn distillers' dry grains with solubles (DDGS) is one of the most common supplements used across the Great Plains region of the United States (Troyer et al. 2020). Beneficial effects of feeding DDGS to beef and dairy cattle have been reported in previous studies (Buckner et al., 2008; Swanson et al., 2014). Continued utilization of corn DDGS in cattle rations will likely be affected by availability and pricing. Factors such as an increase in corn oil price can result in a drastic reduction in DDGS production and an increase in the price of DDGS. As the price of oil continues to increase, the demand for alternative feed ingredients which can replace corn DDGS as sources of energy and protein in livestock diets will also increase. Thus, there is need to continually investigate and evaluate protein and energy sources that can cost-effectively replace corn DDGS in cattle rations.

Field peas are a palatable source of protein and energy, which makes them a valuable livestock feed (Anderson et al., 2007). The energy content of field peas is similar to cereal grains such as corn and barley when included in high-concentrate finishing diets (Lardy et al., 2009). Field peas are primarily grown for human consumption and for the pet food industry (Lardy et al., 2009; Troyer et al. 2020). However, the livestock industry is a potential market for field peas in situations where there is excessive field pea production thus saturating the pet food market (Troyer et al. 2020) or production of field peas which do not meet specifications for human consumption (Lardy et al., 2009; Troyer et al. 2020). The major field pea growing areas include North Dakota and Montana in the US (Lardy et al., 2009) and Manitoba, Saskatchewan and Alberta in western Canada (Chen et al., 2003). In such areas, feeding peas to livestock presents a realistic, on-farm value-adding opportunity for pea growers (Chen et al., 2003).

Field peas have been successfully included in cattle finishing diets (Gilbery et al., 2007; Lardy et al., 2009). In such a diet, peas have to compete with feeds such as barley, corn, wheat middling, distillers’ grains, and oil seed meals (Anderson et al., 2007). Compared to other feedstuffs, the price of field peas is likely to be a major factor in determining utilization of field peas in cattle rations (Anderson et al., 2007). However, identifying a price for field peas as livestock feed presents a challenge since field peas for livestock do not have a formal market compared to other feeds as they are normally priced for human food and pet food markets (Lardy et al., 2009; Troyer et al. 2020). Therefore, there is need for data on which to base reliable recommendations on the economic viability of utilizing field peas as a replacement of supplements such as corn DDGS in growing heifer diets. This study was conducted to determine the economic potential of field peas relative to corn DDGS in diets of growing heifers, and to identify relative price points for competitive utilization of field peas as an alternative to corn DDGS in diets of growing heifers.

MATERIALS AND METHODS

Animal Management

This study was conducted at the Central Grasslands Research Extension Center located in Kidder and Stutsman counties in North Dakota. The 2-year study starting on Nov. 24, 2020 through Feb. 17, 2021 (year 1) and Nov. 8, 2021 through Feb. 24, 2022 (year 2). In the fall of each year, 162 growing Angus heifers (2020/2021, BW = 312 ± 38 kg; 2021/2022, 283 ± 32 kg) were divided into 2 groups of similar average body weight and the groups were randomly assigned to 6 dry lot pens. Dry lot pens were surrounded by 2.5m high wooden windbreaks on 3 sides of the pen. Each pen contained a 16m long feed bunk and a winterized water bowl (Richie Industries Inc., Conrad, IA, USA). Three groups of heifers (27 heifers/pen) were assigned randomly to either a field pea-based or corn DDGS-based total mixed rations (TMR).

Heifer feeding was accomplished using a "clean bunk" feeding management. The goal of clean bunk management is for all feed delivered to a pen to be consumed daily, with bunks being empty for a certain period of time prior to next feeding, without restricting feed intake (Erickson et al., 2003). The heifers were fed once daily at approximately 09:00 each day and feed bunks were targeted to be empty of feed by 16:00. Amount of feed delivered to bunks each week was based on bunk clearance from the previous week. Heifers had *ad libitum* access to fresh water. Heifer performance was assessed from average of two-day body weights taken at the start and end of the study.

Statistical Analysis

Animal performance data were analyzed using the MIXED procedure of SAS (SAS Institute Inc., 2008) with pen as the experimental unit. The statistical model was: $Y_{ijk} = \mu + d_i + s_j + ds_{ij} + e_{ijk}$, where: Y_{ijk} = response variable, μ= overall mean, d_i = effect of the ith diet, s_j = effect of jth season, ds_{ij} = interaction effects of the ith diet and jth season, and e_{ijk} = is the error term. The fixed effects in the model were diet (DDGS or peas), season (fall and winter), and diet x season interaction. Year within pen was considered a random effect. Least square means were calculated and, where appropriate, differences between treatment means were tested using the Bonferroni test at a significance level of $P \leq 0.05$. Initial and final BW were collected on individual animals and a pen value was calculated by averaging the respective individual animal values within a pen. Animal performance measures evaluated included initial and final body weight (BW), average daily gain (ADG), dry matter intake (DMI), and total gain (TG).

Economic Evaluation

Economic evaluation of the feed costs for each TMR treatment (DDGS and Peas) was based on the two-year average measures of DMI (kg hd^{-1} day^{-1}), TG (kg hd^{-1}), and days on feed. Total mixed rations fed in this study were formulated to be isocaloric and isonitrogenous which hypothesis testing revealed similar performance between the heifers on both treatments. This response allowed for an economic comparative ration cost analysis without the need to account for differences in animal performance. Therefore, enterprise budgeting techniques were used to calculate the two-year average costs of individual ingredients for each diet treatment (AAEA, 2000). On March 1, 2022, prices of corn grain, hay, and DDGS were obtained from a local farm input supplier (Farmers Coop Elevator Company, Streeter, N.D.) and were priced at \$275, \$88, and \$325 MT^{-1}, respectively. In addition, a price of \$34 MT^{-1} for corn silage was used and based on local production and estimated from corn production (LaPorte, 2019). Also, in March of 2022, based on conversations with field peas producers, the price of field peas was concluded to be in a range between \$294 and \$404 MT^{-1} (\$8 to \$11 $bushel^{-1}$). For the analysis, then, we used the average base-case price of \$366 MT^{-1} for field peas.

Ration costs (\$ hd^{-1}) were calculated as the product of DMI (kg/day) for each ingredient (DDGS versus peas), days on feed, and individual ingredient price. Individual ingredient DMI was calculated from feed delivered (kg hd^{-1} day^{-1}) and diet composition. Over a two-year period, an average of 4.2% DDGS and 6% field peas were required in the corn DDGS-based and field peas-based diets, respectively. At a feed intake of approximately 8 kg day^{-1} for both diets, 0.30 and 0.43 kg day^{-1} of corn DDGS and field peas, respectively, were included in the respective diets.

Because the price of field peas as source of feed for animal production is not likely directly affected by the price of corn or DDGS, sensitivity analysis was conducted to calculate relative total cost of feeding peas versus DDGS for combinations of prices ranging from ±50% of the base-case prices of \$325 and \$366 MT^{-1} for DDGS and field peas, respectively.

RESULTS AND DISCUSSION

Animal Performance

Animal performance data are reported in Table 1. Initial BW, final BW, DMI, ADG, and TG were not influenced (P > 0.05) by diet but there were seasonal differences for each (P <0.001). Initial and final BW was greater (P < 0.001) in winter relative to fall, which was expected since the same heifers were utilized in winter. Average DMI was greater (P < 0.001) in the winter relative to fall, which follows logic that animals tend to eat more when colder. Conversely, TG and ADG were greater in the fall relative to winter, which reflects the typical observation that animals do not perform as well in the extreme cold that is common to North Dakota in the winter. In general, animal performance was not impacted by diet, which was expected since the diets were formulated to be isocaloric and isonitrogenous.

Table 1. Performance of growing heifers consuming field peas-based or corn DDGS-based total mixed rations.

	TMR diet			Season			P-value		
	DDGS	**Peas**	**SE**	**Fall**	**Winter**	**SE**	**Diet**	**Season**	**Diet x Season**
DMI, kg/d	7.9	8	0.09	7.6^b	8.2^a	0.03	0.55	<0.001	0.718
DMI, %BW	2.6	2.5	0.06	2.6^a	2.5^b	0.03	0.772	0.001	0.75
Initial BW, kg	297	300	9.6	280^b	316^a	2.90	0.707	<0.001	0.655
Final BW, kg	331	336	8.9	317^b	349^a	3.00	0.602	<0.001	0.685
Total gain, kg	34.7	35.7	1.23	37.4^a	32.9^b	0.66	0.439	<0.001	0.533
ADG, kg/d	0.77	0.75	0.05	0.84^a	0.67^b	0.02	0.696	<0.001	0.657

[a-b]Means with a different letter within column for diet or season differ significantly ($P \leq 0.05$).

Economic

Two-year average cost of feed for each ingredient on a (\$ $head^{-1}$ day^{-1}) and (\$ $head^{-1}$) basis are reported in Table 2. The cost of hay, silage, corn grain, and supplements equaled \$82.09 $head^{-1}$ (or \$1.84 $head^{-1}$ day^{-1}) over the total feeding period, accounted for 87% and 81% of the total cost of the corn DDGS-based ration and dry field peas-based ration, respectively. The total cost of feed for a representative heifer for the total (fall plus winter) feeding period for the corn DDGS-based ration is \$93.89 head^{-1} (or \$2.10 head^{1} day^{-1}) and is \$6.88 head^{-1} (7.3%) less than the dry peas-based ration cost of \$100.77 head^{-1} (or \$2.26 head^{-1} day^{-1}) for base-case prices of \$325 MT^{-1} and \$366 MT^{-1} for corn DDGS and field peas, respectively. For perspective, at the base-case prices, a producer interested in feeding a group of 100 heifers similar to those fed in the study, the cost of feeding field peas instead of DDGS in the TMR would cost him an extra \$688 over the total feeding period.

Table 2. Two-year average cost of feed for individual feed ingredients for two total mixed rations for fall, winter and total grazing periods

	Fall		Winter		Total	
Feed ingredient	$/hd/d	$/hd	$/hd/d	$/hd	$/hd/d	$/hd
Hay	0.32	14.61	0.36	16.80	0.66	29.91
Silage	0.13	5.68	0.14	6.76	0.27	12.07
Corn grain	0.29	12.78	0.35	16.41	0.68	29.92
Supplement	0.10	4.71	0.12	5.68	0.23	10.20
Dry distiller grains (DDGS)	0.12	5.46	0.14	6.68	0.26	11.79
Total cost with DDGS included	0.96	43.24	1.11	52.32	2.10	93.89
Field peas	0.20	9.35	0.22	10.48	0.42	18.68
Total cost with field peas included	1.04	47.13	1.20	56.12	2.26	100.77
Difference in cost between rations	0.08	3.89	0.08	3.80	0.16	6.88

Table 3 reports differences in the total cost of field peas relative to the total cost of DDGS for alternative combinations of prices of field peas and DDGS that range from ± 50% of the base-case prices. For reference, price combinations that have a negative total cost indicate market situations where field pea-based rations have an economic advantage over corn DDGS-based rations. For instance, in cases where field peas can be purchased at a price 30% below the base-case price for peas (i.e., peas can be purchased for \$256 MT^{-1} instead of \$366 MT^{-1}), then the price of DDGS must be at least 30% higher than the base-case price (i.e., \$423 MT^{-1} instead of \$325 MT^{-1}) for peas to have a \$2.28 $head^{-1}$ economic advantage over DDGS. For a market scenario where peas can be purchased at a price that is 50% less than the base-case price of peas and the price of DDGS is priced 50% higher than the base-case price, a producer would benefit economically from buying peas and saving \$8.37 $head^{-1}$ of feed cost, holding all other feed ingredient prices constant. Overall, for a base-case average price of \$325 MT^{-1} for DDGS, the breakeven price for field peas was equal to \$231.15 MT^{-1}, which was 36.8% less than the base-case price of \$366 MT^{-1} for peas, and 71% of the base-case price of DDGS. Conversely, for the base-case price of field peas of \$366, the breakeven price of DDGS was equal to \$514.60 MT^{-1}, which was 58.3% more than the base-case price of \$325 MT for DDGS and 141% more than the base-case price for field peas. At the respective breakeven prices, producers would be indifferent between using field peas or corn-based DDGS in their TMR.

Situations that result in excess production of field peas, resulting in drastically lower prices of field peas, might offer opportunities for competitively-priced field peas for use in cattle diets. However, producers typically rely on feed supply companies that they have built a trusting relationship for their feed ingredients, and these relationships have been developed over time because they are accompanied with a reliable supply of competitively prices feeds. Therefore, the pea industry will have to develop a reliable market for cattle quality peas or producers will likely not switch away from their reliable and trustworthy suppliers.

Table 3. Difference in total cost of field peas relative to total cost of dry distiller grains (DDGS) ($/hd) for alternative price ($/MT) combinations

			PEAS						
	%	-	-50%	-30%	-10%	Base*	10%	30%	50%
	-	$/MT	183	256	329	366	403	476	549
DDGS	-50%	163	3.42	7.15	10.88	12.76	14.65	18.38	22.10
	-30%	228	1.07	4.79	8.52	10.41	12.29	16.02	19.75
	-10%	293	-1.29	2.43	6.16	8.05	9.94	13.66	17.39
	Base*	325	-2.45	1.27	5.00	6.88	8.77	11.76	16.23
	10%	358	-3.64	0.07	3.80	5.69	7.58	11.30	15.03
	30%	423	-6.01	-2.28	1.44	3.33	5.22	8.94	12.67
	50%	488	-8.37	-4.64	0.53	2.42	2.86	6.59	10.31

*Base-case net return assuming a price of $325 and $366 per MT for DDGS and field peas, respectively.

CONCLUSIONS

The relative value of field peas as an alternative to corn DDGS in diets for growing heifers was mainly driven by the level of incorporation of field peas into diets and the relative price of field peas to DDGS. Compared to a corn DDGS-based diet, a field peas-based diet that met nutrient requirements of growing heifers required 43% more field peas. At this level of incorporation, field peas would be an economically-feasible replacement for corn DDGS in growing heifer diets when the price of the field peas is less than or equal to 71% of the price of corn DDGS. Our results offer the field pea processing industry useful economic information about the range of prices that beef cattle producers can afford to pay for peas relative to DDGS. This information will help pea processors and feed supply dealers develop a reliable supply chain for a beef cattle quality pea feed. As a result, future research designed to investigate the economically optimal level of field peas production and the development of a reliable supply chain is warranted.

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AGRONOMIC AND ECONOMIC EFFECTS OF WETLANDS ON CROP YIELDS USING PRECISION AGRICULTURE DATA

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Abstract

Wetland drainage has become an increasingly important conservation issue in the Prairie Pothole region of North America. Financial incentives for annual crop production have driven wetland drainage for decades, to the detriment of wetland ecosystem services such as wildlife habitat and carbon sequestration. Past studies which model the farmer's decision to drain wetlands often assume that drained wetlands will produce similar yields to upland regions of the field. We combine precision yield data and detailed wetland mapping data to estimate the agronomic and economic impacts of wetlands and their buffer areas on crop yields and farm financial performance in Saskatchewan.

We find that yields in wetland basins are relatively lower than the field's average yield. Wetland drainage can mitigate these yield effects, but yields in drained wetland basins still fail to meet the field's average yield. These effects can extend more than 50m beyond the wetland boundary. We include these wetland and buffer yield effects in a farm financial analysis and find that these effects impact the net benefits and economic incentives for wetland drainage. The results demonstrate the importance of considering wetland and buffer zone yield effects in wetland drainage decisions and improve our understanding of wetland conservation costs.

Keywords: Wetlands, Wetland buffer zone, Wetland drainage, Crop yields, Precision agriculture, Farm financial analysis

1.0 Introduction

Annual crop production has transformed the landscapes of the Prairie Pothole Region (PPR) in North America over the last century. The PPR is known as such due to the presence of depressions or pothole wetlands that dot the terrain, and includes Canada's Prairie Provinces – Alberta, Saskatchewan, and Manitoba – alongside several northern American states. These low-lying areas were formed by retreating glaciers at the end of the last ice age, and are hydrated with snowmelt each spring, serving a crucial role in the ecology of the region by providing habitat for numerous species, alongside other ecosystem services (Doherty et al, 2018). These wetlands that once defined the landscape of the PPR have been disappearing over time, often drained and converted to farmland, to increase agricultural productivity on a given parcel of land. Drainage activity is ongoing across the PPR. However, the literature reports a wide range in estimates of PPR wetland area lost to drainage, due to a lack of reliable data, varying definitions of loss and minimum wetland size, and timeframe constraints (Waz and Creed, 2017). Wetland drainage can have wide-ranging effects on the landscape, resulting in changes to watershed storage capacity, flood magnitude, nutrient distribution, groundwater recharge, salinity, biodiversity and habitat loss, and carbon sequestration (Baulch et al, 2021).

Although these wetlands provide immense value in ecosystem and recreational services (Pattison et al, 2011; Vickruck et al, 2019), the benefits that PPR wetlands afford to society are rarely reflected in representative markets and therefore not captured by landowners. The opportunity costs of forgone crop production associated with wetland preservation on private property motivate decisions to drain or farm through these areas (Gelso et al, 2008; Cortus et al, 2011; De Laporte, 2014; Clare et al, 2021, Asare et al., 2022). Further, wetlands can be a source of direct costs to landowners and producers. Nuisance and overlap costs arise as farmers spend increased time, fuel, and agricultural inputs navigating around wetlands when seeding, spraying, and harvesting (Gelso et al, 2008; De Laporte, 2014). Wetland drainage can reduce nuisance and overlap costs, subsequently increasing efficiency at the field level (Clare et al, 2021). Landowners in this region have also reported that undrained wetlands can impact crop productivity (Clare et al, 2021); however, these effects have rarely been considered or quantified in past economic research.

While a growing body of work on the topic has improved our understanding of the economic and ecological implications of wetland drainage, much of this research relies on the assumption that wetland areas and surrounding buffer zones will yield at levels similar to the remainder of the field. Realistically, yields in and around wetlands will be at least partially dependent upon the agronomic conditions imposed by the wetland, whereas yields in upland areas would not. This assumption creates a persistent gap in our understanding of how wetlands affect agricultural productivity and incentives for drainage.

The purpose of this paper is to use precision agricultural yield and wetland inventory data in Saskatchewan to estimate the effects of wetland drainage on field crop productivity inside wetland areas and their surrounding buffer zones. We then include these effects in a farm financial analysis to assess the impacts of wetland drainage on farm profitability. This research will foster a stronger understanding of the relationships between wetlands, agricultural yields, and farm financial performance, improving on-farm wetland management and conservation efforts in the Prairie Pothole Region.

2.0 Data

2.1 Study Area

The study area is in the Prairie Pothole region of Saskatchewan, Canada. This is an agriculturally productive region with Chernozemic soils. The region includes both a Black and Dark Brown soil zone and the spatial agronomic differences between these two soil zones allows for a representative investigation of the effects of wetlands on yields in the Prairie Pothole region. The Black soil zone encompasses a wide swathe of land in central and eastern

Saskatchewan, while the Dark Brown soil zone lies directly to the south and west of the Black soil zone (Bedard-Haughn et al, 2018). There tends to be climatic and soil characteristic differences between the Dark Brown and Black soil zones. For example, the Black soil zone is slightly cooler, with more precipitation than the Dark Brown soil zone (Pennock et al, 2011).

2.2 Precision Yield Data

We use precision yield data to quantify the effects of wetland areas and buffer zones on field crop productivity. Advances in agricultural technology in recent decades have resulted in the development of precision agriculture production methods. Precision agriculture technology allows producers to spatially track input use and yields throughout the field to optimize technical and economic efficiency at the sub-field level. Precision agriculture techniques have become increasingly popular among Canadian farmers – 84% of surveyed farmers were utilizing some sort of this technology by 2017, and 60% were using GPS yield monitors (Steel, 2017). Moreover, Saskatchewan farms have the highest adoption rates for many precision agriculture technologies, including auto-steer, variable-rate input application, and GIS field mapping (St. Pierre and Mhlanga, 2022). Increasingly widespread availability of precision agriculture data facilitates accurate and detailed farm financial analysis.

Precision yield data was captured by the combine in the sampled fields at the time of harvest. Yield monitors measured the weight and percent moisture of the crop to calculate a yield per unit area every three meters along each harvested path, which were typically 15 meters apart. The combine yield data is then interpolated to produce a raster dataset of yield for the field, displaying how yield varies in different parts of the field. Each field is then divided into polygons consisting of upland acres, wetland basin acres, and wetland buffer zone acres, which facilitate analysis of the factors which drive yield variance among different areas within a field.

The data used in this analysis was collected from 36 fields in the Black and Dark Brown soil zones. The Black soil zone data is represented by 16 fields, containing 4,689 acres, and encompassing 7 years (2014-2020). Meanwhile, the data from the Dark Brown soil zone is represented by 20 fields, containing 10,433 acres, and spanning a timeframe of 4 years (2016-2019). The data was unbalanced, since not all fields had yield data for all of the study years. Although yield data is collected from a variety of crops, only four – wheat, canola, malt barley, and yellow peas – were considered, due to a lack of sufficient data for other crop types. Malt barley is considered in both soil zones in the descriptive analysis but is only considered in the Black soil zone in the statistical and economic analyses due to data limitations.

Several data cleaning and transformation steps were taken with the raw combine yield data. Many factors can impact the raw data across fields and seasons, including weather, inherent soil quality, crop type, field fertility history, annual fertility and weed control methods, and uncertainty about the calibration of yield monitors. To address these sources of variation, we relativize each polygon's yield data to be expressed as a percentage of the average yield in the field for that year. Therefore, a yield value of 80 in a given polygon implies that the yield in that area is 80% of the field average in that year. The expression of yield in this way elicits direct comparisons of yields in wetlands, their buffer areas, and upland areas of the same field. These data cleaning and transformation procedures are necessary to ensure spatial and temporal comparisons of yield remain sound. We also remove some outliers from the data where yield exceeded 200% of the field average (528 (0.66%) in total), as these values are agronomically unlikely. There are 298 (0.37%) instances of yield being equal to zero, which remain in the dataset. Steps were taken to ensure that unseeded areas were not included in the final dataset, though some may have been missed. Therefore, we assume that these areas simply did not yield any noticeable amount at the time of harvest.

2.3 Wetland and Buffer Zone Data

Wetland inventory of the study area was collected per Canadian Wetland Inventory (CWI) methods (Boychuk et al, 2014). GIS polygons were used to delineate each wetland area. In total, 6,179 wetland polygons were identified on the 36 fields over the study timeframe, enabling multiple year-observations for each wetland, though some fields only have one year of data. Further, the number of wetland observations varies year-by-year and field-by-field due to crop yield data availability and removal of crop types for which there was insufficient data. While the area of each wetland basin is static through time, there is some variation in data availability within and for each field over time.

Yield polygons from a 50m buffer zone surrounding the each wetland basin are also identified. Yield polygons in the buffer zone are separated into 5m increments beginning at the edge of the wetland and extending to 50m away from the wetland. The dataset contains 73,425 buffer zone polygons across all fields. Yield data from outside the wetland and wetland buffer zone areas is not included in the analysis, but since yield is specified as the percentage of field average, the yield variable within the wetland and buffer polygons serves as a comparison to average of the entire field. In total, the data from the Black soil zone contains 49,453 wetland and buffer zone observations, while the Dark Brown soil zone data contains 30,151 wetland and buffer zone observations.

The wetlands in the dataset are categorized and classified based wetland impact code (Boychuk et al, 2014). Wetland impact code describes the level of drainage a given wetland has been subjected to. We use four of the levels most relevant to our study area[1] and present their definitions in Table 1. Impact codes were only categorized once, and thus are assumed to remain static over the period of the study.

Table 1: Definitions of wetland impact code variable.

Impact Code	Definition
Intact	No evidence of drainage.
Partially drained	The water level has been lowered, but the soil contains enough moisture to support hydrophytes (water plants).
Farmed	The soil area has been altered for crop production but remains undrained. If farming is discontinued, hydrophytes will return.
Completely drained	The soil surface has been altered for crop production, and the water level has been lowered.

3.0 Empirical Yield Analysis

3.1 Descriptive Analysis

Note: the descriptive analysis has been omitted from the manuscript due to submission formatting requirements regarding word count and use of colour images. Results display yield trends in and around wetland basins with respect to impact code, crop type, and annual precipitation.

3.2 Statistical Analysis

To better quantify the effects of wetland drainage on crop yields in the Black and Dark Brown soil zones, a regression model incorporating full factorial interactions of crop, impact code, and wetland/buffer location is estimated for both soil zones. The model outputs can be

[1] The two impact codes we do not consider are not represented in the data and include constructed wetlands (the soil area has been excavated to create a water-holding basin) and partially filled wetlands (the basin shows evidence of clearing).

described as average yield responses for each crop within or surrounding wetland basins subject to varying levels of drainage activity. These estimates expand upon on the descriptive analysis and serve as inputs for quantifying the effects of wetland drainage on farm financial performance.

Let yield as a percentage of field average in polygon *i*, in field *j*, during year *t* be modelled as:

$$\frac{Yield_{ijt}}{Field\ Average\ Yield_{jt}} = \beta c_{jt} x_i z_i + \varepsilon_{ijt} \qquad (4.1)$$

Where c_{jt} is the crop planted in field *j* in year *t*, x_i is the impact code of polygon *i*, and z_i is the location of polygon *i* – either inside a wetland basin or in a surrounding buffer zone, and ε_{ijt} is an error term capturing remaining unobserved factors. The estimated parameter vector β is interpreted as the average yield response of each crop, in each impact code, in either a wetland basin or buffer zone as a percentage of the field average. These estimated parameters reveal and control for the effects of these characteristics on yield as a percent of field average in and around wetlands of various drainage impact. Standard errors are clustered at the year and field level to address the fact that multiple polygon data points are from the same field in the same year. Model results and summary statistics of the model parameters are presented in Appendix D.

The model uses observational data, and caution is warranted in assigning causality to the estimated yield effects. While factors such as crop input use (fertilizers, pesticides, etc.), soil quality, and pest pressure, amongst others, are key determinants of yield, data on these factors is unavailable. However, given that crop yield is expressed as a percentage of the field's average, the potential confounding nature of these factors is addressed to the extent that these factors have similar effects across the field. The use of variable rate input application can result in a high degree of subfield input use variability, so it is assumed that input application rates maintain a proportional relationship with crop yields across polygons and fields. The degree to which variable rate application technology was utilized across the fields and years in the dataset is unknown. Since intact and partially drained wetland basins are assumed to be unseeded, average yield response in these areas is zero with no variance in yield.

3.3 Farm Financial Analysis

We integrate the yield response results from the empirical yield analysis into a farm financial analysis to reveal how farm financial performance changes when accounting for the yield effects of wetlands and their buffer zones. We focus on changes in per cultivated acre farm profitability and consider three wetland drainage scenarios: 1) a current conditions scenario, 2) a full drainage scenario, where all wetland basins feasible to drain are assumed to be drained (30% by area remain farmed but not drained), and 3) a restoration scenario, where all wetland basins are assumed to be intact. These drainage scenarios allow for the annual net benefits of wetland drainage to be assessed and compared across a broad spectrum of outcomes.

Table 2: Summary of wetland drainage scenarios considered in financial analysis.

Wetland Drainage Scenario	**Description**
Current Conditions	Regression model average yield response estimates are applied directly from the model, with unique values for each crop, associated with each impact code of wetland basin/buffer zone. The proportions of wetland basins adhering to each impact code in this scenario align with those described in Table 2.
Full Drainage	Under the full drainage scenario, all intact and partially drained wetlands are assumed to be drained. Therefore, the average yield response values for each crop in each location associated with intact and partially drained wetlands are changed to the average yield responses associated with drained wetlands and buffer zones. Farmed but undrained wetlands are assumed to remain undrained.
Restoration	Under the restoration scenario, all drained and partially drained wetlands are assumed to be intact. Therefore, the average yield response values for each crop in each location associated with drained or partially drained wetlands are changed to the average yield responses associated with intact wetlands and buffer zones.

The financial analysis is conducted under two crop yield assumptions: one where yield responses to wetland and buffer zone conditions are accounted for, and one where no yield response is considered, where wetland and buffer zone yields are assumed equal to the field average yield. This elicits a comparison of financial analysis results between the commonly held yield assumptions in previous research, and the yield responses observed over the span of the study, highlighting a disparity with key implications for future research.

The net benefits of wetland drainage are calculated with the same yield data used in the regression analysis. Thus, results for the financial analysis can be described as the annual per cultivated acre net benefits of crop production from the entire field area available in the dataset. This makes profit estimates comparable across fields and drainage scenarios, independent from arable land constraints that may vary by field. The revenues and costs of farm production for the financial analysis are derived from the 2022 Saskatchewan Crop Planning Guide (Government of Saskatchewan, 2022). The analysis considers revenues from crop production under both yield response assumptions, the annual costs of crop production, input overlap costs (as a percentage of crop input costs), nuisance costs (as a percentage of machinery operating costs), and wetland drainage costs. The financial analysis is calculated separately for the Black and Dark Brown soil zones and specified as follows:

$$Per\ Cultivated\ Acre\ Farm\ Net\ Benefits = \frac{\sum(P_c * Y_{cs} * \beta_{cxzs}) - \sum(C_{cs} + O_{cs} + N_s + D_s)}{Cultivated\ Acres_s}$$

Where P_c is the farm gate price for crop *c*, Y_{cs} is the 80th percentile target yield for crop *c* under drainage scenario *s*, β_{cxzs} is the yield response for crop *c*, impact code *x*, and location *z* under drainage scenario *s* (equal to 1 for upland yields and the no yield response assumption), C_{cs} is the annual input costs associated with achieving the target yield under drainage scenario *s*, O_{cs} is the overlap costs of crop *c* under drainage scenario *s*, N_s is the nuisance costs under drainage scenario *s*, and D_s is the drainage costs associated with drainage scenario *s*. A detailed account of cost and benefit calculations can be found in Appendix I.

4.0 Financial Analysis Results

Results from the farm financial analysis, under each yield assumption and drainage scenario, are displayed in Table 4. This set of results assumes the use of sectional control, as this technology is commonly used across Saskatchewan farming operations. In total, the Black soil zone study area consists of 4,689 acres, while the Dark Brown soil zone study area contains 10,433 acres. However, the amount of cultivated acres varies by scenario. For example, since all wetlands are either drained or farmed through in the full drainage scenario, 100% of the acres in the study area are cultivated. Meanwhile, cultivated acres are reduced in the other two scenarios, since intact and partially drained wetlands are assumed to be unseeded.

Table 3: Annual per cultivated acre farm net benefits under three wetland drainage scenarios with sectional control technology and two yield response assumptions.

	Scenario		
	Full Drainage	Current Conditions	Restoration
Black Soil Zone			
% Cultivated Acres	100%	96%	93%
% Wetlands Fully Drained/Farmed	100%	58%	30%
No Yield Response Assumption			
Net benefits	$148	$153	$156
Difference in Profits Relative to Current Conditions	-$5	-	$3
Yield Response Assumption			
Net Benefits	$112	$98	$79
Difference in Profits Relative to Current Conditions	$14	-	-$19
Dark Brown Soil Zone			
% Cultivated Acres	100%	97%	95%
% Wetlands Fully Drained/ Farmed	100%	59%	18%
No Yield Response Assumption			
Net Benefits	$181	$185	$189
Difference in Profits Relative to Current Conditions	-$4	-	$4
Yield Response Assumption			
Net Benefits	$173	$162	$156
Difference in Profits Relative to Current Conditions	$11	-	-$6

Wetland yield response assumptions are responsible for substantial differences in farm net benefit estimates. When yield response effects are not considered, net benefit estimates are higher than those calculated under the yield response assumption, suggesting that previous estimations of the benefits of wetland drainage could be similarly exaggerated. Further, the marginal benefits – or economic incentives – of wetland drainage decrease across drainage scenarios, implying that farmers are disincentivized to drain wetlands, a surprising result which does not align with observed trends of wetland drainage (Lloyd-Smith et al, 2020).

When yield effects are accounted for, raw net benefit estimates are lower, but the marginal benefits of wetland drainage increase across drainage scenarios. Thus, the farmer is incentivized to continue draining wetlands to increase per cultivated acre profitability. Although drained wetlands tend to yield less than upland areas, drainage does improve yields relative to intact wetlands, therefore increasing crop yields across the operation and making up for drainage costs. This relative yield improvement is not captured without the inclusion of yield responses, and the reductions in overlap and nuisance costs facilitated by drainage do not outweigh drainage costs without the consideration of yield effects. Therefore, yield effects are a necessary consideration to accurately model the farmer's incentives for wetland drainage.

Importantly, net benefit estimates are best interpreted in terms relative to one another, rather than as standalone values. Each profit estimate is dependent upon assumptions for baseline crop yields, commodity prices, and input use. Therefore, the relative magnitudes among estimates between the drainage scenarios, and yield assumptions are the most valuable results of this analysis.

Note: We also conduct the farm financial analysis without the use of sectional control, and under different precipitation conditions. These results are presented and discussed in Appendix J.

5.0 Conclusions

The results of this study show that wetland yield effects have substantial impacts on farm productivity and profitability in the Prairie Pothole Region. While factors such as the opportunity cost of uncropped land and nuisance costs have long been known to drive wetland conversion to cropland (Cortus et al, 2011; De Laporte, 2014), the effects of wetlands and their buffer zones on crop yields have rarely been directly addressed in previous research (Clare et al, 2021). We include these effects into a farm financial analysis to illustrate the importance of these factors in incentivizing wetland drainage.

The differences in net benefit estimates between the two yield assumptions reveal the annual costs of wetland yield effects. These costs are as high as $77 per cultivated acre in the restoration scenario, $55 per cultivated acre in the current conditions scenario, and $36 per cultivated acre in the full drainage scenario. This disparity implies that past estimates of wetland retention costs incurred by agricultural producers have been underestimated.

Since wetland retention presents clear opportunity and nuisance costs to landowners and farmers (Cortus et al, 2011), payments to farmers can incentivize increased wetland conservation. In the past, these payments have been insufficient to achieve certain conservation goals (van Kooten and Schmitz, 1992; Cortus et al, 2011). The effects of wetland and buffer zone yield responses escalate the economic incentives for wetland drainage. This finding is vital from a policy perspective, and further suggests that wetland conservation payments may need to increase to properly compensate landowners for wetland retention. This research fills a key gap in understanding how wetlands and their buffer zones affect field crop yields, financial outcomes, and conservation costs in the PPR.

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Appendix A: Definitions of wetland permanence class and cross-tabulation counts and percentages of wetland permanence class and impact code in the study fields.

Wetland class	Definition (Stewart and Kantrud, 1971)
1	Ephemeral – The wetland has free surface water for a short period of time.
2	Temporary – the wetland is periodically covered by water, typically lasting only a few weeks.
3	Seasonal ponds and lakes – the wetland is usually dry by midsummer.
4	Semi-permanent ponds and lakes – the wetland frequently maintains surface water throughout the growing season.
5	Permanent ponds and lakes – the wetland has permanent open water.

Wetland Characteristic		Impact Code				
		Intact	Partially Drained	Farmed	Drained	Total
Class	Temporary	158	35	2711	1055	3959
		(2.6%)	(0.6%)	(43.9%)	(17.1%)	(64.1%)
	Seasonal	465	121	466	596	1648
		(7.5%)	(2.0%)	(7.5%)	(9.6%)	(26.7%)
	Semi-permanent	166	97	49	95	407
		(2.7%)	(1.6%)	(0.8%)	(1.5%)	(6.6%)
	Permanent	86	27	5	47	165
		(1.4%)	(0.4%)	(0.1%)	(0.8%)	(2.7%)
	Total	875	280	3231	1793	6179
		(14.2%)	(4.5%)	(52.3%)	(29.0%)	(100%)

Appendix B: Mean and standard deviations of yields by crop and impact code through the 50m buffer zone.

Buffer Zone Increment (m)	0	5	10	15	20	25	30	35	40	45	50
Yield by… (St. Dev.)											
Crop											
Barley	80.72	86.06	89.94	91.86	92.33	92.55	93.45	93.96	94.72	95.60	96.02
	(43.3)	(36.6)	(33.2)	(30.5)	(28.7)	(28.1)	(26.6)	(25.0)	(23.9)	(23.4)	(22.9)
Canola	80.63	87.95	90.97	92.27	92.92	93.47	94.50	95.10	95.81	96.14	96.68
	(45.5)	(38.8)	(35.5)	(33.4)	(32.0)	(30.9)	(30.0)	(29.0)	(28.1)	(27.2)	(26.1)
Wheat	94.92	95.86	94.52	91.73	89.81	89.34	90.13	91.36	92.93	94.15	94.91
	(45.1)	(39.5)	(36.5)	(34.8)	(33.5)	(32.4)	(30.9)	(29.5)	(28.2)	(27.0)	(25.8)
Yellow	64.92	75.81	81.35	82.94	84.17	85.96	87.88	88.81	90.20	91.25	92.53
Peas	(42.1)	(40.1)	(39.2)	(37.2)	(36.2)	(35.4)	(34.0)	(32.0)	(30.3)	(29.6)	(28.5)
Wetland Impact Code											
Drained	88.25	92.28	93.64	93.89	94.32	95.03	95.96	96.93	97.87	98.38	99.19
	(42.4)	(36.0)	(32.9)	(30.5)	(28.9)	(27.3)	(25.9)	(24.8)	(23.6)	(23.1)	(22.3)
Farmed	87.27	94.11	96.96	97.59	97.74	98.04	98.83	99.35	99.81	100.12	100.15
	(47.2)	(39.5)	(35.3)	(32.3)	(30.3)	(29.1)	(27.9)	(27.0)	(25.9)	(25.0)	(24.5)
Partially	71.91	72.71	70.86	68.85	68.04	69.07	71.43	75.05	79.38	82.26	84.26
Drained	(46.4)	(41.2)	(37.1)	(35.8)	(34.2)	(33.7)	(31.5)	(29.5)	(29.0)	(27.7)	(26.1)
Intact	74.27	77.52	78.27	76.94	75.66	75.85	77.72	79.03	81.27	83.29	85.02
	(44.4)	(39.9)	(37.5)	(35.8)	(35.0)	(34.1)	(33.3)	(31.5)	(30.7)	(30.0)	(28.2)
All Crops and Impact	85.02	89.93	91.54	91.38	91.08	91.30	92.29	93.14	94.22	95.00	95.67
Codes	(45.7)	(39.3)	(36.1)	(34.0)	(32.6)	(31.6)	(30.3)	(29.1)	(27.9)	(26.9)	(25.9)

Appendix C: Precipitation data used in the descriptive analysis.

Precipitation data is derived from three weather stations in both the Black and Dark Brown soil zones, dispersed among the study fields (Government of Canada, 2022). The average of annual precipitation from the three weather stations in each soil zone is taken. Therefore, the analysis utilizes a separate value for average annual precipitation in the Black and Dark Brown soil zones in each year of data collection. Sites in the Black soil zone tend to receive more precipitation on average, and these differences in precipitation and soil type could drive regional differences in agricultural productivity in and around wetland areas.

Annual precipitation from each weather station in the Black and Dark Brown soil zones (mm/year).

Weather Station	2014	2015	2016	2017	2018	2019	2020
Black Soil Zone							
Elkhorn 2 East, MB	629	403	623	362	457	400	316
Virden, MB	-	588	338	246	365	459	263
Kipling, SK	604	429	591	273	452	477	280
Black Soil Zone Average	617	470	517	294	425	445	286
Dark Brown Soil Zone							
Last Mountain CS, SK	-	-	382	229	247	256	-
Moose Jaw CS, SK	-	-	515	218	229	405	-
Regina RCS, SK	-	-	437	152	204	375	-
Dark Brown Soil Zone Average	-	-	445	200	226	345	-

The annual precipitation data above is compared to the average annual precipitation for each soil zone to delineate wet and dry years in the descriptive analysis. If annual precipitation in a given year was greater than the average for that soil zone, it is classified as a wet year, and vice versa. Annual precipitation data by soil zone is obtained from McKenzie, 2019. Average annual precipitation is 437.5mm in the Black soil zone and 350mm in the Dark Brown soil zone.

Appendix D: Regression model parameter summary statistics and results.

Table 2: Summary statistics for dependent and explanatory variables

	Black Soil Zone	Dark Brown Soil Zone
	Mean	
Number of Observations	49,453	27,669
Yield as a Percentage of Field Average [a]	90	93
Crop (proportion of observations)		
Barley	0.13	- [b]
Canola	0.55	0.29
Wheat	0.29	0.56
Yellow Peas	0.03	0.14
Wetland Impact Code (proportion of observations)		
Intact	0.21	0.17
Partially Drained	0.04	0.07
Farmed	0.49	0.50
Drained	0.26	0.26
Location (proportion of observations)		
Wetland Basin	0.08	0.08
Buffer Zone	0.92	0.92

Notes: [a] Yield in each polygon divided by the average yield in field. Percentage values are multiplied by 100, such that the range is 0 to 200.

[b] Malt barley is only considered for the Black soil zone due to data limitations.

Black Soil Zone			
Location	Crop	Impact Code	Average Yield Response (Standard Error)
Wetland Basin	Barley	Drained	71.07*** (5.46)
		Farmed	75.94*** (7.02)
		Partially Drained	0.00
		Intact	0.00
	Canola	Drained	83.12*** (7.15)
		Farmed	71.47*** (8.88)
		Partially Drained	0.00
		Intact	0.00
	Wheat	Drained	91.93*** (8.67)
		Farmed	79.20*** (1.10)
		Partially Drained	0.00
		Intact	0.00
	Yellow Peas	Drained	50.47*** (2.68)

18

		Farmed	65.20*** (7.19)
		Partially Drained	0.00
		Intact	0.00
Buffer Zone	Barley	Drained	92.75*** (2.29)
		Farmed	95.45*** (1.28)
		Partially Drained	72.66*** (0.00)
		Intact	79.57*** (3.56)
	Canola	Drained	97.48*** (2.74)
		Farmed	97.95*** (1.89)
		Partially Drained	82.44*** (3.69)
		Intact	77.92*** (4.25)
	Wheat	Drained	96.70*** (3.34)
		Farmed	97.96*** (1.86)
		Partially Drained	75.38*** (6.89)
		Intact	77.71*** (3.77)
	Yellow Peas	Drained	85.72*** (6.24)
		Farmed	94.95*** (5.01)
		Partially Drained	70.58*** (0.00)
		Intact	51.15*** (6.75)
Number of Observations	49,453		
Adjusted R^2	0.1893		

Notes: Statistical significance indicators: * Significance at $p < 0.10$; ** Significance at $p < 0.05$; *** Significance at $p < 0.01$.

Dark Brown Soil Zone

Location	Crop	Impact Code	Average Yield Response (Standard Error)
Wetland Basin	Canola	Drained	106.28*** (4.69)
		Farmed	115.38*** (12.27)
		Partially Drained	0.00
		Intact	0.00
	Wheat	Drained	107.41*** (6.52)
		Farmed	114.51*** (12.61)
		Partially Drained	0.00
		Intact	0.00
	Yellow Peas	Drained	68.10** (12.01)
		Farmed	68.37*** (9.41)
		Partially Drained	0.00
		Intact	0.00
Buffer Zone	Canola	Drained	102.05*** (1.74)
		Farmed	103.96*** (3.18)
		Partially Drained	77.47*** (6.72)
		Intact	82.08*** (2.18)

	Wheat	Drained	93.88*** (1.82)
		Farmed	98.53*** (3.33)
		Partially Drained	70.47*** (0.73)
		Intact	82.93*** (1.32)
	Yellow Peas	Drained	89.05*** (3.38)
		Farmed	95.28*** (2.83)
		Partially Drained	57.26*** (6.41)
		Intact	79.64*** (4.79)
Number of Observations	27,669		
Adjusted R^2	0.1808		

Notes: Statistical significance indicators: * Significance at $p < 0.10$; ** Significance at $p < 0.05$; *** Significance at $p < 0.01$.

Appendix E: Summary of costs and revenues from field crop production used in the financial analysis (Government of Saskatchewan, 2022).

Black Soil Zone	Crop			
Field Crop Revenues	Wheat	Canola	Peas	Barley
Target Yield (bu/ac)	64.3	51.15	55.12	73.73
Price ($/bu)	$10.56	$17.01	$12.00	$6.11
Baseline Revenue ($/ac)	$679.01	$870.06	$661.44	$450.49
Input Costs ($/ac)				
Seed	$30.60	$75.73	$71.20	$40.61
Seed Treatments/Inoculants	$0.84	$9.00	$12.31	$1.02
Fertilizer				
Nitrogen	$141.15	$143.81	$11.85	$103.86
Phosphorous (P2O5)	$35.81	$49.45	$35.81	$28.99
Sulphur and Other	$0.00	$9.21	$0.00	$0.00
Crop Protection				
Herbicides	$63.33	$66.28	$72.41	$63.78
Insecticides	$21.89	$2.46	$15.22	$21.89
Fungicides	$19.35	$14.18	$14.18	$19.35
Machinery Operating				
Fuel	$19.14	$20.27	$21.39	$19.14
Repair	$11.29	$11.29	$11.29	$11.29
Custom Work and Hired Labour	$23.05	$21.05	$20.30	$21.05
Crop Insurance Premium	$4.78	$10.96	$6.01	$4.68
Hail Insurance Premium	$12.25	$12.25	$12.25	$12.25
Utilities and Miscellaneous	$4.88	$4.88	$4.88	$4.88
Interest on Variable Expenses	$7.79	$9.05	$6.20	$7.08
Other (buildings, property, machinery)	$116.87	$116.87	$116.87	$116.87
Total Cost ($/ac)	$513.02	$576.74	$432.18	$476.75
Net Profit ($/ac)	$165.99	$293.32	$229.26	$(26.26)

Dark Brown Soil Zone	Crop		
Field Crop Revenue	Wheat	Canola	Peas
Target Yield (bu/ac)	57.32	47.18	48.13
Price ($/bu)	$10.56	$17.01	$12.00
Baseline Revenue ($/ac)	$ 605.30	$ 802.53	$ 577.56
Input Costs ($/ac)			
Seed	$26.92	$75.73	$63.20
Seed Treatments/Inoculants	$0.74	$9.00	$10.93
Fertilizer			
Nitrogen	$126.50	$133.16	$10.39
Phosphorous (P2O5)	$31.55	$46.04	$31.55
Sulphur and Other	$0.00	$8.42	$0.00
Crop Protection			
Herbicides	$59.95	$58.24	$66.08
Insecticides	$21.89	$2.46	$15.22
Fungicides	$19.35	$14.18	$14.18
Machinery Operating			
Fuel	$15.31	$16.21	$17.12
Repair	$9.98	$9.98	$9.98
Custom Work and Hired Labour	$22.05	$21.05	$20.30
Crop Insurance Premium	$4.59	$10.51	$5.14
Hail Insurance Premium	$12.25	$12.25	$12.25
Utilities and Miscellaneous	$4.23	$4.23	$4.23
Interest on Variable Expenses	$7.13	$8.46	$5.63
Other (buildings, property, machinery)	$107.53	$107.53	$107.53
Total Cost ($/ac)	$469.96	$537.45	$393.71
Net Profit ($/ac)	$135.34	$265.09	$183.85

Appendix F: Agronomic assumptions from the Black and Dark Brown soil zones (Government of Saskatchewan, 2022).

Crop	Seed	Fertilizer	Plant Protection	Machinery Operating	Hired Labour	Crop Insurance Premium	Utilities and Misc.	Interest Expenses	Other
Black Soil Zone									
Wheat	25 plants/sq. ft. target plant stand.	Nitrogen: 78 lb/ac P2O5: 34 lb/ac.	Based on provincial insect, disease, and weed pressure.	Based on diesel priced $0.901/ litre with a repair rate of 2.6% of yearly machinery investment.	Labour assumed to be $26.40 per hour for custom farm operations.	Five-year averages of premiums by producers who attained targeted yield.	Cost of electricity, natural gas, water, and telephone expenses.	A rate of 3.01% used on all variable expenses applied for 8 months.	Buildings, property, and machinery.
Canola	5 lb/ac. seeding rate.	Nitrogen: 108 lb/ac. P2O5: 58 lb/ac. Sulphur: 15 lb/ac.							
Yellow Peas	178 lb/ac. seeding rate.	Nitrogen: 9 lb/ac. P2O5: 42 lb/ac.							
Barley	25 plants/sq. ft. target plant stand.	Nitrogen: 78 lb/ac. P2O5: 34 lb/ac.							
Dark Brown Soil Zone									
Wheat	22 plants/sq. ft. target plant stand.	Nitrogen: 95 lb/ac P2O5: 37 lb/ac.	Based on provincial insect, disease, and weed pressure.	Based on diesel priced $0.901/ litre with a repair rate of 2.6% of yearly machinery investment.	Labour assumed to be $26.40 per hour for custom farm operations.	Five-year averages of premiums by producers who attained targeted yield.	Cost of electricity, natural gas, water, and telephone expenses.	A rate of 3.01% used on all variable expenses applied for 8 months.	Buildings, property, and machinery.
Canola	5 lb/ac. seeding rate.	Nitrogen: 100 lb/ac. P2O5: 54 lb/ac. Sulphur: 15 lb/ac.							
Yellow Peas	158 lb/ac. seeding rate.	Nitrogen: 8 lb/ac. P2O5: 37 lb/ac.							

Appendix G: Wetland and corrected buffer zone acres by impact code and soil zone.

		Black Soil Zone	Dark Brown Soil Zone
Impact Code		Wetland Area (acres)	
Intact	(0)	117	152
Partially Drained	(1)	69	111
Farmed	(2)	113	117
Drained	(5)	127	256
Total		446	637
Impact Code		Corrected Buffer Area (acres)	
Intact	(0)	558	888
Partially Drained	(1)	215	387
Farmed	(2)	1369	1844
Drained	(5)	731	1367
Total		2873	4486

Appendix H: Yield response matrices for each soil zone and drainage scenario.

Yield response matrix in the Black soil zone, restoration scenario.

Original Data Impact Code	Polygon Type	Scenario Impact Code	Yield Response Index (yield as % of field average)			
			Wheat	Canola	Yellow Peas	Malt Barley
0	Wetland	0	0	0	0	0
1	Wetland	0	0	0	0	0
2	Wetland	2	0.792	0.715	0.652	0.759
5	Wetland	0	0	0	0	0
0	5-50m Buffer	0	0.777	0.779	0.511	0.796
1	5-50m Buffer	0	0.777	0.779	0.511	0.796
2	5-50m Buffer	2	0.98	0.98	0.949	0.955
5	5-50m Buffer	0	0.777	0.779	0.511	0.796

Yield response matrix in the Black soil zone, current conditions scenario.

Original Data Impact Code	Polygon Type	Scenario Impact Code	Yield Response Index (yield as % of field average)			
			Wheat	Canola	Yellow Peas	Malt Barley
0	Wetland	0	0	0	0	0
1	Wetland	1	0	0	0	0
2	Wetland	2	0.792	0.715	0.652	0.759
5	Wetland	5	0.919	0.831	0.505	0.711
0	5-50m Buffer	0	0.777	0.779	0.511	0.796
1	5-50m Buffer	1	0.754	0.824	0.706	0.727
2	5-50m Buffer	2	0.980	0.980	0.949	0.955
5	5-50m Buffer	5	0.967	0.975	0.857	0.928

Yield response matrix in the Black soil zone, full drainage scenario.

Original Data Impact Code	Polygon Type	Scenario Impact Code	Yield Response Index (yield as % of field average)			
			Wheat	Canola	Yellow Peas	Malt Barley
0	Wetland	5	0.919	0.831	0.505	0.711
1	Wetland	5	0.919	0.831	0.505	0.711
2	Wetland	2	0.792	0.715	0.652	0.759
5	Wetland	5	0.919	0.831	0.505	0.711
0	5-50m Buffer	5	0.967	0.975	0.857	0.928
1	5-50m Buffer	5	0.967	0.975	0.857	0.928
2	5-50m Buffer	2	0.980	0.980	0.949	0.955

5	5-50m Buffer	5	0.967 0.975	0.857	0.928

Yield response matrix in the Dark Brown soil zone, restoration scenario.

Original Data Impact Code	Polygon Type	Scenario Impact Code	Yield Response Index (yield as % of field average)		
			Wheat	Canola	Yellow Peas
0	Wetland	0	0	0	0
1	Wetland	0	0	0	0
2	Wetland	2	1.145	1.154	0.684
5	Wetland	0	0	0	0
0	5-50m Buffer	0	0.829	0.821	0.796
1	5-50m Buffer	0	0.829	0.821	0.796
2	5-50m Buffer	2	0.985	1.040	0.953
5	5-50m Buffer	0	0.829	0.821	0.796

Yield response matrix in the Dark Brown soil zone, current conditions scenario.

Original Data Impact Code	Polygon Type	Scenario Impact Code	Yield Response Index (yield as % of field average)		
			Wheat	Canola	Yellow Peas
0	Wetland	0	0	0	0
1	Wetland	1	0	0	0
2	Wetland	2	1.145	1.154	0.684
5	Wetland	5	1.074	1.063	0.681
0	5-50m Buffer	0	0.829	0.821	0.796
1	5-50m Buffer	1	0.705	0.775	0.573
2	5-50m Buffer	2	0.985	1.040	0.953
5	5-50m Buffer	5	0.939	1.020	0.890

Yield response matrix in the Dark Brown soil zone, full drainage scenario.

Original Data Impact Code	Polygon Type	Scenario Impact Code	Yield Response Index (yield as % of field average)		
			Wheat	Canola	Yellow Peas
0	Wetland	5	1.074	1.063	0.681
1	Wetland	5	1.074	1.063	0.681
2	Wetland	2	1.145	1.154	0.684
5	Wetland	5	1.074	1.063	0.681
0	5-50m Buffer	5	0.939	1.020	0.890
1	5-50m Buffer	5	0.939	1.020	0.890
2	5-50m Buffer	2	0.985	1.040	0.953
5	5-50m Buffer	5	0.939	1.020	0.890

Yield response matrix under wet conditions in the Black soil zone, restoration scenario

Original Data Impact Code	Polygon Type	Scenario Impact Code	Yield Response Index (yield as % of field average)		
			Wheat	Canola	Malt Barley
0	Wetland	0	0	0	0
1	Wetland	0	0	0	0
2	Wetland	2	0.871	0.648	0.687
5	Wetland	0	0	0	0
0	5-50m Buffer	0	0.778	0.646	0.769
1	5-50m Buffer	0	0.778	0.646	0.769
2	5-50m Buffer	2	0.981	0.945	0.941
5	5-50m Buffer	0	0.778	0.646	0.769

Yield response matrix under wet conditions in the Black soil zone, current conditions scenario

Original Data Impact Code	Polygon Type	Scenario Impact Code	Yield Response Index (yield as % of field average)		
			Wheat	Canola	Malt Barley
0	Wetland	0	0	0	0
1	Wetland	1	0	0	0
2	Wetland	2	0.871	0.648	0.687
5	Wetland	5	0.920	0.724	0.655
0	5-50m Buffer	0	0.778	0.646	0.769
1	5-50m Buffer	1	0.720	0.735	0.817
2	5-50m Buffer	2	0.981	0.945	0.941
5	5-50m Buffer	5	0.953	0.926	0.896

Yield response matrix under wet conditions in the Black soil zone, full drainage scenario

Original Data Impact Code	Polygon Type	Scenario Impact Code	Yield Response Index (yield as % of field average)		
			Wheat	Canola	Malt Barley
0	Wetland	5	0.920	0.724	0.655
1	Wetland	5	0.920	0.724	0.655
2	Wetland	2	0.871	0.648	0.687
5	Wetland	5	0.920	0.724	0.655
0	5-50m Buffer	5	0.953	0.926	0.896
1	5-50m Buffer	5	0.953	0.926	0.896
2	5-50m Buffer	2	0.981	0.945	0.941
5	5-50m Buffer	5	0.953	0.926	0.896

Yield response matrix under dry conditions in the Black soil zone, restoration scenario.

Original Data Impact Code	Polygon Type	Scenario Impact Code	Yield Response Index (yield as % of field average)		
			Wheat	Canola	Malt Barley
0	Wetland	0	0	0	0
1	Wetland	0	0	0	0
2	Wetland	2	0.704	0.750	0.821
5	Wetland	0	0	0	0
0	5-50m Buffer	0	0.773	0.817	0.826
1	5-50m Buffer	0	0.773	0.817	0.826
2	5-50m Buffer	2	0.978	1.000	0.969
5	5-50m Buffer	0	0.773	0.817	0.826

Yield response matrix under dry conditions in the Black soil zone, current conditions scenario.

Original Data Impact Code	Polygon Type	Scenario Impact Code	Yield Response Index (yield as % of field average)		
			Wheat	Canola	Malt Barley
0	Wetland	0	0	0	0
1	Wetland	1	0	0	0
2	Wetland	2	0.704	0.750	0.821
5	Wetland	5	0.918	0.882	0.794
0	5-50m Buffer	0	0.779	0.817	0.826
1	5-50m Buffer	1	0.826	0.847	0.677
2	5-50m Buffer	2	0.978	1.000	0.969
5	5-50m Buffer	5	1.005	1.000	0.980

Yield response matrix under dry conditions in the Black soil zone, full drainage scenario.

Original Data Impact Code	Polygon Type	Scenario Impact Code	Yield Response Index (yield as % of field average)		
			Wheat	Canola	Malt Barley
0	Wetland	5	0.918	0.882	0.797
1	Wetland	5	0.918	0.882	0.797
2	Wetland	2	0.704	0.750	0.821
5	Wetland	5	0.918	0.882	0.797
0	5-50m Buffer	5	1.005	1.000	0.980
1	5-50m Buffer	5	1.005	1.000	0.980
2	5-50m Buffer	2	0.978	1.000	0.969
5	5-50m Buffer	5	1.005	1.000	0.980

Appendix I: Detailed description of financial analysis

We integrate the yield response results from the empirical yield analysis into a farm financial model to reveal how farm financial performance changes when accounting for the yield effects of wetlands and their buffer zones. We focus on changes in per cultivated acre farm profitability and consider three wetland drainage scenarios: 1) a current conditions scenario, 2) a full drainage scenario, where all wetland basins feasible to drain are assumed to be drained (30% by area remain farmed but not drained), and 3) a restoration scenario, where all wetland basins are assumed to be intact. The financial analysis is conducted under two crop yield assumptions: one where yield responses to wetland and buffer zone conditions are accounted for, and one where no yield response is considered, where wetland and buffer zone yields are assumed equal to the field average yield. This elicits a comparison of financial analysis results between the commonly held yield assumptions in previous research, and the yield responses observed over the span of the study, highlighting a disparity with key implications for future research. We expand the analysis to compare the differences in profitability across drainage scenarios in relatively wet and dry years, and investigate how estimates change with the adoption of sectional control technology on field operations equipment.

The net benefits of wetland drainage are calculated with the same yield data used in the regression analysis. Thus, results for the financial analysis can be described as the annual per cultivated acre net benefits of crop production from the entire field area available in the dataset. This makes profit estimates comparable across fields and drainage scenarios, independent from arable land constraints that may vary by field. Notably, much of the previous literature expresses profit estimates in dollars per wetland acre, rather than per cultivated acre, meaning that monetary values may not be directly comparable to other research.

The revenues and costs of farm production for the financial analysis are derived from the 2022 Saskatchewan Crop Planning Guide (Government of Saskatchewan, 2022). Crop input cost values are based on those required to achieve 80th percentile target yields, unique to the agronomic conditions of the Dark Brown and Black soil zones respectively. These target yields are also assumed to be the field average yields. While crop yields may not always achieve the 80th percentile target in practice, this target yield was selected to represent the realistic per acre input costs a Saskatchewan farmer incurs. The analysis considers revenues from crop production under both yield response assumptions, the annual costs of crop production, input overlap costs (as a percentage of crop input costs), nuisance costs (as a percentage of machinery operating costs), and wetland drainage costs. The financial analysis is calculated separately for the Black and Dark Brown soil zones and specified as follows:

$$Per\ Cultivated\ Acre\ Farm\ Net\ Benefits = \frac{\sum(P_c * Y_{cs} * \beta_{cxzs}) - \sum(C_{cs} + O_{cs} + N_s + D_s)}{Cultivated\ Acres_s}$$

Where P_c is the farm gate price for crop c, Y_{cs} is the 80th percentile target yield for crop c under drainage scenario s, β_{cxzs} is the yield response for crop c, impact code x, and location z under drainage scenario s (equal to 1 for upland yields and the no yield response assumption), C_{cs} is the annual input costs associated with achieving the target yield under drainage scenario s, O_{cs} is the overlap costs of crop c under drainage scenario s, N_s is the nuisance costs under drainage scenario s, and D_s is the drainage costs associated with drainage scenario s.

The model assumes an equal crop rotation; therefore, wheat, canola, yellow peas, and malt barley each make up 25% of Black soil zone acres, while acres in the Dark Brown soil zone are equal parts wheat, canola, and yellow peas. The costs and revenues associated with field crop production are detailed in Appendix E. Associated agronomic assumptions are presented in Appendix F.

Drainage, overlap, and nuisance costs are included in the financial model to comprehensively evaluate the costs and benefits of wetland drainage. Drainage costs are derived from a digital elevation model (DEM) of 148 drainage ditches identified in the fields in the sample. To estimate annual wetland drainage costs, a relationship between ditch excavation volume and area of wetland drained is established and factored together with drainage costs of $4/m^3 of ditch material excavated and a borrowing rate of 5% amortized over 25 years, resulting in an annual cost of $267/acre drained.

Overlap and nuisance costs are developed using similar processes. Field path data, implement width, and total seeded/sprayed area are used to determine the percentage of input overlap on each field. Then, a linear relationship between overlap percentage and the percentage of the field represented as intact and partially drained wetland is estimated and used as an index to determine the overlap cost percentage. This value is applied to crop input costs and machinery expenses to estimate input overlap and nuisance costs respectively.

Scenarios involving sectional control on field operations equipment are also considered. Sectional control reduces input overlap by turning off individual portions of farm implements when farmers navigate around obstacles and field boundaries. Sectional control technology is becoming increasingly available to Canadian farmers; 73% of surveyed farmers used this technology on at least one piece of equipment in 2017 (Steel, 2017). This analysis assumes that when sectional control is used, overlap with previous input applications is decreased such that application costs are 8 times less than they would be without sectional control. This estimate is based on the suggestion of the Water Security Agency for the average effectiveness of sectional control technology in Saskatchewan. In practicality, the effectiveness of sectional control in reducing overlap costs will vary based on a number of factors, including implement size, row spacing, field size, and the size and shape of wetlands and other obstacles (Gaetz and Lung, 2020; Barker, 2022). The relative benefits of wetland drainage between drainage scenarios are expected to be reduced when sectional control technology is adopted.

There are several instances where buffer zone polygons are within 100m of one another, therefore overlapping. To alleviate this issue, a buffer correction index was developed by dividing the buffer area (total field area, less total wetland area and non-buffer area) by the area of all buffer zone polygons. This index was used to adjust the buffer areas associated with each wetland impact code. Wetland and corrected buffer zone areas are displayed in Appendix G.

Appendix J: Financial analysis results based on annual precipitation and without sectional control.

The descriptive analysis reveals differing trends in crop yields within the wetland basin and across the 50m buffer zone with respect to annual precipitation. To quantify these effects on farm profitability, we adjust the yield response matrices for relatively wet and dry years, where years with above average annual precipitation are denoted as a wet year, and years where annual precipitation is below average are considered dry. Since the Dark Brown soil zone sample only consists of four years, net benefits are only presented for the Black soil zone to ensure an informative sample. Further, yellow peas are excluded from the analysis due to a lack of data in certain years. Since yellow peas tend to cost less to produce and yield relatively poorly in and around wetland basins, inclusion of yellow peas in the crop rotation would reduce per acre farm revenues and decrease per acre input costs across the crop rotation, resulting in an ambiguous effect on farm profits. Therefore, these results should only be interpreted as a comparison between relatively wet and dry conditions and are not directly comparable with the four-crop rotation results presented in Table 4. Precipitation data used in the analysis can be found in Appendix C, and results are presented in Table 5.

Annual per cultivated acre farm net benefits under three wetland drainage scenarios, using average yield response indices under relatively wet and dry conditions, with sectional control technology, in the Black soil zone.

	Scenario		
Black Soil Zone	Full Drainage	Current Conditions	Restoration
Under Relatively Wet Conditions			
Net Benefits	$88	$74	$56
Difference in Profits Relative to Current Conditions	$14	-	-$18
Under Relatively Dry Conditions			
Net Benefits	$113	$98	$82
Difference in Profits Relative to Current Conditions	$15	-	-$16

In the Black soil zone, wetland basins and their surrounding buffer zones are more profitable in relatively dry years. This result aligns with the yield effects observed in the descriptive analysis, where yields tend to be noticeably higher in the wetland basin and across the buffer zone in dry years. The relative lack of moisture in these years may mitigate some of the negative agronomic effects of wetland basins.

While changes in per acre profits across drainage scenarios are similar in both wet and dry years in absolute terms, the changes as a proportion of total net benefits is much higher in wet years, showing that economic incentives for wetland drainage are higher under relatively wet conditions. Wetland drainage can mitigate the adverse effects of wetlands on farm profitability in wet years, and these economic benefits are retained in drier years.

To compare how farm financial analysis and the benefits of wetland drainage can be influenced by the adoption of farming technology, Table 6 displays the financial model results without the use of sectional control.

Table 6: Annual per cultivated acre farm net benefits under three wetland drainage scenarios and two yield response assumptions, without the use of sectional control technology.

	Scenario		
	Full Drainage	Current Conditions	Restoration
Black Soil Zone			
No Yield Response Assumption, without Sectional Control			
Net Benefits	$148	$137	$128
Difference in Profits Relative to Current Conditions	$11	-	-$9
Yield Response Assumption, without Sectional Control			
Net Benefits	$112	$83	$51
Difference in Profits Relative to Current Conditions	$29	-	-$32
Dark Brown Soil Zone			
No Yield Response Assumption, without Sectional Control			
Net benefits	$181	$176	$170
Difference in Profits Relative to Current Conditions	$5	-	-$6
Yield Response Assumption, without Sectional Control			
Net Benefits	$173	$153	$138
Difference in Profits Relative to Current Conditions	$20	-	-$15

The ability to turn off input application when farm implements overlap reduces costs of production, thereby increasing profitability. The results show broadly reduced profit margins when this technology is not utilized. Economic incentives for wetland drainage are also altered when sectional control is forgone. For example, in the Black soil zone without sectional control, full wetland drainage increases profits by $29/cultivated acre relative to the current conditions. However, when sectional control is used, this disparity is only $14/cultivated acre. The adoption of sectional control technology reduces farmer incentives to drain wetlands as nuisance and overlap costs are mitigated. When all wetlands are drained or farmed through, sectional control does not affect net benefits of drainage, since farm machinery is not forced to navigate around wetland areas.

BATTLEFIELD TACTICS FOR THE MANAGEMENT OF *ZYMOSEPTORIA TRITICI*

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Abstract

Zymoseptoria tritici, often known as Septoria Tritici Blotch or STB, is a major disease of wheat which can cause yield reductions of 30-50% by reducing the photosynthetic area of the crop. A range of cultural techniques can be employed but in isolation these have limited success for control. Z. tritici control is still heavily reliant on fungicides which is becoming ever more challenging due to increasing fungicide resistance. This paper discusses how Z. tritici can be controlled by a series the military battlefield strategy through shaping, decisive and sustaining actions, underpinned by a constantly refreshed understanding of the operating environment. Decisive actions are those actions that, without which, the mission (in this case achieving a good yield from a wheat crop) could not be achieved. Shaping actions are those actions that set conditions for a successful decisive action. Sustaining actions are those which sustain the ability to deliver shaping and decisive actions Considering Z. tritici management using this range of strategies will effectively help severe yield loss from disease infection.

Keywords

Septoria, Leaf Blotch, wheat, disease, *Zymoseptoria tritici*, battlefield

Introduction

Septoria Tritici Blotch (STB) (*Zymoseptoria tritici)* is a foliar disease of wheat, rye, and triticale (AHDB, 2020a). It is the most ubiquitous wheat disease globally (Suffert et al., 2010) causing significant yield losses, especially in temperate regions (Dean, et al., 2012). Z. tritici is characterised by brown necrotic lesions on the leaves and stems of the infected plant, which surround dark fruiting bodies (Ponomarenko et al., 2011 (Quaedvlieg, et al., 2011)). Z. tritici epidemics have two district phases.

<u>Phase 1</u>

Early Epidemic Phase: This phase begins during leaf emergence and tillering, with the initial infection of the crop by the spores of the Z. tritici fungus (Suffert et al., 2010). These spores come in two forms. Ascospores are dispersed aerially from pseudothecia, a dark fruiting body which contains spore producing organs, and are characterised by reproducing sexually and their double cell wall which absorbs water to violently expels spores (Wyatt et al., 2013). Pycnidiospores are dispersed either aquatically or by direct contact and emanate from pycnidia, a dark fruiting body which contains spore producing organs. They are characterised by asexual reproduction and oozing their spores (Emlab, 2022).

Initial Infection: 70% of initial infection occurs through aerial transmission of ascospores (AHDB, 2020a) with 30% occurring through splashing of pycnidiospores (Suffert et al., 2010). The most significant source of spores is external wheat debris, followed by internal wheat debris (especially in second wheats), infected volunteers, and infected grass margins (Suffert et al., 2010).

Latent Phase: Within 24 hours of landing on a leaf spores germinate and produce hyphae which bypass the protective epidermis of the leaf by entering stomatal cavities (Steinberg, 2015). The hyphae colonise the mesophyll of the leaf, linking up stomatal cavities in a network in up to 15 days post infection (Shetty, et al., 2003). Concurrently, colonised stomal cavities fill with pre-pycnidia which begin to develop (Kema et al., 1996). If the colonised areas of two different strains of *Z. tritici*, that are of opposite mating types meet they will reproduce sexually resulting in pseudothecia (Suffert et al., 2010). During the latent phase identification of infection by visual inspection will prove difficult (Bayer, 2022).

<u>Phase 2</u>

Necrotic Phase: 14 to 28 DPI pycnidia and pseudothecia reach maturity and the infection enters the necrotic phase characterised by lesions and exposed dark fruiting bodies on the leaf (AHDB, 2020a).

Secondary Infection: During leaf emergence and tillering, interleaf transfer of pycnidiospores occurs by rain splash and physical contact. This expands the number of infected leaves within the crop (Ponomarenko et al., 2011) and the latent, necrotic and secondary infection phases cycle. Lower temperatures during the winter suppress fungal activity and slower plant growth reduces availability of new host leaves, further suppressing the expansion of infection within the crop (Suffert et al., 2010).

Late Epidemic Phase: Fungal activity resumes in the spring, as increased temperatures and plant growth enable further infection (Ponomarenko et al., 2011). The primary driver of disease spread during the late epidemic phase is secondary infection via the transition of pycnidiospores, from infected lower leaves to emerging upper leaves (AHDB, 2020a). Ascospores provide a second vector for infection enabling new primary infection (Suffert et al., 2010). As temperatures increase towards the fungus' optimal range of 15-20^{o}C, the latent period shortens (AHDB, 2020a) and the rate of infection increases (AHDB, 2021a). When the crop is harvested Z. tritici remains in the sources discussed above and the cycle begins again in the next harvest year.

The importance of Septoria Tritici Blotch

Z. tritici is considered a challenging disease because it can cause catastrophic yield losses in one of the most important cash crops and is highly adaptable making it difficult to manage (Dean, et al., 2012).

a. **Yield Loss**. Z. tritici can cause reductions in yield ranging from 30% to 50% (AHDB, 2020a). Yield loss is caused by lesions which reduce the leaf area available for photosynthesis. A 1% loss of photosynthesising surface of the flag leaf and second leaf will result in a 1% and 0.6% reduction in yield respectively (Bayer, 2022).

b. **Regional Significance**. Fones and Gurr (2015) assessed that yield losses caused by Z. tritici cost UK agriculture up to €240 million per annum, following a spend of c. €163 million per annum on crop protection, making Z. tritici the target of around 70% of fungicide applied. In the UK, Z. tritici is particularly significant in the South West because it experiences higher rainfall and fewer days below -2^{0}C (Met Office, 2013) which enables better survival overwinter (Gladders, et al., 2001) and easier transmission (AHDB, 2020a).

c. **Adaptability**. Z. tritici can reproduce sexually and undergo many cycles of reproduction during a growing season, resulting rapid evolution (Ponomarenko et al., 2011). It develops fungicide resistance and adapts to resistant genes in plants quickly. Up 90% of its genetic pool can be present in a single field (Zhan et al., 2003) and this diversity increases the likelihood of an effective strain of Z. tritici being present while the rapid sexual reproductive cycle enables the initial breakdown to be exploited (Orton et al., 2011). Z. tritici is not the only arable disease capable of developing and overcoming resistance, it is currently seen as the greatest risk (FRAG UK, 2020), so much so that in the 22/23 growing season, wheat received a

3 year resistance rating and a 1 year resistance rating on AHDB's Recommended List (RL) (AHDB, 2022a).

Historic Management of Z. tritici

Z. tritici has been an active pathogen since the domestication of wheat around 8000 BC and has co-evolved and spread around the world with wheat (Stukenbrock, et al., 2010). In the 1980's it overtook Septoria nodorum as the most endemic foliar disease, possibly due to a reduction in atmospheric SO_2 levels and the introduction of dwarf genes to wheat (Shaw et al., 2007).

Crop protection control measures can be broadly broken in to four categories; resistant cultivars, cultural controls, biological controls, and chemical controls (Back et al., 2021). Chemical and cultural controls dominated historic Z. tritici management as resistant cultivars did not emerge until the 1990's (Goodwin, 2007) and biological controls are still developing.

Loss of Controls to Fungicide Resistance. Continuous erosion of fungicide efficacy, and occasional total breakdown, due to poor fungicide resistance management has been the leading issue in Z. tritici management. Repeated use of the same fungicide, failure to combine modes of action, and over reliance on chemical controls have led to the loss of several products (Brent & Holloman, 2007). This historic loss of fungicides, particularly single-site fungicides, seriously restricts current management by reducing the pool of fungicides available for rotation to avoid resistance (FRAG UK, 2020).

1) *Methyl Benzimidazole Carbamates (MBCs)*, were the main form of control up to the 1980s, but repeated single use and no combination of mode of action selected for a resistant allele (E198A) resulting in loss of control (Lucas et al., 2015).

2) *Quinone Outside Inhibitors (QoIs)/Strobilurin fungicides*, were introduced to the UK in 1997 with excellent efficacy. Resistance was identified in 2002 and control was lost at an unprecedented rate over the subsequent 3 seasons despite efforts to check the decline (Fraaijie, et al., 2005). As with MBCs, poor management practices selected for a resistant allele (G143A). To prevent further loss of control solo use of QoIs was abandoned in favor of pairing it with a product with a different mode of action and the number of uses within a season was reduced to two. Despite these efforts QoIs became largely ineffective in the UK and other countries by 2004 (Lucas et al., 2015).

3) *Demethylation Inhibitors (DMIs)/Azoles:* The loss of QoIs led to increased use of Chlorothalonil (CTL) and azoles to control Z. tritici. DMIs, a Group 3 Sterol Biosynthesis Inhibitor (SBI) (FRAC, 2022), have a varying efficacy on Z. tritici which has declined over time driven by target site changes (Leroux & Walker, 2011). AHDB trials have shown show that azole efficacy is below 50% with prothioconazole as low as 20%, but the newer mefentrifluconazole shows very high efficacy (AHDB, 2021b).

4) *Succinate Dehydrogenase Inhibitors* (SDHIs). The new generation of SDHIs were introduced after resistance management was better understood and practiced. Their use for managing Z. tritici has become widespread in Europe and up to 2015 no reduction in efficacy had been found (Lucas, Hawkins, & Fraaije, 2015). Recently there has been a gradual reduction in the level of control provided but resistance management techniques appear to be effective in reducing the speed of control loss (AHDB, 2021b).

*Loss of Controls to Legislation***:** CTL had been a vital element of resistance management strategies as it provided a highly effective, low cost, multisite action with a low risk of resistance development that reduced the pressure on the higher risk fungicides. Its approval for use in the EU was withdrawn in 2019. Folpet and mancozeb (legal in the UK but withdrawn in the EU (HSE, 2022) are both alternative multisites but have a higher cost and lower efficacy making them poor replacements (AHDB, 2022b). The recent loss of this vital control measure is a defining feature of current and Z. tritici management strategies.

Current Management practices

Integrated Pest Management (IPM) is a systemic approach to crop protection aimed at using non-chemical controls to manage pest incidence to a level where chemical controls can be used economically and sustainably (AHDB, 2019). IPM can be best understood through the lens of the Operational Framework, an effective method for articulating how actions contribute to achieving a desired outcome (Land Warfare Development Centre, 2017). This framework divides activity into, shaping, decisive and sustaining actions, underpinned by a constantly refreshed understanding of the operating environment. Decisive actions are those actions that, without which, the mission (in this case achieving a good yield from a wheat crop) could not be achieved. Shaping actions are those actions that set conditions for a successful decisive action. Sustaining actions are those which sustain the ability to deliver shaping and decisive actions (Land Warfare Development Centre, 2017).

a. *Understanding the Environment*: Regional variations in weather patterns influence disease pressure (Gladders, et al., 2001). For example an area which experiences mild wet conditions are likely to experience high levels of disease pressure and plans should reflect the forecast elevated level of risk by adopting more robust shaping activities. In year weather should be used to revise the plan, a cooler dry spell will reduce the threat (Gladders, et al., 2001) and wet weather during peak growing conditions would increase the threat (AHDB, 2019). Understanding the real time disease burden within crops by crop walking will enable refinement of the crop protection plan to correctly allocate resources, maximising margin by reducing expenditure or increasing yield (Finch et al., 2014). Crop walking will also enable effective timing of applications based on the crop growth stage (AHDB, 2019). Finally, understanding the level of threat posed by other foliar fungal diseases will also impact spraying decisions as other diseases may present a greater threat.

b. *Shaping Actions*: Three shaping actions set the conditions for the decisive action by keeping disease pressure at a level which can be economically managed.

1) *Varietal resistance selection*: The key shaping action is selecting a variety of wheat with high Z. tritici resistance from the varieties available. Resistant varieties reduce the severity of Z. tritici I epidemics, enabling a greater yield response from fungicide applications (Morgan, et al., 2021). While there have been recent breakdowns in varietal resistance, especially in the decedents of Cougar 8 (AHDB, 2021c), varieties such as KWS Extase (AHDB, 2022a) still restrict Z. tritici to a manageable level. It could be argued that in the south west selecting for varietal resistance is the decisive action as without selecting a high resistance variety Z. tritici could be unmanageable, however no variety on the RL gives complete resistance (AHDB, 2022a) and even with the selection of the highest resistance varieties the application of fungicide will still be necessary in a normal year. Mixtures of varieties with resistance provided by different genes can also help in reducing the disease pressure within a crop (Orellana-Torrejonet al., 2022).

2) *Sowing date:* The second most important shaping action is sowing date (AHDB, 2019). Reducing the period of exposure by later drilling shortens the window for primary infection especially where there are long growing seasons in temperate regions, reducing disease levels. Drilling slightly later rather can reduce disease levels by 6% in high threat regions (Morgan, et al., 2021) but can result in yield reductions where disease pressures are low.

3) *Establishment technique:* Reduced seed rates and cultivation techniques which bury infected debris can have some effect on disease burden. Lower seed rates can lead to lower-than-expected levels of disease by reducing humidity and temperature within the canopy. However reduced seed rates can also negatively impact final yield so there needs to be a fine balance to between the two (Morgan, et al., 2021). Cultivation methods can bury localised infected trash, reducing infection from pycnidiospores, but as ascospores are the driving force behind primary infection in the early growth stages, it will only have a limited effect (Suffert et al., 2010).

c. *Decisive Actions:* In wheat the flag leaf and second leave provide c. 40% and 25% of total yield respectively (AHDB, 2019). Protecting the flag leaf and leaf 2's ability to photosynthesise at maximum efficiency are both decisive actions, but as the flag leaf contributes more to yield protecting it is the main effort. The effectiveness of fungicides in protecting these leaves is a function of timing, product choice and product dose. As fungicides are more effective in prevention rather than in eradication (NIAB TAG, 2019) they need to be applied before spores arrive on the upper leaves.

1) *T2 application* is critical for providing protection to the flag leaf as it is timed to coincide with GS39 which is the earliest application timing which can be used to directly protect the full surface of the flag leaf (AHDB, 2021a). If leaf 2 is infected it will still be early in the latent phase and T2 application will provide some eradicative effect (AHDB, 2020b) see Figure 2. Product choice and dosage depend on the assessed disease pressure as the amount spent on protection needs to be proportional to the threat to maximise margin (NIAB TAG, 2019). Multiple modes of action should be used to achieve best control. Azoles and folpet are the baseline treatment for T2, providing protection and helping manage resistance, SDHIs or Quinone Inside Inhibitors (QiLs) should be added depending on

disease pressure (AHDB, 2020b) to provide protection to the flag leaf and have an eradicative effect on Z. tritici latent on leaf 2 (AHDB, 2021b), QiLs can only be used once in a season and should be used at T2 to benefit from their eradicant effect.

2) *T1 application* is timed to coincide with GS32 when leaf 3 is just emerged and is designed to protect leaf 3 from infection and in doing so protect leaf 2 from spore transfer from leaf 3 (AHDB, 2019). DMIs and folpet should be used with an SDHI but actives should be different to T2 to maximise effect and manage resistance (AHDB, 2021b).

d. *Sustaining Actions:* Consistently applied fungicide resistance management strategies are the principal sustaining action for Z. tritici management as they preserve our control of Z. tritici in wheat. The history of Z. tritici management clearly illustrates the importance of continued discipline in fungicide use. Breeding to create new Z. TRITICI resistant or tolerant varieties of wheat, and the creation of new biological and chemical controls are also vital sustaining actions.

Future Management of Z. tritici

There are several technologies under adoption or on the horizon for Z. tritici management that are incremental improvements to current practice but do not overhaul it. Accurate and automated disease detection with tools using rapid pathogen DNA recognition (Microgenetics, 2022) and remote infield spore traps networked with modern agricultural data management platforms will provide accurate, field level disease modelling, enabling better understanding of the environment. The approval of new fungicides such as the QiL fenpicoxamid in 2021 (Corteva, 2021) will replace lost controls and new application technologies will improve their delivery (Teagasc, 2021), maintaining or improving the decisive action but not fundamentally changing it. Gene editing will increase the speed with which resistant varieties of wheat can be created (DEFRA, 2022) providing farmers with more effective shaping actions but not negating the requirement for the application of chemical controls. Developments in biopesticides or bioprotectants may enable a strategic shift in Z. tritici management (Back et al., 2021). Bioprotectants are agents based on micro-organisms, semiochemicals or botanicals that can be used to manage disease epidemics (AHDB, 2022c). The biochemical Iodus, already approved for use in the UK, has provided similar levels of Z. tritici control to folpet when applied at T0 (Agrii, 2021) with no residue or buffer zones (UPL, 2022) and Lipoetides have been shown to reduce Z.

tritici levels by up to 82% under laboratory conditions (Mejri, et al., 2018). Currently, high costs, slow action, poor supply, and issues with application are restricting adoption (Fenibo et al. 2021). Increased funding and research driven by the need for greener and more sustainable solutions are likely to resolve many of the issues with bioprotectants but with widespread adoption will come widespread evolution of Z. tritici.

Conclusion

Von Clausewitz (1874) argues that the nature of war, a violent politically motivated contest between forces, is immutable, but the character of war, the ways and means by which the war is conducted, is ever changing. The same is true for Z. tritici management and crop protection in general. The nature of Z. tritici management, the contest between the pathogens drive to reproduce and managers drive to maximise margin, is immutable, but the character of Z. tritici management, the means by which both sides achieve their outcome, is constantly evolving. In the future crop managers and those supporting them will continue to create new resistant cultivars, chemical controls, cultural controls, and biological controls, which will be targeted and applied in novel and increasingly accurate ways. Z. tritici will continue to adapt to the evolutionary pressure these changes apply and become resistant to new controls and overcome the resistance of new cultivars. Both sides in this battle will run very hard and stay in the same place (Dyer, 2014). Its immutable nature makes the contest Sisyphean but does not denude its importance. Until a truly paradigm shifting technology emerges, IPM and the Operational Framework guided by the ultimate objective of maximising margin will remain the most helpful principles in STB management.

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IFMA24: Resilience through Innovation

THE USE OF DRONES AND COMPARISON WITH OTHER REMOTE SENSING METHODS IN CROP PRODUCTION

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Academic Paper[1]

Abstract

The uses of remote sensing technologies are becoming increasingly important also for agriculture. Aerial images from satellites, small aircrafts and drone flights can provide information for resource-saving crop production. The range of aerial drone services in the agricultural sector is still limited. Interested farmers therefore must ask themselves whether their own investment in a flying drone would be profitable. As part of the AgriSens Demmin 4.0 project, this question is addressed at the operational level. The first steps to get started with remote sensing are explained using the example of a multi-rotor drone and the working time required for a drone flight and the processing of aerial images to create an NDVI biomass map are described. Furthermore, the average annual costs of a drone flight are shown as an example for a 1,000-hectare arable farm in Mecklenburg-Western Pomerania and compared with the expenses for remote sensing data from aircraft flights and satellite use. Finally, further possible applications specifically for drones are described e.g. wild animal detection, assessment of damage to crops, e.g. in silage maize cultivation, and quantity recording, e.g. of sugar beet piles.

Keywords: Remote Sensing, aerial views from *satellite, aircraft, drones,* crop production, appraisals, and damage assessment

1 Introduction

The uses of remote sensing technologies are becoming increasingly important also for agriculture. Aerial images from satellites, aircraft and drone flights can provide information for resource-saving crop production. The applications of remote sensing technologies are very diverse. Plant populations can be recorded, and biomass maps can be created over large areas in a short time, weed nests or drought stress can be identified and deficiencies in nutrient supply

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can be assessed (Bendig et al. 2014; Gašparovića et al. 2020; Guan et al. 2019; Tao et al. 2020; Zhang et al. 2019; Istiak et al. 2023). With the help of aerial photos, defective drainage pipes, overgrown hedges, storm damage at the edge of the forest and damage caused by wildlife can still be identified. Drones can also be used in natural protection or to detect wild animals e.g. deer fawn in front of grassland mowing and to record the quantity of silage and sugar beet piles (KTBL 2021, Schöttker et al. 2023).

The range of aerial drone services in the agricultural sector is still limited, in a German-wide survey only 20 suppliers could be identified (Ellmann und Strohfeldt 2023). Interested farmers therefore must ask themselves whether their own investment in a flying drone would be profitable. As part of the AgriSens Demmin project, the Neubrandenburg University of Applied Sciences, the University of Halle Wittenberg and the KTBL, among others, addressed this question at the operational level. The first results of the investigations carried out are presented below. The first steps to get started with remote sensing are explained using the example of a multi-rotor drone and the working time required for a drone flight and the processing of aerial images to create an NDVI biomass map are described (Frisch et al. 2021). Furthermore, the average annual costs of a drone flight are shown as an example for a 1,000-hectare arable farm in Mecklenburg-Western Pomerania and compared with the expenses for remote sensing data from aircraft flights and satellite use. Finally, further possible applications specifically for drones are described e.g. wild animal detection, assessment of damage to crops, e.g. in silage maize cultivation, and quantity recording, e.g. of sugar beet piles.

2 Material and Methods

2.1 Getting Started with Flying Drones - First Steps

In order to be able to fly a drone in Germany, numerous steps must be taken, which are presented below in 13 sections (Table 1). To get started, it is necessary to qualify for the right to use a drone (1, 2). The maximum permissible take-off mass of the aircraft requires different qualification measures. To fly class C1 drones with a take-off weight of up to 900 Gramm, an online test is required (1). For larger drones in class C2 (take-off weight up to 4 kg), a drone driving license is required (2) (KTBL 2021). Furthermore, the intended use of the aircraft influences the type of analysis software (4). Commercial programs from providers such as Pix4D and Agisoft Metashape are suitable for the automated processing of individual images in orthomosaics of a field. Biomass indices can be calculated in the open-source software

QGIS. To operate the drone, it must be insured and registered with the Federal Aviation Authority (Luftfahrtbundesamt, LBA, in Germany) (5, 6). Depending on the region, additional permits may be required for flight (7). Before the flight, targeted flight preparation is necessary (8). This includes planning the route, preparing the technology (checking the charge level of the batteries) and checking the weather conditions. Flights can be carried out in two different flight configurations, manual and automated. Automated flights are configured in a flight mission as part of the flight preparation. The drone flies completely autonomously over a defined route based on defined criteria. Weather conditions should be checked before every flight. In strong winds, the drone may fly too fast or too slow. If the camera's recording rate is constant, a different number of recordings is generated in each flight direction depending on the flight speed. This can lead to problems in processing the data to create the orthomosaic. In addition, strong headwinds increase the energy consumption of the multi-rotor. Furthermore, unfavourable weather conditions can have a negative impact on flight safety during the flight. To minimize the risk of collisions with other users in the airspace, it is suitable to use special programs in which flying objects in the area surrounding the flight area are visibly displayed on a map. In principle, drones in Germany can be flown at visual line of sight operation (VLOS). Once the flight preparation has been completed, the multi-rotor is put into operation. To do this, the aircraft and remote control are activated individually, coupled and, if necessary, the multi-rotor software is updated (9 to 11). The multi-rotor can then be started and a functional test of the controls can be carried out (12). This means that the aircraft is ready for operation (13) (Tab.1).

Regardless of whether you fly a drone yourself or whether a corresponding service is to be offered, information about the working time required to use the drone is of interest and is the basis for calculating the costs of the service. Separate surveys were carried out for this purpose.

Table 1: Measures for getting started with drone flights

No.	Measures	Description
1	EU certificate of competence	Online at EASA, LBA (5 h reading time; 30 min exam)
2	EU remote pilot certificate	Register with the LBA for a drone driving license, Course over 2 days with 12 hours of theory and 12 hours of practice
3	Obtain drone/accessories	Order drone and accessories
4	Obtain a flight evaluation program	Request and compare offers, approx. 30 min download and installation time (QGIS; optionally Google Earth Pro; Pix4D, Agisoft Metashape)
5	Liability insurance	Insurance has been mandatory for private and commercially operated drones since 2017. Check offers
6	Registration of the drone	Online registration, 1 hour registration and setup time
7	Register a flight in no-fly zones; if necessary	Make an application for a no-fly zone (submit an application to the responsible aviation authority or military commander)
8	Flight preparation	Create polygons for flying over any area in planning software such as Mission Planner (ARDUPILOT), optionally create individual missions in freehand mode on the controller, charge batteries, check flight conditions
9	Start controller	Put controller into operation
10	Activate the drone	Switch the drone on and park it in the starting position
11	Connect drone and controller	If necessary, follow instructions in the controller
12	Perform flight test	Test drone (climb to 10 meters, then: forward/backward/left/right, sink to the starting position)
13	Operational readiness for the first flight established	

Source: Own illustration

2.2 Material and Working Time Required when Flying Drones

Two different drone models were used to record the working time requirements for a drone flight. A multi-rotor and fixed-wing drone were used. The multi-rotor drone is particularly suitable for flying over smaller areas (27 ha/hour). In contrast, higher area performance (60 ha/hour) can be achieved with the fixed-wing aircraft. Both drones were equipped with a multispectral camera to record the aerial images. The flights were carried out on the test field at the University of Halle, Germany and on a partner farm in the AgriSens research project near Demmin between spring 2022 and summer 2023. To collect data, defined sections of the fields were flown over and the work steps carried out were measured repeatedly. The aerial photographs were evaluated using the Quantum GIS and Agisoft Metashape programs. The UAV Forecast applications were also used to query weather information and the Droniq app to display aircraft in the study area. The annual costs[2] were calculated in Microsoft Excel 2016 (Table 2).

Table 2: Overview of the materials used

Materials	Description	Intended use
Drone	DJI Inspire 2 (multi-rotor drone) WingtraOne GEN II (fixed-wing drone)	Flight
Multispectral camera	Model MicaSense RedEdge MX-Dual	Assessment of plants
Programs	UAV-Forecast Droniq App Agisoft Metashape Quantum GIS (Version 3.28.0 RC) Microsoft Office Professional Plus 2016	Weather Information Aviation safety Data processing Calculating the NDVI Evaluation, documentation

Source: Own illustration

The differences in area performance between the types of drones used are also reflected in the working time required by the two methods. Working time requirements of between 6.80 hours/100 ha (multi-rotor drone) and 4.50 hours/100 ha (fixed-wing drone) were determined for flight preparation, flying, data evaluation and maintenance of the drones. Depending on the type of drone, between 11% and 16% of working time is spent on flight preparation. A total of 70% (multi-rotor drone) and 47% (fixed-wing drone) of the working time required are spent on flight and flight follow-up as well as maintenance of the drones. Between 19% and 38% of working time is still required for data transmission and evaluation. The transmission and evaluation of the data depends on the total area flown over (number of aerial images), as well as on the transmission and processing speed of the hardware or software used. The evaluation in Table 3 is based on an area of 16 hectares. The individual work steps were measured in multiple repetitions.

[2] Annual costs $= \frac{AW-RW}{N} + \left[(AW - RW) \times f_{i_{kalk};N} + RW\right] \times i_{kalk} + \frac{1}{N} \times \sum_{t=1}^{N} BK_t$; with N: Duration of use (years), i_{kalk}: interest, BK_t: Operating costs (repair costs, operating materials, insurance), $f_{i_{kalk};N}$: Factor for the average investment, AW: Purchase value, RW: residual value (RW = 0)

Table 3: Working time required for area flights with drones and creation of NDVI biomass maps

	Multi-rotor drone	Fixed wing drone
Flight preparation	11 %	16 %
Flight	55 %	32 %
Flight follow-up	7 %	8 %
Data transmission, data evaluation	19 %	38 %
Drone maintenance	8 %	7 %
Working time requirement	6.80 hours/100 ha	4.50 hours/100 ha

Source: Own surveys

The results of the working time analysis indicate that fixed-wing drones are more economically efficient to operate than multi-rotor drones due to their higher area performance. The following analysis therefore uses a practical example to examine the extent to which the described advantages in terms of area performance could impact the average annual costs.

3 Results

3.1 Costs of Flying Over 1,000 Hectares of Arable Land

The following example shows the average annual expenditure for the investment (capital costs) in a multi-rotor or fixed-wing drone and the other costs for regular flights (once per year) for a 1,000-hectare arable farm. These are compared with the costs for using satellite data or flying with a Cessna aircraft[3].

To invest in the drone models used, a capital requirement of €15,192 for the multi-rotor drone or €44,080 for the fixed-wing aircraft is necessary. The annual capital costs, the sum of depreciation and interest, are between €4,016 (multi-rotor drone) and €9,048 for the fixed-wing aircraft (Table 4).

In contrast, no extensive investments are necessary to use the satellite and Cessna aircraft. This means there are no capital costs here. There are charter costs of €376 p.a. for a one-time flight to the company with a Cessna aircraft. An amount of €35 p.a. was calculated for travel to and from the airport. The use of drones involves energy costs for charging the batteries of the aircraft and travel costs. For both drone models, a flat rate of €50 p.a. is charged.

[3] Renting a drone (flight and processing of aerial images to create an NDVI biomass map) costs approximately 21 EUR/ha.

The use of the four remote sensing methods still involves labour costs. In the cheapest variant, these are €121 and €179 for satellite and Cessna aircraft, and in the most expensive variant they are €801 and €1,202 for flights with a fixed-wing or multi-rotor drone, each for a one-time annual flight over 1,000 hectares of arable land. Overall, the average annual costs of the four methods are between €0.20/ha (satellite) and €10.18/ha (fixed-wing drone) (Table 4).

Table 4: Capital requirements and average annual costs for the use of remote sensing technologies using the example of the 1,000-hectare arable farm

Procedure	Unit	Satellite [1]	Cessna aircraft [2]	Multi-rotor drone	Fixed-wing drone
Total capital requirement	€			€15,192	€44,080
Period of exploitation	years			8	8
Capital costs (depreciation, interest)	€ p.a.			€4,016	€9,048
Energy for battery charging; Car travel costs	€ p.a.		€35	€50	€50
Labor costs (€21/hour)	€ p.a.	€121	€179	€1,202	€801
Training[3] measures for remote sensing	€ p.a.	82 €	€67	€260	€292
Aircraft charter costs	€ p.a.		€376		
Total annual costs	€ p.a.	€204	€658	€5,528	€10,191
Costs, € per ha	€/ha	€0.20	€0.66	€5.52	€10.18

Source: Own calculations, note: [1] Sentinel-2, open-source data; [2] Cessna single-engine passenger aircraft; [3] calculated based on remote sensing workshops with farmers in AgriSens Demmin 4.0

A look at the relative distribution of the individual costs makes the differences between the four remote sensing methods clear again. The two drone variants are among the most expensive remote sensing methods due to the high purchase costs; Here, 72% and 88% of annual expenses are accounted for by capital costs (depreciation and interest). In the satellite and aircraft variant, the highest percentage shares are attributable to labour costs (60% of €204 p.a.) for evaluating the satellite images or for renting the Cessna aircraft (57% of €658 p.a.). The proportion of labour costs for fixed-wing aircraft is 8% (of €801 p.a.) and for multi-rotor drones is 22% (of €1,202 p.a.) (Tab 5).

Table 5: Total annual costs and shares of various cost items depending on the respective remote sensing technology

Position	Satellite	Cessna aircraft	Multi-rotor drone	Fixed-wing drone
Total annual costs for flying over 1,000 hectares of fields, € p.a.	€204	€658	€5,528	€10,191
Shares of individual cost items:				
○ Capital costs (depreciation, interest costs)			72 %	88 %
○ Energy for battery charging, Car travel costs		6 %	1 %	1 %
○ Labour costs	60 %	27 %	22 %	8 %
○ Training measures for remote sensing	40 %	10 %	5 %	3 %
○ Aircraft charter costs		57 %		
Total	100 %	100 %	100 %	100 %

Source: Own calculations

In addition to the different costs shown, other characteristics such as the quality of the aerial images, the area coverage, and the level of difficulty in application can be important when choosing a suitable remote sensing method. Despite the low area costs and high area performance for satellite images in the application example, the quality of the aerial images is often low. In addition to the low image resolution of 10 x 10 meters at a flight altitude of 786 km, compared to small aircrafts and drones with 80 x 80 cm or 7 x 7 cm resolution, the quality can be significantly reduced due to cloud cover at the time of recording. Images from small aircrafts or drones provide significantly better image quality; under normal weather conditions, these fly at a height of 1,000 m or 100 m above the ground and are therefore less limited by cloud cover. Further differences exist in the level of difficulty of the application. Practice is required to create oblique aerial images, as the images are taken during the flight from the side window of the Cessna aircraft. In addition, the recording angle may vary between the different oblique aerial images and the comparability between different recording times may be limited. In contrast, drone recordings can be carried out using a standardized technique (camera recording angle, flight altitude, flight speed, etc.), so that the recordings are very comparable. However, the use of drones is generally more difficult, involves higher annual costs and is associated with a lower area performance (Table 6).

Table 6: Comparison of the tested remote sensing technologies in the categories of quality, area performance, costs, applicability

Category	Sentinel-2 Satelite	Cessna aircraft	Multi-rotor drone	Fixed-wing drone
Quality of the aerial images	+	+++	+++++	+++++
Area output ha per hour	+++++	+++	+	++
Costs per ha	+	+	+++	+++++
Applicability/Difficulty Level	+	+++	++++	+++++

Source: Own illustration; Note: Scaling from + very low to +++++ very high

Based on the differences presented between the remote sensing methods considered, various areas of application can be described. For an initial overview of operational areas or larger units, satellite images can be particularly advantageous due to their low cost and ease of use. In order to obtain significantly better recording quality at low cost, oblique aerial images taken from a small aircraft are suitable. With the help of an aircraft, large areas can be flown over and assessed in a short time. For example, differences in plant population development, effects of soil compaction, hedges in need of care and defective drainage can be made clearly visible. Therefore, this process can reveal vulnerabilities on the field with little additional effort. Drone recordings are particularly suitable for planning precise procedural measures. Due to the high resolution and standardized recording, these data enable precision farming to apply ecologically sensitive measures e.g. in fertilization, crop protection and sowing through targeted and minimal input. Area-specific management will be the basis for ecological and economic optimization in the future.

In addition to the areas of use of drones in crop cultivation practice described so far, other applications such as wild animal detection, the recording of game damage or emergence damage and the quantity recording of sugar beet crops, for example, are possible. These application examples were also examined as part of the research project and are outlined below as examples.

3.3 Further Application Examples for The Use of Drones

3.3.1 Working Time Requirements and Costs of Wild Animal Detection

Searching for wild animals before mowing grassland in spring is part of good agricultural practice. In Germany, an increasing number of companies are also using drones with thermal imaging cameras. Since wildlife detection in practice is often supported by hunting tenants and volunteers, the working time requirements and associated wage costs are often unknown. In the working time analysis of the use of multi-rotor drones, the working time required for an exemplary fawn search was recorded under practice conditions and the labour costs were calculated. The study was carried out on a farm in eastern Mecklenburg-Western Pomerania. The company uses a commercially available multi-rotor drone with a thermal imaging camera to search for fawns before grassland mowing. The survey of working time requirements was carried out twice using plastic dummies on an area of 15.20 ha. In order to map the local distribution of fawns, the flight logs from a total of 40 flights in the region were evaluated and then based on a distribution of 3 fawns on 15 hectares (Fig. 1).

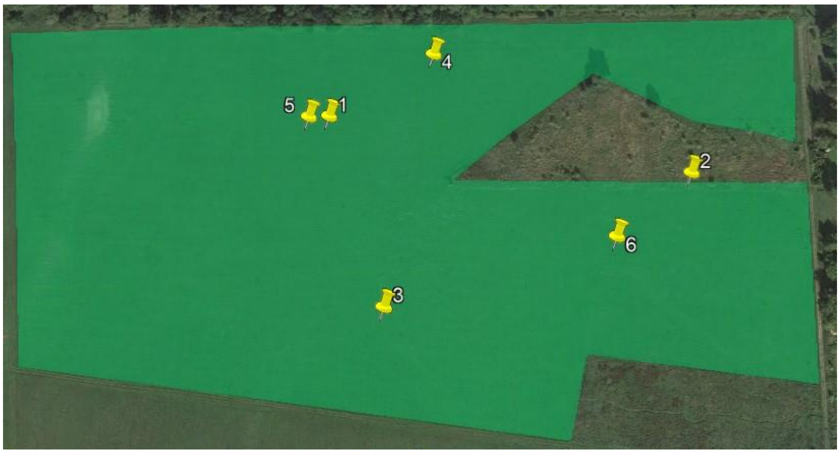

Figure 1: Study area to determine the working time requirements for wild animal detection (example area 30 ha, placement of 6 plastic dummies)

Source: Own illustration

To record the working time required for the deer fawn search, a labour requirement of two people was assumed (drone pilot and deer fawn searcher in the area). The flight was carried out in the drone's autonomous flight mode. For this purpose, the polygon of the flight area was stored in the control software and the flight route was interrupted when visual contact was made with a dummy. The work steps recorded were: setting up before the flight, test flight, flight, search on the ground, dismantling after the flight and maintenance. The time required for the return trips to the meadow and the transport of the fawns to the edge of the forest after mowing was estimated using route information from Google Maps. A total time requirement of 45 minutes was calculated for a total of two workers. The labour costs total €13.79 for an example area of 15 ha or €0.86/ha (Table 7).

Table 7: Survey of working time requirements for wild animal detection in grassland (example area 15 ha)

	Work step	Decimal hours	Labour requirement, persons	€ per work step
1	Trip to the meadow	0.01	2	€0.43
2	Getting ready before the flight	0.06	2	€2.60
3	Test flight	0.02	2	€0.73
4	Flight	0.28	1	€5.92
5	Search on the ground	0.00	2	€-
6	Dismantling	0.05	2	€1.96
7	Return tour	0.01	2	€0.43
8	Maintenance	0.07	1	€1.48
9	Trip to the meadow/to the farm	0.01	2	€0.23
Total		0.50		€13.79
Total labour requirement, hours		0.66		
Labour requirement, hours/ha		0.04		
Labour costs (€21/hour); €/ha		€0.86		

Source: Own calculation

3.3.2 Damage Assessment in The Event of Damage Caused by Wild Animals or Damage During Emergence of Seeds

In the next application example, defects in ready-to-harvest silage maize were mapped using a multi-rotor drone and the lost yield was economically assessed. The cause of such defects can be damage from game or already caused by sowing errors. An area of 10 hectares that was damaged by wild boars was examined. The condition was captured with a DJI Mavic 3T multi-rotor drone in September 2023. Quantum GIS was used to evaluate the image material. The defects in the plant population were differentiated into defects in the plant row (yellow) and defects in the area (red). In total, missing plant areas amounting to 0.40 ha or 4% of the total area recorded were documented. A working time of two hours was required for data collection and analysis (Fig. 2). However, the evaluation methods continue to develop. The use of AI can help to obtain even more precise results in a shorter time (Maes and Steppe 2019).

Based on the average soil quality of the field, a yield potential of 21.4 t fresh matter per ha was assumed using standard values from the literature (Hanff and Lau 2021). The total yield loss is estimated at 8.5 t fresh matter. To calculate the economic losses, an internal transfer price of €35 per t fresh matter was assumed. The amount of loss is therefore €298.

During the data evaluation, additional information could be gained about the yield variability of the field. And a standard aerial survey of maize areas before harvest can help uncover weak points in production management.

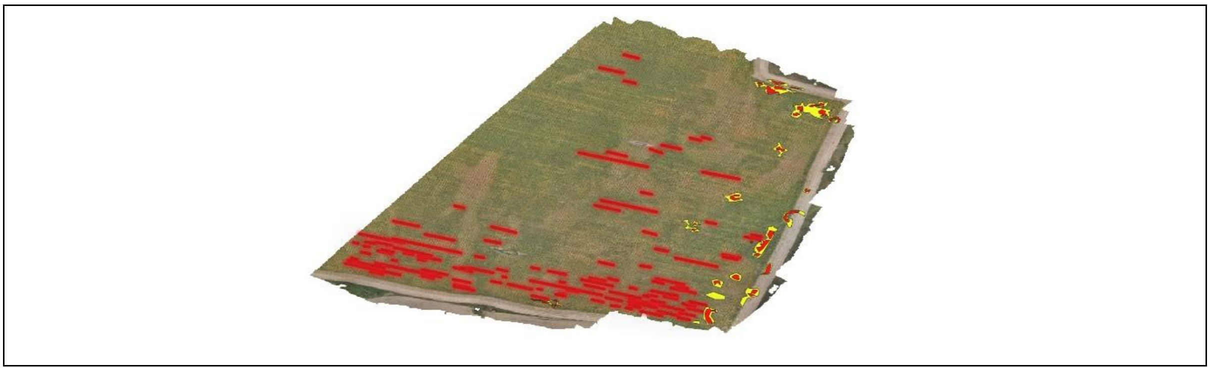

Figure 2: Determination of damaged areas in silage maize; Orthomosaic with damaged areas marked yellow = defects in the plant row (n = 98 lines), red = defects in the area (n = 20 polygons); Recorded on September 22nd, 2023
Source: Ellmann, 2023

The problem that an agricultural appraiser, for example, would have to spend a lot of time recording the damage from the ground to be able to record the extent of damage with some degree of accuracy is also shown in the following example “Field emergence of sugar beet seeds” (Fig. 3). In this case, it was initially difficult to see from the ground which part of the field the seeds had delayed emergence. The aerial photo, taken from a small aircraft, clearly shows the actual extent of the damage. Another aerial photo, shortly before the harvest (October 5th, 2022; not shown here) shows that the entire beet stock had appeared, but for the most part late. The lower weights of the beet bodies in question due to the shortened growth period could be determined representative on the ground and the extent of damage could be extrapolated based on the area previously determined from the aerial photograph. This example shows that valid data on the condition of individual fields (uneven seed emergence, differences in cultivation, weed nests, etc.) can be obtained, particularly in combination with point-by-point data collection marked with GPS coordinates (e.g. photos, measurements, etc.) with aerial images from drones or small aircraft can. For the agricultural appraiser this usually not only saves time, but also makes an accurate damage assessment possible.

Figure 3: Delayed seeds emergence on a sugar beet field, size 43,3 ha; Image from the ground (left; May 27th, 2022) and oblique aerial image taken from a small aircraft (right; June 15th, 2022)

Photos: Fuchs and Weier, 2022

3.3.3 Quantity Recording in an Elevation Model

In the last application example shown here, the use of a multi-rotor drone for quantity recording of bulk goods is described using the example of the sugar beet harvest on a farm in the north of Mecklenburg-Western Pomerania. The company has been using drones to fly over agricultural areas for many years and has already gained extensive experience in using this technology. On this farm, a multi-rotor and a fixed-wing drone is used to prepare site-specific measures in fertilization and crop protection. Here, every year, 10,000 hectares are flown with drones. In addition to answering crop cultivation questions, the company uses a multi-rotor drone to measure sugar beet piles after the harvest. In this way, beet yields can be recorded and documented field by field without special yield recording on the harvesting machine. To measure a sugar beet heap, the operations manager calculates that a total of 1.50 hours of working time will be required, of which 15 minutes are spent on GPS-supported flights on site and around 75 minutes are spent on data analysis in the office. In this analysis step, the aerial photographs of the sugar beet heap are combined into an orthomosaic and the harvest quantity is calculated using an elevation model (Fig. 4).

(a)

(b)

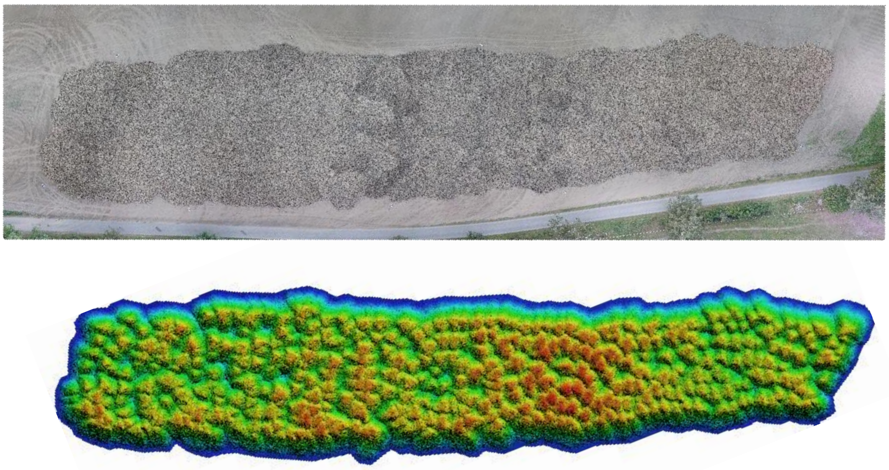

Figure 4: Aerial photo (a) and elevation model (b) of a sugar beet heap

Source: Harbort, 2023

Further areas of application include the measurement of wood chip storage, silo systems or the quantity recording of manure deposits at the edge of the field. With the help of the drone data evaluated in the elevation model, harvest and sales quantities can be recorded, feed reserves in the silo can be documented and the application of solid manure can be planned more precisely.

4 Discussion and Conclusion

The use of remote sensing technologies such as satellites, small aircrafts and drones offers a wide range of possible applications for agriculture. The analyses carried out showed that the choice of remote sensing method depends on the specific question and can be associated with varying costs. Free satellite images are particularly suitable for a quick overview. Depending on the location of the company, these are available up to once a week. However, to be able to obtain a more precise and extensive overview of the field stocks at short notice, flying with a small aircraft is advantageous. With this, large areas can be recorded and assessed in terms of crop production in a short time. However, to prepare particularly economically relevant measures in fertilization, plant protection and sowing, aerial images that are as high-resolution as possible should be used. Flying with drones is suitable for this purpose. These can be used to prepare and plan site-specific management measures. In addition, wild animals can be detected before grassland is mowed, planting errors and damage caused by wild animals in the field can be documented and bulk materials can be measured.

The range of services using drones is still relatively limited and often very expensive. Therefore, for technically experienced farmers and consultants, purchasing their own drone and offering services beyond their own business is an alternative worth considering. To use the different remote sensing methods in agriculture as efficiently as possible, training, and advisory services can be of great importance in the future. In this way, application errors can be reduced, and additional costs can be avoided.

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EVALUATING THE EFFECT OF ENVIRONMENTAL LEGUME MANAGEMENT OPTIONS ON CROP ESTABLISHMENT AND NITROGEN AVAILABILITY IN THE SUBSEQUENT BARLEY CROP

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Abstract

Biological nitrogen fixation can offer an alternative to the reliance of cereal production systems on synthetic nitrogen applications. The use of synthetic nitrogen is threatened due to the high greenhouse gas emissions associated with its manufacture and use. To reduce reliance on synthetic nitrogen, legume fallows can be included in crop rotations. Field trials found that legume fallows with a higher proportion of sown legume species in proportion to grass and herbs had higher soil nitrate levels and improved initial establishment of the following barley crop. The difference in soil nitrate levels in the top 5-15cm and 15-25cm became less pronounced as the winter after the legume mixes were destroyed progressed, and by February the number of barley plants and the soil nitrate levels did not differ between the previous species sown.

Introduction

Synthetic nitrogen (N) fertilisers are heavily relied upon in conventional systems. In 2023, global demand for synthetic agricultural N reached 109.7 MmT, a number which is expected to rise to 111.6 MmT tonnes by the end of 2024 (Statista, 2024). The invention of synthetic N, in the form of ammonium nitrate, in the early 1900s increased the number of humans an acre of land could support from 1.9 to 4.3 (Erisman et al., 2008). While synthetic N has allowed food production to increase alongside a growing population, the escalation of agricultural synthetic N use has pressing environmental consequences, contributing to climate change through N_2O release (Sosulski et al., 2020), causing long-term acidification of agricultural soils (Tian & Niu, 2015), and polluting watercourses through leaching (Bijay-Singh & Craswell, 2021).

The "Agri-climate report" (DEFRA, 2022) concluded that N_2O emissions from agriculture in the UK were 14.5 $MtCO_2e$ in 2020 and that agriculture was responsible for 69% of total

N_2O emissions nationwide. According to the report, these figures can be partly attributed to soil N_2O emissions due to synthetic N fertiliser application. The findings from this research are especially troubling, as N_2O contributes to climate change due to its high potency as one tonne of N_2O has a warming potential 265 times greater than one tonne of carbon dioxide (Stocker et al., 2013). These environmental issues introduce complexity into the narrative of N utilisation in agriculture, since although the benefits of synthetic N application are evident (30-50% of crop yield (Stewart et al. (2005)), environmental stewardship issues are less simple.

Prior to the invention of synthetic N, the use of legumes in crop rotation was a principal method of supplying N to crops; in fact, their use within crop rotations can be traced back to the Roman Empire, where they were used as part of a three-year “food, feed, fallow” rotation (White, 1970, Fussell, 1967). In a modern-day context, the integration of environmental legume management options or “legume leys” into crop rotations offers an opportunity to reduce synthetic inputs (Berge et al., 2016), and reduce environmental impacts (Jensen & Hauggaard-Nielsen, 2003), by capitalising on the biological N fixation (BNF) capacity of leguminous plant species (Liu et al., 2011).

BNF is incredibly important in the context of sustainable agriculture: it could have the potential to drastically reduce nitrogen inputs required in agriculture (Soumaré et al., 2020). BNF is a form of symbiotic N fixation, where soil microorganisms (*Rhizobium leguminosarum)* create a symbiotic relationship with the leguminous plant (Wagner, 2011), to fix atmospheric N into the soil and break it down into usable ammonium, via ammonification. Following this process, the legume can use this ammonium for growth and development (Iantcheva & Naydenova, 2021). Once the leguminous plant dies, soil fertility is improved through legume residue decomposition (Thilakarathna et al., 2016) which could have the potential to drastically reduce N inputs for the following crop (Wen et al., 2021). These factors exemplify the nutritional benefit that can be expected from integrating legume management options into the rotation while demonstrating their role in facilitating the transition to sustainable agricultural practices.

Legume management options could further complement sustainable practices by improving the agroecological function of arable land by delivering a wide variety of ecosystem services. A study by Hamblin & Hamblin (1985) found the decomposition of legume roots, which are typically deep and structurally dense, improved soil porosity. This means that improved water infiltration of the soil could be gained through the addition of legumes to a rotation (Basset et al., 2023). It is also widely accepted that biodiversity is improved by adding legumes to a rotation, as it adds a diverse range of flora to the farmed landscape. Many legumes are flowering plants, which supports biodiversity by providing a source of food for many pollinators (Everwand et al., 2017).

Above-ground biodiversity is not the only factor influenced by the integration of leguminous leys; it has been found that earthworm abundance can increase within ley systems (Prendergast-Miller et al., 2021). Earthworms provide a wide range of benefits to soil health, including improving soil structure, stabilising soil organic matter and improving crop growth (Bertrand et al.,2015). While the benefits of legume management options to the agroecological environment are evident in these findings, and the ecosystem services offered by leguminous options have clear benefits to crop production, evaluating the specific agronomic effects of using environmental management options is vital.

Many papers have addressed the agronomic benefits of including leguminous leys in rotations; Kayser (2009) found that including a grass-clover ley in a three-year crop rotation led to increased yield of the subsequent crop. The same study identified that the use of grass-clover leys contributed towards increased soil mineral nitrogen (SMN) levels, which suggests a link between SMN levels and yields, demonstrating the potential of leguminous leys as a viable tool to increase the sustainable production of cereals. This research is further cemented by Hargrove (1986), who found that annual legume cover cropping provided an average of 72KgN/ha of legacy N to a following crop. This level of N sequestration could significantly reduce synthetic N inputs in agriculture, as concluded by Nilsson et al. (2023), who found that short-term ley systems were effective for reducing dependency on synthetic N inputs. Together, these studies demonstrate the effectiveness of legumes in increasing SMN levels and improving yield. These findings, when set in the context of our research, highlight further the potential effect of legume management options on N availability.

To effectively assess the effect of legume management options on subsequent crop establishment, it is firstly vital to understand the role N plays in various processes that are key to the establishment of barley (*Hordeum vulgare)*. The assimilation of N is vital for multiple processes that take place during the establishment stage, notably, protein synthesis (Wan et al., 2023), chlorophyll production (Hamann et al., 2020) and root growth (Goss et al., 1993). N availability has also been found to improve barley's stress response by improving metabolic responses while the plant is under water stress, particularly in early growth stages and establishment (Olšovská et al., 2024). Considering these factors, the importance of maintaining an adequate level of SMN levels is evident, thus, the addition of nitrogen-fixing legume management options could be advantageous to the establishment of barley.

Our research aimed to link the N fixing abilities of legume management options with improved establishment, by assessing two specific legume management options available under Countryside Stewardship, an agri-environment scheme available in England.

Materials and Methods

Site selection and history

A trial site was established at The Allerton Project, Loddington, Leicestershire (grid ref: 52.60483, -0.8295660) in August 2021, where two different legume management options were drilled into a single field, spilt into two sections, using an Opico grass harrow. The plots were then left in fallow for two years, before being mown and conserved after 15 August of the second year. The specific options assessed were AB15, a two-year sown legume fallow, and GS4, a legume and herb-rich sward, the species content of which can be seen in Table 1.

Table 1- Species content of the treatments

Legume management option	**Included species**
AB15 – Sown legume fallow	Red clover, vetch, birdsfoot trefoil, lucerne, black medick and alsike clover.
GS4- Legume and herb rich sward	Festulolium, intermediate perennial ryegrasses (diploid and tetraploid), Timothy, cocksfoot, strong creeping red fescue, sweet clover, red clover, alsike clover, birdsfoot trefoil, plantain, burnet, wild carrot, perennial chicory and yarrow.

The two legume mixtures were both sprayed with glyphosate in the first week of September 2023, following this, the plots containing the legume mixtures were low disturbance sub-soiled and rolled. Barley variety SY Buzzard was sown in the first week of October 2023 at 350 seeds m^2 using an avatar disc drill.

Establishment monitoring

Establishment was determined by placing a 30cm ruler alongside a row of barley, counting the number of plants along the length and repeating at 10 random locations across each plot. Plants/m^2 was then calculated by establishing the area counted (30cm x drill coulter width) and dividing the area counted by 10,000cm^2. The number of plants in each plot was then multiplied by this factor to determine plants/m^2. This process was repeated every six weeks following full emergence in late October.

Soil nitrogen content determination

At the same time as establishment monitoring, soil samples were taken at 4 random sampling points in each legume plot using a auger marked at 5, 15, 20, 25 and 30cm. Samples were then collected from the soil horizons of 5-15cm and 15-25cm. These samples were oven dried for 72 hours at 70^{o}c, before being ground using a pestle and mortar and sieved with a 2mm sieve then fine milled using a micro hammer-cutter mill.

45g of each milled sample was weighed using a four decimal place scientific balance, then combined with 0.8g of calcium sulphate and 80ml of de-ionised water in a 150ml screw top bottle. The samples were then shaken for one minute before being filtered through filter paper with a 8-11 µm micron pore size.

10ml of the extracted solution was then placed in sample cells, and one NitraVer 5 Nitrate Reagent Powder Pillow was added to each cell. The cell was then shaken for one minute, then left to react for five minutes. An additional blank cell was filled with 10ml of the extracted solution and placed into the HACH DR900 (set to programme 355N) and used to zero the device. Once the five minutes had elapsed, the sample cell containing the powder pillow was placed in the HACH DR900 to determine the Mg/L NO_3-N of the sample. This process was then repeated for all samples.

Statistical analysis

A two-way analysis of variance (ANOVA) was used to assess differences between the previous species sown and the sampling period using GENSTAT (Genstat 23rd ed, 2024, VSN International Ltd, Hemel Hempstead, UK).

Results

Plant establishment

On the 30th of October the plant numbers per m^2 were significantly higher in AB15 (306.2) than in GS4 (143.6). The plant numbers within AB15 significantly differed between October (306.2) and December (234.4) with the latter having significantly higher plants m^2. The February plant count was not significantly different from either the October or December plant count at 219.3 plants m2. There was a significant interaction between the legume sown species and the date sampled with the AB15 having higher plant numbers in October and reducing by February whereas the numbers did not differ between sowing dates for the GS4 (see Table 2).

Table 2 – Summary of plants per meter^2 across all sampling dates

	AB15	GS4
30th October	306.2	143.6
19th December	234.4	153.1
5th February	219.2	185.2
sed	18.88	
FProb	<0.001	

Soil nitrogen testing

Across all the sampling dates, AB15 had higher nitrate levels at 2.20 Mg/L NO_3-N compared to GS4 1.52 Mg/L NO_3-N , at 15-25cm horizon but no significant difference in the 0-15cm horizon (mean 1.62 NO_3-N). There was a significant interaction between previous legume treatment and sampling date as shown in 5-15cm horizon [Figure 2] where the earlier samplings on the upper horizon had significantly higher nitrate levels but this effect was no longer evident in the February sampling.

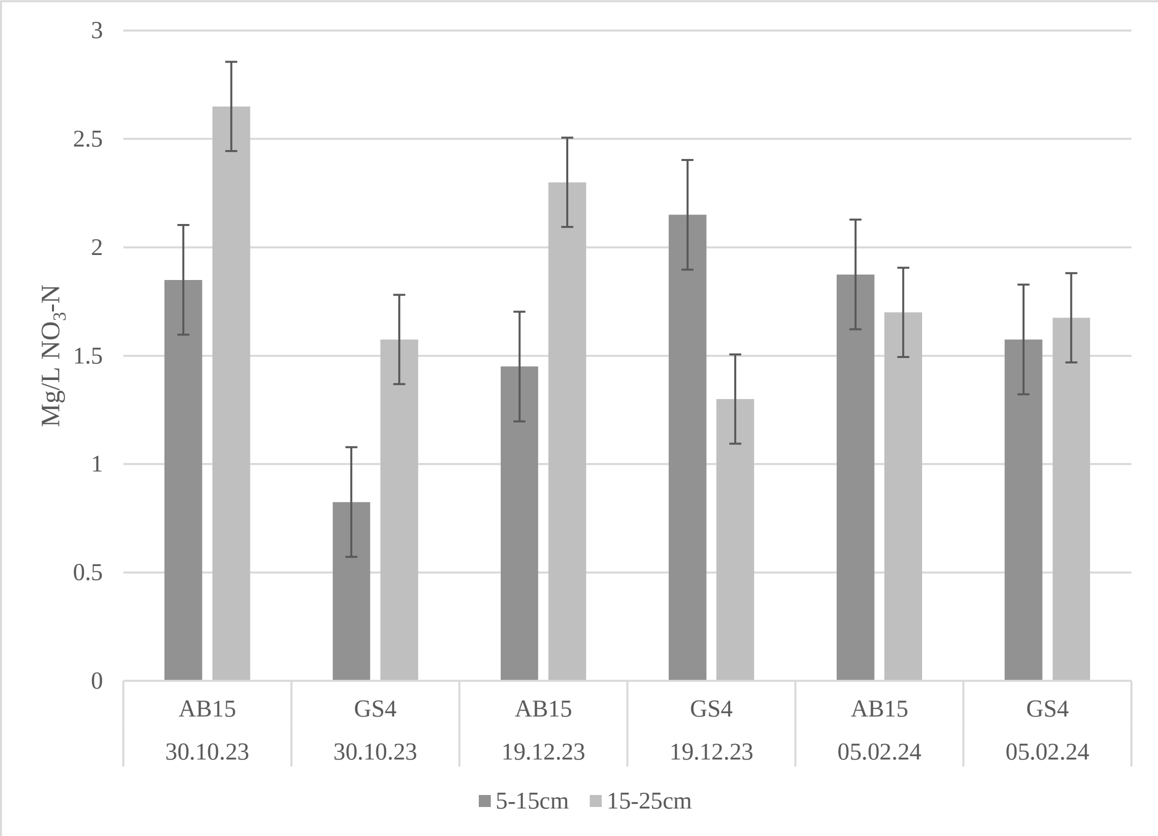

Figure 2 - Bar graph showing mean Mg/L NO3-N levels of each plot

Discussion

Soil Nitrogen Levels

The two-year legume ley (AB15) had a greater effect in the first two samplings on soil nitrate levels in the upper horizon when compared to the legume and herb sward (GS4). Similar differences were observed by Ruz-Jerez et al. (1991) who found that although herbal leys and grass-clover leys (legume leys) delivered similar nitrogen fixation, the efficiency of fixation was greater in grass-clover leys. This could explain the gradual reduction in the difference between N levels within the GS4 and AB15 plots.

Differences in N levels in the tested horizons were observed within the results [Figure 2]. Within the AB15 plot, the 15-25cm horizon was consistently higher in N than the 5-15cm horizon, until the final testing, whereas the GS4 showed no dominant horizon. Within the GS4 plot, the N levels were initially highest in the 15-25cm horizon, then 5-15cm and finally 15-25cm. This could be a result of leaching through the soil profile. Various studies have assessed the leaching risk that goes alongside legume use in agriculture, Pattinson &

Pattinson (1985) concluded that Nitrate-N leaching losses from legumes could be as much as 10% from clover, and Scholefield et al (2002) determined that clover species could leach 20-24kg N per hectare, which would explain the difference in the concentration of N between the two treatments.

The differences seen between the two seed mixtures could largely be down to species content. As can be seen in Figure 1, AB15 contains a higher proportion of leguminous species than GS4, which would explain the higher contribution of nitrates in the soil from this option. A study by Rasmussen et al. (2012) investigated the fixation and residual effect of four legume species: white clover, red clover, lucerne and birdsfoot trefoil, all of which were included within AB15. In the study it was established that red clover had a high residual effect, white clover and lucerne a medium residual effect and birds-foot trefoil a low residual effect. Although the GS4 contained the above species, minus lucerne, the mix also included a variety of herbs, meaning the concentration of legumes within this option was less. This could explain why the AB15 appeared to provide much more residual N than the GS4.

Barley establishment

Throughout the barley establishment period, a significant difference was seen in the plant populations of GS4 and AB15 plots. Initially, the difference in plant population levels was large between AB15 and GS4, this could be explained by higher soil N concentration in the AB15 plot. N is vital for many processes relating to the early growth of barley (Wan et al., 2023, Hamann et al., 2020, Goss et al., 1993) which could explain the difference between the plant population in the plots at this early stage.

Alzueta et al. (2012) found that increased soil N levels increased both tiller appearance rate and maximum tiller numbers although their study only measured plant numbers. This is further reinforced by a study focused on different N application rates and timings, which found an early application of a high rate of N provided the highest number of barley shoots (Dubey et al., 2018).

A significant difference was also seen on the second assessment date, where AB15 still had more plants per m^2 than GS4, although the difference was less. This could also be due to higher soil N levels in the AB15 plot at this time. By the final establishment monitoring date there was less significant difference between the two plots, which would correlate with the N testing as by this time, the N-levels within the two plots were also similar. This would suggest a correlation between soil N content and establishment.

The results of the establishment monitoring also observed variation in plant numbers over time. In the AB15 plot, the plant numbers were significantly higher in October than in December, but a significant difference was not seen between December and February. This could be explained by continuous water logging due to many unseasonably wet weather events over this time. In late October storm Babet brought large amounts of precipitation to the trial site, which could be a factor in the reduction of plant numbers over this time. Barley is highly sensitive to excess precipitation in the early season, and the correlation between decreased barley yields and high early-season precipitation has been observed in other studies (Hakala et al., 2020, Hakala et al., 2011).

Conclusions

It appears that the differences in soil N levels from the previous legume management options influenced the early establishment of barley. Although variation of soil N levels was observed between horizons, the enrichment to soil N provided by legume management options was evident.

Our findings highlight the potential of legume management options to enrich soil N levels and improve the performance of a following crop, aligning with many other researchers who have highlighted the benefit of integrating legume management options to improve crop productivity. In addition to this, the contribution of both AB15 and GS4 to soil nitrate levels highlights the potential of these options as a sustainable alternative to synthetic nitrogen inputs in the early stages of production of the following crop where in total 181 kg nitrogen are required to grow a 8.8 t/ha crop at 15% moisture content when harvested (AHDB, 2023). In England, it is prohibited to apply synthetic nitrogen to barley in the autumn due to the leaching risk, but cereal crop can show signs of nitrogen deficiency and the opportunity to scavenge available nitrogen from the soil can help develop a strong early canopy and promote tillering in barley (AHDB, 2023). As barley is often a sink limited crop, management factors which help promote early tillering can result in more ears per m^2 and therefore increase final crop yield by creating more grain sites and therefore lowering the risk of sink limitation.

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Sub-theme: Leadership and organization; Developing the Future Farmer

EXPLORING YOUTHS' ASPIRATIONS, PERCEPTIONS AND INTEREST TOWARDS PARTICIPATION WITHIN THE AGRICULTURAL SECTOR

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Academic

Abstract

Many countries have earmarked youth participation as a contributor to reducing the unemployment experienced by youth. Despite the promise identified and shown by the agricultural sector, youth participation remains low and has been explained by low perceptions, aspirations and interest from youth. With this research, we aim to establish whether the youth in rural South Africa have negative perceptions, aspirations, and low interest towards participating in the agricultural sector. The research was conducted in the rural areas of the Free State province, South Africa, by interviewing 233 youth and analysing their responses with descriptive statistics. The results show that the rural youth have positive perceptions and aspirations towards the agricultural sector; however, despite these positive indicators, fewer youth are interested in participating. It was also found that most youth not currently involved are interested in being involved in the sector, while the opposite was found for those currently involved. Interest towards participation should thus be a key indicator for development strategies to involve youth in the sector.

Keywords: Youth, Agriculture, unemployment, aspirations, perceptions, interest

1 Background

Although agriculture is seen as the answer to youth unemployment and provides the capacity to overcome economic issues, young people seem to have negative attitudes towards agriculture (D'Silva et al., 2010). The youth are not interested in joining agriculture because of their oppositional view (perception) of agriculture (Abdullah, Samah and Othman, 2012). In South Africa, the commonly shared perception is that young people, primarily young black people, do not consider farming a viable occupation or a primary source of revenue (Mathivha, 2012). Muthee (2010) argues that young people have little or no engagement in farming and related projects because agriculture as a career option is burdened with misperceptions and a lack of knowledge and awareness. The narrative on youth participation in the sector remains essentially that of disinterest (Kidido, Bugri and Kasanga, 2017).

The perception and disinterest are similar in different areas of the world and based on various factors. Lithuanian and Latvian youths' perceptions towards agriculture include back-breaking hours in the field, low skills requirements, and low wages (Kusis, Miltovica and Feldmane, 2014). Leavy and Smith (2010) ascertained that the youth regarded agriculture as an uninteresting job with poor amenities. Kritzinger (2002) found that most girls are particularly critical of the following aspects of farm life: the nature of farm work, low wages associated with farm work, and the low status ascribed to farm children when compared with urban children, as well as farm workers' alcohol abuse, gossip among farm workers, workers' jealousy, lack of privacy, boredom, social isolation, and limited leisure opportunities. Mathivha (2012) found that urban-based youth perceive agriculture as isolating them from a trendy, youthful lifestyle, unattractive and of the poorer class, low economic returns and being only suitable for old and destitute people residing in rural areas.

Consequently, youth prefer and aspire to occupations outside agriculture since non-farming professions are perceived as more economically rewarding, stable, and not "back-breaking" (White, 2012; Tafere and Woldehanna, 2012). Muthee (2010) and Cheteni (2016) cited negative perceptions, while lack of knowledge and awareness (Muthee, 2010) and attitudes (Cheteni (2016) for their disinterest. It is thus not only the physicality keeping youth from the agricultural sector but also the observational aspects. Youth aspirations have not gone unnoticed in past research; however, the study did not specifically explore youth aspirations towards participation in the agricultural sector. Social science research has mostly been limited to academic aspirations and their influence on young people's career choices (Schaefer and Meece, 2009; Sergo, 2014).

When considering youth involvement in agriculture, the research tends to focus on socio-demographic and economic factors that constrain youth involvement in the sector, for example, Nnadi and Akwizu (2008); Adekunle et al. (2009); Ahaibwe et al. (2013); Naamwintome and Bagson, (2013); Kimaro et al., (2015); Akpan et al., (2015); Anania and Kimaro, (2016), Henning et al., (2022). There are also cases where research has shifted the focus towards perceptions and aspirations (Anyidoho, Leavy and Asenso-Okyere, 2012; Kimaro, Town and Moshi, 2015; Zantsi, 2016; Douglas, Singh and Zvenyika, 2017). However, willingness, aspirations, perceptions, and interests remain poorly understood (Leavy and Smith, 2010; Giuliani et al., 2017; Njeru, 2017). Given the opposing views of youth towards agriculture, it is important to determine whether this is the case. This is especially important given the unemployment among youth and the significant amount of money spent on attracting youth towards the sector. The question should be whether the investments are worthwhile if the youth are unwilling, aspiring or interested in the sector. This has recently been incorporated in development pathways by Madende, Henning and Jordaan (2023), stating that the interest of youth in being involved in the sector should be the starting point of development pathways towards agricultural participation while focusing on individual development as opposed to blanket approaches. This notion emphasises the need to understand the youth's perceptions, aspirations, and interests in the agricultural sector. Therefore, the research explores youths' willingness, aspirations, and interest in participating in the agricultural sector by considering two areas in the Free State province of South Africa.

2 Study area and data

Two study areas (Thaba Nchu and Maluti-a-Phofong) in the Free State province were selected according to their agricultural potential, proximity to research institutions, youth unemployment, and the willingness of officials from the Department of Agriculture and Rural Development to assist in accessing youth in their respective regions. A discussion on the study area selection can be found in the report by Henning et al. (2024). The sampling method used is similar to that of Wale and Chipfupa (2018), which is random, stratified, and convenient. Participants were informed that participation was voluntary and provided written consent. The data from 233 youth respondents were captured in Excel, and descriptive statistics and correlation analysis were used to understand the youths' perceptions, aspirations, and interests towards participating in the agricultural sector. The descriptive statistics are shown in Table 1 and indicate that the respondents were mostly single females with an average age of 25 who completed their schooling education and did not have access to or own land. Very few have received training or been beneficiaries of government support programmes.

Table 1: Descriptive statistics of the youth respondents

	Average	Standard Dev.	Min	Max			
Age (years)	25.46	4.57	18	36			
Household size (members)	4.53	2.22	1	15			
Education level (years)	11.03	2.48	0	15			
Farming experience (years)	3.17	5.04	0	31			
Size of land (Ha)	1.93	5.97	0	39			
	Youth involvement	Gender	Marital status	Tertiary agricultural education	Agricultural or business short term training	Government support program beneficiary	Own or access to land
Involved (%)	57.94						
Not involved (%)	42.06						
Male (%)		37.77					
Female (%)		62.23					
Single (%)			88.84				
Married (%)			9.87				
Widowed (%)			1.29				
Yes (%)				96.57	86.27	95.28	36.05
No (%)				3.43	13.73	4.72	63.95

Source: Research survey

3 Results

The following sections present the results by first discussing youth perceptions and their aspirations towards the agricultural sector. The results conclude with indications and a discussion of their interest in participating in the agricultural sector.

3.1 Perceptions towards the agricultural sector

Given the indication from the literature that the youth have negative perceptions towards the agricultural sector, it was expected that similar conclusions would be reached from this research. However, the responses from the youth have shown the opposite. The youth indicated their perceptions towards the agricultural sector at that specific time, and 82% of the respondents indicated a positive perception towards the industry. A few respondents indicated negative perceptions (6%) towards the agricultural sector, with some suggesting that they were unsure (12%). Further, it was found that most of the youth currently involved in the sector and most of those not involved have very similar positive views towards the sector, at 86% and 78%, respectively. The difference between the groups is attributable to several youths (17%) who stated that they were unsure about their perceptions of the sector at that time. A positive correlation exists between the youth involved in the sector and positive perceptions towards the sector, as shown in Table 2.

Table 2: Correlation matrix between youth involved, positive perception, willingness and interest towards the agricultural sector

	Involved	Positive perception	Aspire (agric)	Interested
Involved	1.000			
Positive perception	0.109	1.000		
Aspire (agric)	0.178	0.265	1.000	
Interested	-0.505	-0.044	-0.046	1

Source: Research survey

There is very little difference between the indications of youth who are involved and those who are not as shown in Table 3. Responses show that office jobs are preferred over working outside/field jobs. The respondents involved also seem divided, with no clear indication of a preference. In contrast, half of the youth who were not involved in the agricultural sector indicated that they preferred an office job.

Table 3: Perception indications of youth towards agriculture

Statement	Involved (n=135)			Not involved (n=98)		
	A	N	D	A	N	D
Primary rain-fed agriculture can offer better livelihood support and is the best way to alleviate poverty	71	10	19	68	13	18
Primary rain-fed agriculture is unattractive, dirty and backbreaking	27	21	52	34	17	49
Primary rain-fed agriculture is an option for under-achieving Students and adults	33	18	50	34	17	49
Primary rain-fed agriculture is reserved for old uneducated people	25	16	59	16	8	76
I find that primary rain-fed agriculture is attractive to me as a young person	68	13	19	68	12	19
Primary rain-fed agriculture would be the last choice if other non-farm options are available	36	19	45	48	12	40
I have seen elders improving their life through primary rain-fed smallholder agriculture	70	16	15	74	11	14
I prefer irrigated smallholder agriculture to rain-fed smallholder farming	56	19	24	57	17	26
Value adding agricultural activities are physically demanding	46	25	29	47	22	31
I prefer an office job than an outside / field job	41	17	42	50	11	39
I can be wealthy / rich through engagement in agricultural value chain economic activities	77	12	11	80	5	15
The youth can engage in agricultural value chain activities related businesses	81	9	10	78	9	13
Smallholder agriculture is not a profitable venture	24	21	54	31	12	57
Participation in agricultural economic activities will lead to economic empowerment of young people	73	13	14	81	9	10
Most people known to me love agriculture and agriculture related businesses	65	21	14	59	17	23
I believe most people known to me will support me if I choose to initiate agricultural business	83	10	7	76	9	15
Agriculture creates employment for the majority of the rural poor	81	9	10	89	6	5

Note: Likert scale data 1 Strongly agree and 5 Strongly disagree.

Source: Research survey

Family and community members (peers) have an important role in forming perceptions towards the agricultural sector, as shown in Figure 1. Personal experiences in the sector have also triggered perceptions in the agricultural sector. Personal experiences ('my experience') were the third highest influencer in forming a perception towards the agricultural sector. This finding provides an important focus area on which positive perceptions can be developed to advance interest towards the sector.

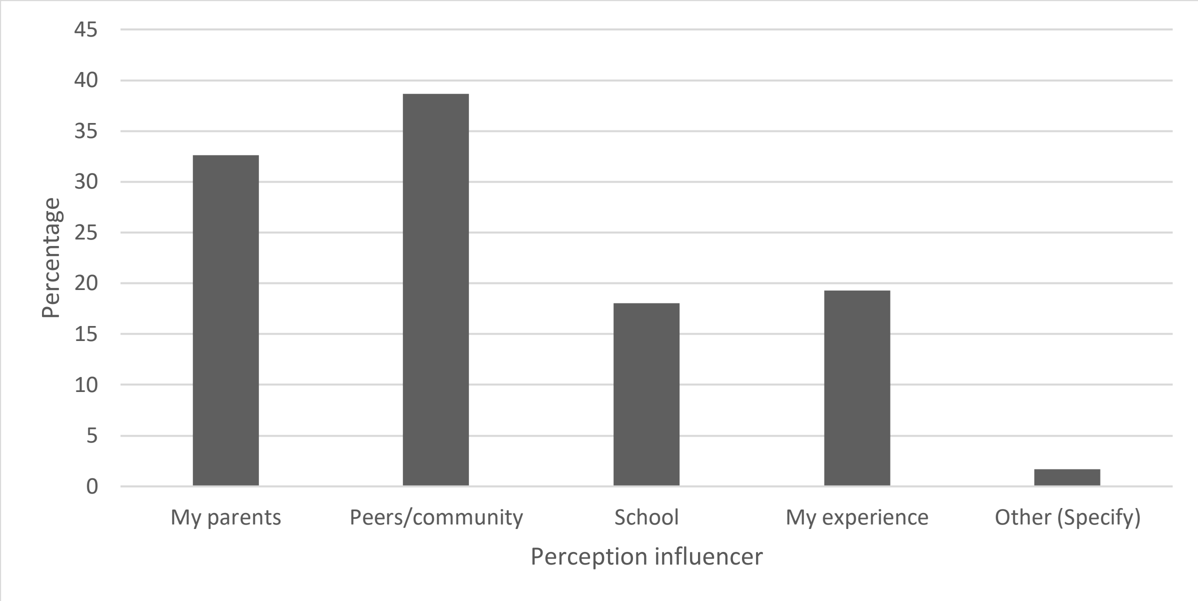

Figure 1: Influencers of youth perceptions towards agriculture (n=233)

Source: Research survey

The results show that the respondents perceive the primary and value-adding agricultural sector as a way to enhance their livelihoods. The indications differ from the literature regarding negative perceptions towards the sector and illustrate positive perceptions by youth towards the agricultural sector. The following section focuses on whether youth aspire to be involved in the sector.

3.2 Aspirations of youth towards agricultural participation

Aspiration refers to a person's wish to attain a specific position or objective (Bernard and Taffesse, 2012). These aspirations might include a particular level of education, a particular employment position, or participation in the agricultural sector. Most respondents had completed their schooling (Grade 12), and 94% indicated they aspire to further their education. An important indication is that 83% indicated they would aspire towards agricultural-related education. This could lead to future involvement in the sector, which is confirmed by the positive aspiration in Table *2*. It should thus be explored to which enterprises they aspire, and the results show their aspirations towards livestock, grain, and vegetable production, as shown in Table 4.

Table 4: Aspirations towards different agricultural enterprises (percentages)

Enterprises	Involved (n=135)					Not involved (n=98)				
	VL	L	N	U	VU	VL	L	N	U	VU
Crop production	41	34	7	3	9	24	32	8	3	17
Vegetable production	44	37	4	3	9	37	36	3	1	12
Livestock	39	27	7	8	12	37	20	7	9	13
Dairy	27	23	13	13	13	22	16	9	11	22

*(VL – Very likely, L – Likely, N – Neutral, U – Unlikely, VU – Very unlikely)

Source: Research Survey

Acknowledging that the agricultural sector comprises more than primary agriculture or farming, business opportunities also exist among the value chains; the respondents listed value-adding activities, including transportation, retailing, selling animal produce, operating a butchery, milling and making traditional clothing from animal skin as shown in Table 5.

Table 5: Aspirations towards agricultural value-adding activities by respondents (n=233)

Value adding activities	Involved (n=135)					Not involved (n=98)				
	VL	L	N	U	VU	VL	L	N	U	VU
Transportation of produce	28	24	13	13	5	28	30	7	5	7
Retailing of produce	36	36	8	9	6	35	40	8	2	3
Selling of animal products	33	30	7	13	8	35	29	7	8	6
Butchery	33	25	6	16	7	35	23	9	9	8
Milling	27	23	12	14	9	27	22	7	9	14
Making traditional clothing from animal skin	16	19	13	19	12	17	20	8	12	17

*(VL – Very likely, L – Likely, N – Neutral, U – Unlikely, VU – Very unlikely)

Source: Research survey

Most respondents indicated they aspire to retail their own or other products and sell animal products. This does not come as a surprise, as some already sell their products to consumers. There were slight differences between the two involvement groups, but the aspiration indications were very similar. The results concerning primary and value-adding activities show no differences in aspiration preferences towards either crop or livestock value-adding activities. This might be very appealing and shows the potential for the agricultural sector. However, it could also be a drawback, as it might indicate desperation or short-term relief for the youth willing to participate and change their aspirations to achieve a better livelihood.

Youth were asked to indicate who or what influenced their aspirations towards the agricultural sector. Figure 2 shows that family and extended family members (42%) affect the formation of their aspirations towards the agricultural sector, followed by peers and community members (19%); this relates to the indications from the literature that youth form their perceptions and aspirations by observing others in the sector.

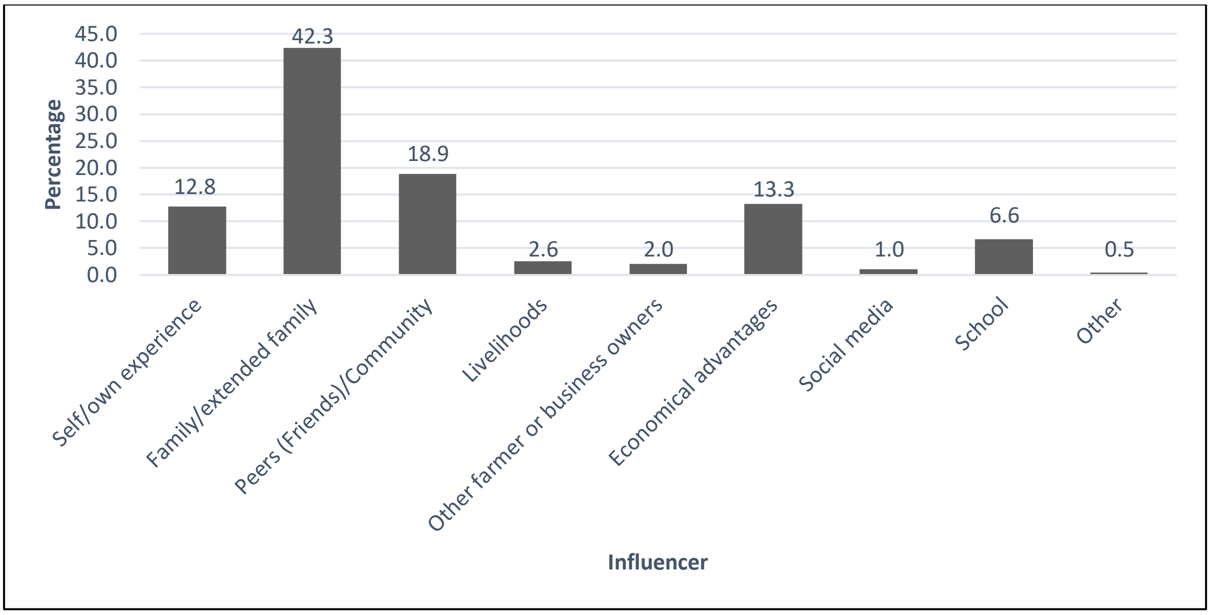

Figure 2: Influencers of aspirations towards agriculture and related activities (n=196)

Source: Research survey

The indications regarding influencers are interesting, given that Information and Communication Technology (ICT), specifically social media, is not an essential source in forming the aspirations of the respondents. Consequently, the results show the importance of social networks and peer relations in communities. Social media is mainly used for social purposes, instead of informing aspirations or identifying business opportunities in the agricultural sector. The research shows that most respondents aspire to become involved in the agricultural sector, with aspirations towards the popular enterprises in the research areas.

3.3 Interest towards participating in the agricultural sector

The respondents see that the agricultural sector provides opportunities to enhance their livelihoods and those of their families. Although the sector is identified as providing opportunities in rural areas, half of the respondents in the survey indicated that they are not involved in the sector. The respondents indicated that 51% (Table 6) are not interested in participating in the sector, as also found in Table 2. Interestingly, indications were that 73% of the respondents are currently involved in the sector, not because they are interested but for other reasons, while the opposite position was found for youth not already involved but are interested.

Table 6: Interest of all respondents to participate in the agricultural sector (n=233)

Interest to participate	**Involved Youth**		**Youth not involved**		**Combined**	
	Freq	**%**	**Freq**	**%**	**Freq**	**%**
No	98	72.59	21	21.43	119	51.1
Yes	37	27.41	77	78.57	114	48.9
Total	**135**	**100**	**98**	**100**	**233**	**100**

Source: Research survey

The result should be considered when implementing policies and development programmes to ensure that resources are allocated to youth who are interested in being involved in the sector and that resources are not wasted on youth who are not interested. Admittedly, their interest might change over time. For example, as youth become successful in their business undertakings in the sector, their interest in being further involved could increase, making spending time and resources on these youth worthwhile.

The respondents' interest in participating in different sector levels was also explored. As the agricultural sector consists of various options for participation, from the production of commodities to varying levels of value-adding, it was further explored where the respondents' interests might lie. Indications of the interests of the youth respondents between value-adding economic activities in the agricultural sector and primary agriculture are shown in Figure 3.

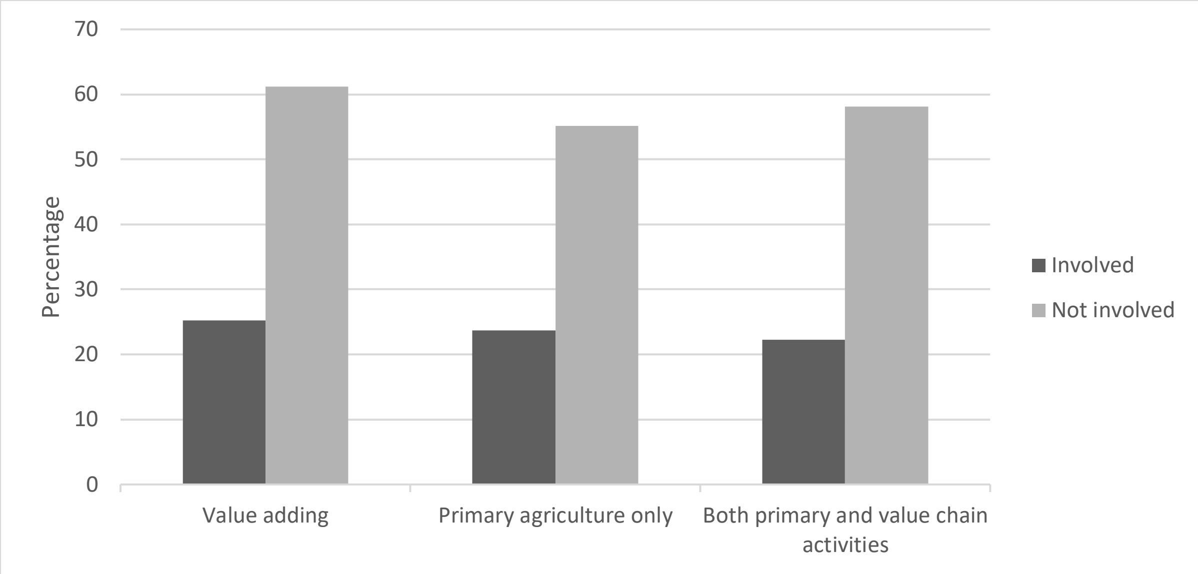

Figure 3: Interest in agriculture and related activities

Source: Research Survey

It is important to note that respondents could indicate interest in both options in the agricultural sector. Limited interest towards the agricultural sector is visible, with few (<30% of the youth currently active) indicating any interest towards specific activities within primary or value-adding in the agricultural sector. The limited interest to be involved in the sector is also illustrated with a negative correlation of -0.51 in Table *2*.

The reasons for being involved in the agricultural sector were explored by asking the respondents what drives their interest. Literature and governmental policy documents have indicated that the agricultural sector is vital in creating employment opportunities. However, for the sector to be used as a vehicle for youth employment and enhancing livelihoods in rural areas, the youth must have some interest and drive to be involved in the agricultural sector.

It has been established that the largest percentage (Table 6) of youth already involved in the sector are, however, not interested in being involved in the sector. In contrast, those not involved indicate interest in participating in the sector. The main terms used in the phrases and sentences supplied by respondents include ‘opportunities’, ‘money’, ‘agriculture’, ‘love’, ‘want’ and ‘farming’. These could be broadly divided into five categories: employment opportunities, knowledge enhancement, business, moneymaking ability and, lastly, love for the sector.

The responses as to why the respondents are interested in the agricultural sector echo indications in the literature that the sector provides employment opportunities. The importance of knowledge transfer is also reflected in the responses by the respondents, which might indicate that they are interested towards the agricultural sector, could also be explained by them being involved as part of a family or any other kind of business in the agricultural sector, where knowledge is transferred from one generation to the next.

Several respondents indicated that the sector provides the opportunity to generate money or create a business from farming. This clearly shows that the respondents see the income-generating potential of the agricultural sector. It was also noted that the sector is seen as an income generator and a source of livelihood in food production. The business opportunities offered by the agricultural sector were also indicated as a reason for the respondents' interest in the agricultural sector. The business side of the sector relates primarily to two aspects in the responses. Firstly, the sector provides food that can be consumed, and the second is the moneymaking or economic advantages that the sector (farming) provides. Responses highlighting these aspects include *getting plants to eat or sell if you want, you can make your own money, make food and money; I can get money, easier way of making money, It makes money* and also *the economic opportunities in the sector.*

The respondents' interest in being involved in the agricultural sector includes an interest that arises from the fact that some youth are already engaged in the agricultural sector or farming, either as individuals or as part of a family. Responses, such as love of the sector or love for growing plants or raising animals, indicate that some youth are interested because of their close relationship with the agricultural sector. As shown in the literature and confirmed earlier, family can play a critical role in enhancing the youth's interest in participating in the agricultural sector. The respondents indicated that they are interested in seeing the involvement of other farmers or participants in the sector. However, as literature has shown, observing other individuals' daily activities could push some youth away from the sector (Tafere and Woldehanna, 2012). Positive observations could attract youth to become interested in participating in the agricultural sector. Other indications of interest towards the agricultural sector are possessing or having access to natural or physical assets such as land and the *love* shown towards the agricultural sector. This can be seen in responses, such as '*I want my own farm*' and '*love vegetables and taking care of land*'.

The respondents' enterprise interests within primary agriculture were also explored. The results (Figure 4) indicate that respondents are interested in more than one enterprise, where livestock (including piggery), vegetables, and crop farming are favoured.

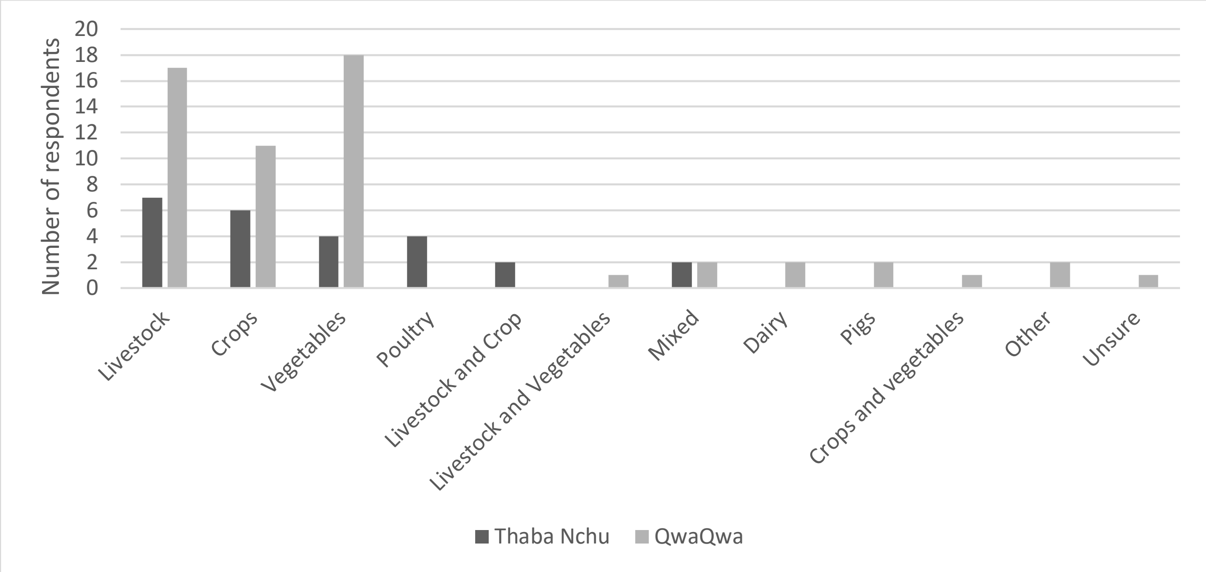

Figure 4: Interests towards different primary agricultural sectors

Source: Research Survey

Unsurprisingly, livestock enterprises attracted the highest levels of interest among all respondents, which might be explained by the dependence on rainfall for crop farming instead of irrigation schemes in the areas. Nevertheless, in both research areas, many respondents were interested in participating in crop enterprises, including vegetables and home gardens.

The youth not involved in the sector also recognise the prospects in the agricultural sector (*The new job opportunities created in agriculture*) to provide job opportunities (*creates more jobs*), which would provide them with food (*have own food production and planting*) and money to enhance their livelihoods (*to see my life improve through agriculture*). Youth also identified that farming or being involved in the agricultural sector provides a vehicle by which they can support their families (*I want to support family*) by providing a source of income, food and job opportunities to family members and other members of communities. Providing job opportunities to community members (*Community assistance*) would also positively impact the local economy by providing sources of income and reducing the local unemployment rate (*Reduction of unemployment*). However, they also recognised their limitations in their predominantly rain-fed agriculture areas. Given the limited rainfall, the respondents replied that, although they are interested, the little or unpredictable rainfall influences their interest in the sector. This has been highlighted in a response such as, *sometimes we don't get rain, sometimes we get it, so we are not sure about the rain*.

4 Summary and conclusions

The research explored youth respondents' aspirations, perceptions and interests towards the agricultural sector. Most respondents indicated positive indications towards the agricultural sector regarding their aspirations, perceptions, and interests, not only limited to primary agriculture activities but also value-adding activities. Observations suggest that the respondents are willing to be involved in primary agriculture (livestock, crop and vegetable) and value-adding activities (transportation of products and retailing of value-added products).

An interesting trend from the research is that although respondents aspire to participate in the agricultural sector, fewer indicated they are willing to participate, and even fewer were interested. Respondents not involved in agriculture also indicated a greater interest in engagement than those already involved. This shows that not all youth who aspire or are willing to be involved in the sector are interested in being actively involved. This might be attributable to them seeking any opportunity to enhance their livelihoods, even if it might be a temporary solution. This finding endorses the suggestion of Madende et al. (2023), who suggested using interest as a starting point for youth development pathways towards agricultural participation. Determining and confirming genuine interest towards agricultural participation is thus key to ensuring youth play their identified role in the economy.

To potentially improve the interests and abilities of youth to participate in the sector, consideration should be given to developing programmes where youth who show interest towards the sector are enabled to produce evidence of their commitment to become involved. This might be through their current activities or by launching smaller agricultural projects. Thus, ensuring these youth can prove their active interest and participation could motivate others to start similar agricultural projects. Youth need to take their development upon themselves and not simply wait for others to intervene and provide them with resources. Minor projects like these could also be built around youth clubs, where one youth member could access specific resources, and responsibilities would be shared among the various members to ensure the success of the project/s.

Given that the research is focused on the Free State province of South Africa, further research should explore these interests of youth in other areas and countries to determine whether similar trends exist. It is also important to ensure that the trends and indications from the research are further explored and investigated to develop pathways and policies which would enhance youth participation in the agricultural sector.

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IFMA24: Agricultural Policy

ECONOMIC CONSEQUENCES OF SUP-OPTIMAL NITROGEN APPLICATION IN DENMARK

- COMPARING EX-ANTE AND EX-POST ANALYSES

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Academic Paper

Abstract:

Denmark was the first country to introduce obligatory fertiliser accounts for all farms in 1987. In 1993 legally binding nitrogen norms were introduced in order to reduce the use of mineral fertiliser. The suboptimal nitrogen norms were introduced in 1998 and this has lowered the N-application 10% to 20% under the optimum for several years. The sub optimal norms have led to lower yields and lower protein content and the economic consequences have been discussed over many years. Following the Food and Agricultural package from 2015 the N-norms were, over a two-year period, increased to the economic optimal level in 2017. This has given a unique possibility to compare expected yield changes with actual yield changes 2016-2019 compared to the yield in 2013-2015 in order to estimate the yield increase from higher norms. The findings suggest that the actual yield loss from lower norms has been a little higher than expected based on trials. The increase in yields after the increase in application has been around 2-3 HKg/ha (4%) for wheat and barley and the protein increase has been 0.8-1.0% units for the same crops. The costs of lower norms are estimated to have been around 460-900 million DKK per year for a 16-19% norm reduction.

Key words: Nitrogen response, fertilizer account, in optimal nitrogen application, cost of lower nitrogen norms

1. Introduction

Nitrogen is a crucial element for agricultural production. Its application via fertilizers or livestock manure supports the growth of plants including crops and pastures. There are, however also a range of side effects, why there have been many attempts to reduce nitrogen pollution from a policy perspective (ENA, 2017). The latest attempt the European Green Deal aims to reduce nutrient losses by 50% and achieve a reduction of mineral fertilizer use by 20% by 2023 (EU commission, 2023). There is generally a high correlation between nitrogen application to soil and the level of nitrate in rivers. The use of nitrogen is also directly linked to the emission of nitrous oxide which is 300 times as harmful as CO_2.

Agricultural measures have already resulted in a moderate reduction in total agricultural nitrogen inputs for the EU-27 of 15% since the 1980s, but agriculture still has a cost-effective emission reduction potential (EU commission, 2019). Analyses show that nitrogen application is among the parameters that have failed most in meeting national targets (Kirschke et al., 2020).

In a policy context, nitrogen norms have been used in Denmark since 1987. First, as a requirement to introduce nitrogen accounts and later in 1993 binding N-norms were introduced (Nemming and Hansen, 2015). Later in 1998 nitrogen norms were reduced to 10% under optimum as this was seen as a cheaper option than other measures. The success is shown in increased NUE (N Use Efficiency) and decreased N losses, and has been ascribed to two main factors, namely (i) mandatory fertilizer plans, with limits on the amount of plant available N to be applied to different crops, and (ii) statutory norms for the fraction of manure N assumed to be plant available. These instruments have been enforced and designed in close dialogue with farmers and farmer associations. Germany and The Netherlands have also considered reducing application norms by 20% in areas with groundwater problems, but rigorous application of regulation is required (Kirschke et al., 2020). Canada also is considering how to reduce nitrogen use through a range of ways, but not a mandatory reduction of use (Government of Canada, 2020).

The Danish sub optimal norms were abolished in 2015 and replaced by economic optimal norms as the costs for the farming sectors was found to be too high. Other measures were implemented to counteract the increased N-losses to the aquatic environment. The return to optimal nitrogen application allows for a unique analyses of the economic consequences of the lower nitrogen application (2013-2015) compared to ex-post (2016-2022). The change in yield is also compared with a newly developed nitrogen response function model (NREMO) which aims to describe the likely impacts on yield and protein content based on a range of parameters. This will give a better insight into the actual effects and costs of the lower norms.

The key issue in this article is to compare the model expected yield effects with the unique option of nationwide reduction and increase in nitrogen application, looking both at the ex-ante and ex-post calculation of lower nitrogen norms on yield and protein content. The economic analysis allows for a comparison of the economic effects of lower norms which has been discussed for many years in Denmark.

The paper is organized so that section 1 describes the setup used to establish the N-norms used in Denmark. Section 2 looks at the estimates of the costs over time. Section 3 looks at the expected reductions in yields based on production functions and section 4 looks at the actual increase in yields based on the increased N application at the national level. Based on this the costs of lower norms are discussed in section 5. The conclusions and discussion session look at the overall impact of lower nitrogen norms.

2. Expected costs of lower norm over time

As mentioned it was in 1998 decided that the N-norms should be reduced to 10% under the economic optimum as part of the Aquatic Program from 1998 (see appendix A) (Dalgard et al., 2014). This measure was found to be one of the cheaper options to reduce nitrogen leaching.

In this paper, the nitrogen norm is the amount of nitrogen which is officially allowed pr. Ha of a given crop and the nitrogen quota is what the farm is allowed to apply in total at the farm level. The quota at the farm level is what is checked every year and so farmers can in fact apply more or less than the norm at the crop level, as the legal requirement is at the farm level. The optimal nitrogen level is determined by the Ministry of Agriculture based on the recommendation from the National Norm Committee (Normudvalget, 2020; DCA, 2018). The committee regarding N-norms gives recommendations regarding three areas. Optimal N-applications for each crop, estimates regarding adjustments in the spring (the prognoses) and estimates regarding N content in livestock manure.

As mentioned, the reduction of 10% to the norms was decided in 1998 as there was a political need to further reduce the nitrogen losses. However, due to other changes in the agricultural policies, the reduction compared to the optimal level and the national level was around 19% in 2015. The reason being that it was decided that the total national N application should not increase due to changes in e.g crop rotation and when the set-a-side requirement was stopped. Also, the increase in optimal N (price of protein etc.) meant that the reduction percentage increased over time.

At the outset, the University of Århus (AU) estimated the yield impact of a 10% norm reduction in barley and wheat. They also came up with an estimate of the likely reduction in protein content. They did not find proof to back a long-term yield reduction. The University of Copenhagen (UCHP) calculated the costs based on this data. As can be noted the Agricultural sector analysis (SEGES) estimates higher yield losses in the short and long term. In some cases SEGES find long term yields to be larger than the short term yield loss and in other cases they use 50%. They, therefore, find the costs to be much higher. (see table 1)

Looking at renewed calculations in 2012-13, the expected yield losses now are higher as the nom reduction was 15%. A key issue behind the difference between the Farmers advisory center estimate (SEGES) and the universities calculation is long term yield losses and the impact on protein levels. Other effects are the losses linked to farms that cannot apply the economic optimal level to their specific farm as they are restricted by a general norm pr. ha.

Table 1. Yearly cost of a 10-15% N-reduction from different sources over time (2003-2013)

Source	UCHP/AU	SEGES	UCHP/AU	SEGES***
Year	2004	2004	2013	2013
Area (mio. ha)	2.0	2.3		2.2
N-reduction assumed (%)	10	10	15	15
Yield effect cereals (hkg/ha)	1.0	1.0	2.0 -3.0	4.5
Long term yield effect (hkg/ha)	0.2	0.8 – 1.3	1.0-2.0	1.5

Other effects (hkg/ha)	0	1.0 – 1.8	--	--
Total effect yield (hkg/ha)	1.2	2.8 – 4.1	3.0 – 5.0	6.0
Protein content (% units)	0.5	1.0	0.5	2.4*
Economic loss (mio. DKK):				
Yield - short term (net cost)	75-115	340	319 - 814	916-1,597
Protein effect	55-75	47 – 95	161	728-1,741
Total economic loss **	130-190	390 – 439	479 - 975	1,644 – 3,337
Total economic loss (DKK/ha)	50-73	150 - 169	184 - 375	632 – 1,283

Source: FOI, DJF & Landscenteret 2004; Kristensen and Jacobsen, 2013.
Note : 100 DKK = 14,5US$ = 20 CAN$ = 13,5 €
Note: The agricultural area is 2.6 million ha, but not all have a N-norm above 0 so only 2.2 million ha have a N-norm. Other effects include variation between farms. Net costs regarding yield are yield effect minus reductions in costs for mineral fertilizer.
*) With low and high protein prices (2.47 and 5.39 DKK per % unit) compared to 2.7 DKK per unit at the UCHP calculation. It can also be noted that some of the costs are directly linked to the norm reduction and others are linked to the introduction of fertilizer accounts in the years before.
**) The forage area is assumed to be around 0.5 million ha and the economic loss for this area is set at half the loss at the area with cereals and other crops of 1.7 million ha.
***) the reduction in mineral fertilizer is 25 kg N/ha at 8 DKK in UCHP calculations, but SEGES use 50 kg N/ha so the reduced costs are twice as high.

The protein content was meant to fall by 0.5 to 1.0, but SEGES has found that the protein content has fallen from around 11.0% around 1990 to around 8.5-8.6% (based on protein in pig feed) and so they state that the lower norms have reduction protein levels with of 2.4%. Others argue that the fall in protein levels is not only due to lower N-norms but a combination of several factors. Such as : Stop for over economic optimum application, increased requirements regarding animal manure, lower N-content in soils and that especially wheat is now grown on less suitable soils.

The long term effect is much debated, but the data behind impacts is difficult to use directly (Thomsen et al., 2003). The Rotherham trails are used as examples of the effect if soils over many years are given no or limited nitrogen. The long term effects have been estimated to be around 20-80% of the short term effects why SEGES have used up to 75%.

3. Costs of lower norms based on modelling using NREMO

The economic optimal N-norm for each crop at the national level is based on production functions for each plot estimated by the advisory service SEGES. The general shape of yield response curves to nitrogen exhibits several meaningful thresholds. These thresholds are not only dependent on the crop but also on the soil, weather and cultural practices. Many functional forms have been suggested over time, but often a polynomial of second or third-degree is used. The model used here is described in more detail in Ørum et al. (2019) and is based on national trials run by the Danish Advisory Service. The response functions and the NREMO-model are estimated and tested against data from trials run by the advisory service (Landsforsøgene) with existing nitrogen applications to winter wheat and spring barley in the period 1992-2018) (Knudsen, 2015).

In the trials conducted by the advisory service (SEGES). A total of 718 trials out of 1051 trials with winter wheat have been used and 366 of 408 for spring barley have been used from the period 1992 to 2016 to validate the model.

Tabel 2. Effects and costs of lower N-norms using the NREMO model

Norm reduction	0	10	20
Wheat (kg N/ha)	208	187	166
Yield (hkg/ha)	88.5	87.9	86.2
Yield reduction (Hkg/ha)	0	0.6	2.3
Protein (%)	11.0	10.6	10.1
Price of crop (DKK/hkg)	118	116	115
Net loss (DKK/ha)	0	59	234
Barley (kg N/Ha)	148	133	119
Yield (hkg/ha)	69.7	69.2	68.1
Yield reduction (hkg/ha)	0	0.5	1.6
Protein (%)	10.9	10.6	10.3

Price (DKK/hkg)	117	116	115
Net loss (DKK/ha)	0	30	120
Average yield reduction (Hkg/ha)	0	0.6	1.9
Average net costs (DKK/ha)	0	45	177

Note : 100 DKK = 14,5US$ = 20 CAN$ = 13,5 €

Source: Eriksen et al. (2020)

As shown in Table 2 the average yield reduction for barley at 10% is 0,5 hkg/ha and protein loss is 0,3 %-units. At 20% norm reduction reduce yield by 1,6 hkg/ha and protein loss is 0,6 %-units. For wheat, the yield reductions are 0.6 and 2.3 hKg/ha for 10 and 20% reduction in application. Protein loss is 0.6% and 0.9% for the two levels.

The long term yield reduction has been estimated over 0 to 100 years. The reduction in N /ha is estimated to be 0-3 kg N/ha for a 10% norm reduction and 0-6 kg N/ha for 20% reduction (Eriksen et al., 2020). The additional costs are 0-18 DKK/ha in barley and 0-73 DKK/Ha in wheat.

5. Change in yield, protein level and income following change to optimal N-norms in the Food and Agricultural Package from 2015

As mentioned earlier the increased norms were decided in December 2015 and so most farms were able to increase N-application in the Spring of 2016 although it would mean a new fertiliser plan. This means that in 2015/2016 the application was 7% under economic optimum and in 2016/2017 it was back to optimal N-norms. The average application was increased by approximately 20 kg N/ha (14 %) when the application in 2016 and 2017 were compared to the levels in 2015. The N-norm for wheat on clay soils increased by 46 kg N/ha or 28% from 2015 to 2017. This large increase is due to the higher value of protein included in the calculations. When the national increase is only 14% it is because the area with spring barley has increased since 2015. The annual increase in the N-quota was, therefore, only 35-38,000 tons N which was lower than expected (Jacobsen, 2019).

Analyses of the fertilizer accounts also show that the utilization of the quota is the same now as before with the sub optimal norms. This would indicate that farmers are using the increased quota, but also that before and after there are farms which do not fully use the full quota (Blicher-Mathiesen et al., 2019; Jacobsen, 2019). The calculations show that around 6% of the quota is not used and e.g. the organic farms do not use the full quota.

The total N-quota includes both the nitrogen from livestock manure and other nitrogen inputs. The effecting N-application from manure and other sources is calculated as the amount of N times the utilization requirements. This has for many years been 75% for slurry from pigs.

A side effect of lower than optimal nitrogen norms has been that the shadow value of nitrogen has increased. This has meant that there was a larger gain from acidification of slurry and receiving manure from biogas plants as these technologies provide higher utilization of manure. With the return to optimal nitrogen norms this incentive has disappeared, but it was replaced in 2019 by increasing the already high requirements for the utilization of N in pig slurry now is 80% (one of the highest in Europe).

It is now possible to estimate the amount of nitrogen which can be purchased as mineral fertilizer. All companies delivering nitrogen in Denmark are included in a register and they are the only companies allowed to sell nitrogen. At the end of the year, each farmer receives an overview of the amount of mineral nitrogen purchased at these companies. Each year the Agricultural Agency compares the allowed purchase with the actual purchase and a fine is given if the purchase is higher than the allowed amount. As there is a limit farmers cannot just buy more mineral fertilizer in case they expect that the utilization requirement regarding manure has not been achieved as the amount of mineral fertilizer purchased is checked.

The actual yields from 2013-2023 for barley and wheat are shown in figure 1. During this period there was a drought in 2018 which reduced the yields significantly just as the yields in 2023 were relatively low. It is therefore not easy to compare yields over time, but it does give an indication of the likely yield impact. So when here the yield in 2016, 2017 and 2019 (2018 is left out) is compared with the average 2013-2015. The results show an increase in the yields of winter wheat of 2.7 hkg/ha and an increase in barley of 1.8 hkg/ha. As an average, this gives an increase of 2.25 Hkg/ha. This is slightly higher than the expected short term effect of 1.9 hkg/ha as shown in Table 2. It should be noted that yields do increase over time due to genetic improvements as seen from 2010 to 2016. If other years have been used to compare the yield effect would have been in the range between 2 and 3 hkg/ha.

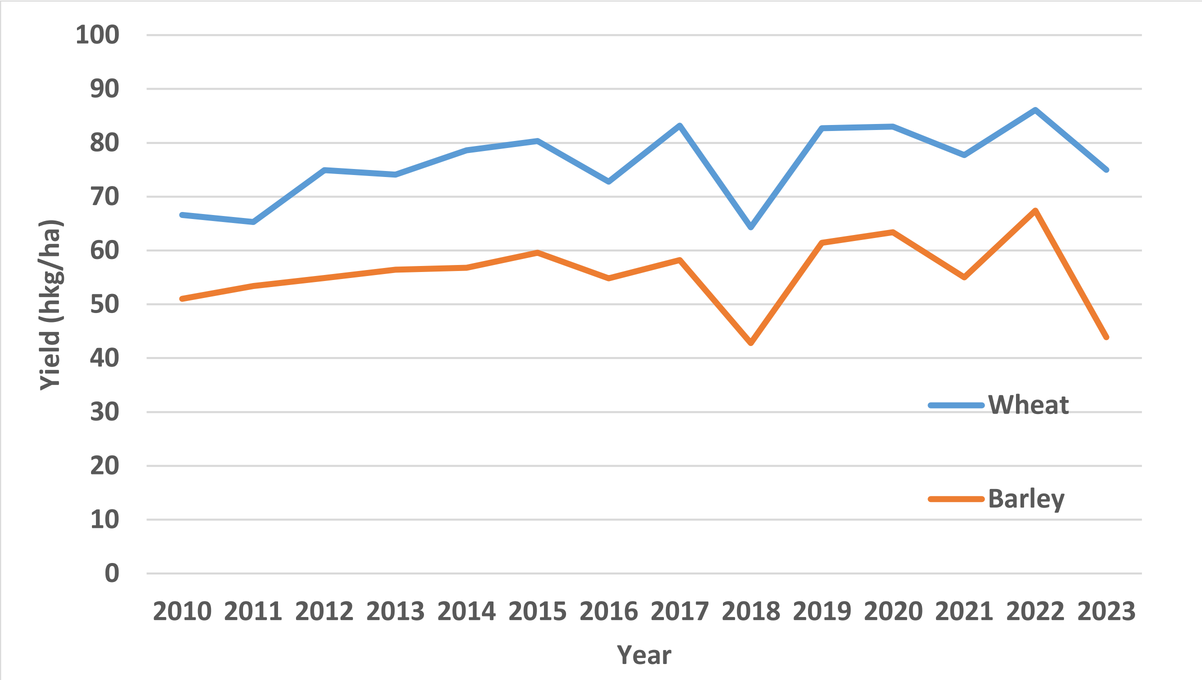

Figure 1. Yield in Winter wheat and spring barley 2010-2023.

Source: Danish Statistics (Statistikbanken, HST77)

Note: 2018 was a draught year so it has been disregarded in the comparison.

In the trials, the protein levels increase by 0.2% units each time another 10 kg N/ha is applied. (Kristensen & Jacobsen, 2013; FOI, DJF & Landscenteret, 2004). This is roughly the same change observed in the analyses (Vinther & Olsen (2019)), where the protein levels have increased by 0.7% in winter wheat and 0.9% in spring barley when 2017 is compared to 2015.

As seen in other analyses from pig farmers (Sloth et al, 2019) the protein levels for pig farmers for winter wheat increased in these years from around 8,7% to around 9,5% (+0.8%) and for spring barley from 8.5% to 9.5% (+1.0%). It would indicate that the protein increase has been around 0.8 to 1.0% for grain for a 30-40 kg N/ha increase in application.

Table 1. Yearly cost of a 10-20% N-reduction based on function estimates and actual yield reduction

Source	UCHP	UCHP/AU	Actual increase
Year	2016 (average of high and low)[(a]	2020 N-Catalogue [b)]	2016 – 2019
N-reduction assumed (%)	10/20	20	15-19
Yield reduction :			
Yield effect (hkg/ha)	1.1/4.4	1.9	
Long Term (hkg/ha)	1.0/2.6	0.05	
Other effects (hkg/ha)			
Total yield effect (hkg/ha)	2.1/7.0	2.0	2.0 – 4.0
Protein reduction (% units)	0.4 / 0.7	0.8	0.8 - 1.0
Economic loss (million DKK):			
Yield - short term	232/1240		
Yield – long term			
Protein loss	149/282	267	267 – 333
Total economic loss	381/1.523	357	357 – 915
Total economic loss (DKK/ha)	147 / 586	135	135 – 345

Source: [a)] Jacobsen og Ørum (2016); [b)]Eriksen et al, (2020) and own calculations. 2.2 mio. Ha (0.5 ha is forage area with half the cost). The reduction in application is 25 kg N/ha at a 20% reduction.

6. Conclusions and discussions

This paper describes the yield and economic effect of norm reductions of 10% and 20% in barley and wheat in Denmark. The comparison is unique as it is possible to compare the expected yield change based on a new response model (NREMO) based on many trials over many years with the actual impact of an increase in nitrogen norms in 2015-2016. It is, thereby possible at the national level to compare expected yield change with estimated changes in yields for wheat and barley.

The NREMO analysis finds that a reduction of N-norms by 10 and 20% would reduce yields in barley by 1,9 hkg/ha and 2.3 hkg/ha. This is a little lower than observed in the national data where a yield increase of around 2.5 – 3.0 hkg/ha or 4% has been observed in both barley and wheat.

The impact on protein levels is found to be roughly the same as expected with an impact of a 20% norm reduction is 0.8-1.0 % units.

The total cost, where the cost for forage area is half the cost per ha of barley and wheat, is around 350- 900 mio. DKK per year for a norm reduction of 15-19%. This estimate is higher than the initial estimates and lower than higher estimates made by the Farmer Advisory Service SEGES.

There have over the years been many discussions in Denmark regarding the total costs of lower N-norms. The fact that farmers can apply the total farm nitrogen quota on the fields with the highest return helps to lower the costs from lower norms. There might be long term effects of lower nitrogen application, but they might have been smaller than anticipated.

Today new Danish nitrogen regulation is more targeted and reduced N-norms are one of the options which farmers can use together with catch crops or early sowing. Lowering N-norms by 10% today is one of the cheaper measures which is recommend for a number of arable farms, but less so on pig farms where the protein level is important (Knudsen, 2020). The finding so far is that catch crops and early sowing is much more popular among farmers than reduced N-norms. It would indicate that farmers still find it to be more costly than what is found when looking at the modelled and actual yield impacts. It could be that this is because a high yield is still a key parameter in farming.

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Appendix A

Year	Measure
1985	Maximum stocking density Mandatory slurry tanks (6-9 month) Ban on winter application
1987	Mandatory fertilizer and crop rotation plans Minimum area with winter crops Manure application within 12 hrs.
1991	Statutory norms for manure utilization Max. N applied to crops equal to economic optimum
1998	Max. N is reduced to 10% under economic optimum
2004	More requirement regarding catch crops Broadcasting of slurry Is banned Utilization of slurry is 75% for pig slurry and 70% for slurry from dairy cows
2006-2009	Max N is reduced to around 15% under optimum Solid cover on new slurry tanks in some cases
2014-15	The proposal is that Max N is 19% under optimum
2015-16	Max N is changed to 7% under optimum
2016-17	Max N is changed to optimum
2019	Targeted regulation is introduced where lower N-norms is one of the measures. Catch crops is used as currency. Requirement is around 110,000 ha catch crops
2020	Requirement regarding catch crops is increased to around 330,000 ha Requirement regarding utilization of manure is increased by 5%
2023-2024	Catch crops are around 370.000 ha focused to new areas due to new nitrogen reduction requirement in the 108 catchments.

Sources: Dalgaard and own description and MST (2018)

IFMA24: Resilience through Innovation

INVESTIGATING THE ECONOMIC VALUE OF SEX-SORTED SEMEN IN SOUTH AFRICA: A BEEF CATTLE EXAMPLE

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Abstract

Within the South African livestock sector, beef production in particular serves as the largest sub-sector emphasizing its prominence in contributing toward enhancing food security, economic growth and the livelihoods of citizens. However, beef cattle producers faces various obstacles which includes relatively low calving rates that lead to decreased revenue obtained per calve within breeding herds. The utilisation of different breeding methods has been identified as one of the ways to overcome these obstacles. In this study, we have examined the cost difference of producing a calve using two different breeding methods in traditional AI and Sex-sorted AI. According to the farm calculation model, utilising SSAI to breed replacement heifers poses great financial advantages for South African beef cattle producers. At various conception rates, obtaining a 1:9 bull calve to replacement heifer calve ratio through SSAI generates more income (R1 540) for beef cattle producer compared to traditional AI. The calculation model also indicates that using SSAI to breed bull calves for the feedlot market can be financially viable at optimal weaning weights. If South African cattle breeders aims to ensure reproductional and economic sustainability whithin their cattle herds, SSAI should be considered as an improved method of breeding.

Key words: Artificial Insemination, Replacement heifer, Beef cattle producers,

1. Introduction

According to the Department of Agriculture, Forestry and Fisheries (DAFF, 2017), the livestock sector is component of South Africa's agricultural industry which significantly contributes more than 48% toward the total value of agricultural output within the country. Moreover, beef cattle production in particular poses as the largest subsector making up a share of 26.2%. Apart from the direct contribution by the primary beef production sector, the indirect contribution through the secondary and tertiary economic sectors in terms of elements such as input suppliers and job creation should also be considered.

Beef cattle producers in South Africa are facing challenging scenarios where they are confronted by various socio-economic and management challenges that have a negative effect on the sustainability of beef production. According to Crites et al., (2018) means of beef herd improvement would include improving conventional natural breeding through scientifically specified breeding methods such as estrus synchronization, Artificial Insemination (AI), In Vitro Fertilization (IVF) and sex- sorted semen. The concept of Sex-Sorted Artificial Insemination (SSAI) has been globally utilized where cattle producers add genetic and economic value to their herds through the advantages posed by this method (Butler et al., 2014; Vishwanath and Moreno, 2018; Walsh et al., 2022 and Patra et al., 2023). The process of sperm sorting uses flow cytometry that relies on the use of a fluorescent dye that stains sperm DNA. Since X-chromosome-bearing sperm contain more DNA than the Y-chromosome-bearing sperm, they emit a brighter signal when exposed to light. This allows the flow cytometer and sophisticated computer software to distinguish between the two sperm populations (Vishwanath and Moreno, 2018).

One of the main advantages of sex-sorted semen is that it provides beef cattle producers with the opportunity to have more control over the amount of male or female calves born in their herd (Thomas et al. 2014). This allows opportunity for increased revenue and profit, where more than 90% of pregnancies from AI with sex-sorted semen will result in the birth of offspring of the preferred sex which reffered to as the gender value (Walsh et al., 2021). The term "gender value" is used in cases where sex-sorted semen is concerned, and refers to the value that producers attach to calves of a certain sex. Through the implementation of sex-sorted semen, beef cattle producers can breed genetically superior cows with female sex-sorted semen for replacement heifers or breeding the top females with male sex-sorted semen to produce stud sires (Thomas et al.,2014). In addition, Patra et al. (2023) stated that sex-sorted semen also creates the opportunity to market surplus females if the price premium (above weaner calf price) is favorable such as in years with abundant grazing and high crop yields. This technology is of use for both commercial as well as stud breeders where the sale of more amounts of female animals also hedges these breeders against the volatility of prices in the weaner calve market (Patra et al.,2023).

The long-term economic viability of cattle breeding is mainly dependent on improved breeding thus emphasizing the need to investigate methods of improved beef cattle animal production (Thomas et al.,2014). Studies such as (Karakaya et al., 2014; Thomas et al., 2014; Crites et al. 2018 and Patra et al. 2023) has analyzed the significance of sex-sorted semen and its contribution toward beef cattle producers. In a South African context sex-sorted semen has been investigated by studies such as Magopa et al. (2022) and Khorshidi et al. (2017). However, no research emphasis have been placed on the economic value that this method could add to South African beef cattle producers. The main objective of this study was to do a cost comparison between traditional AI and SSAI. Consequently, this study developed a calculation tool to calculate the economic advantage of using sexed semen in beef cattle production as it seeks to assist beef cattle producers with when making decisions.

2. Methods

To obtain the main objective of this study, a cost comparison of traditional AI and SSAI was done in Microsoft Excel 21 where the income margin over breeding cost generated per breeding method was calculated. Calculating the economic value of sexed semen is determined by the difference in the gender value of the weaned calves, the reproduction rate (weaning percentage) and the breeding cost differences between breeding systems. The breeding costs used for the calculation model is obtained from a South African reproduction company that provides reproductive services and technology for sheep, goat and cattle breeders (Rasmsem, 2021). This company is based in Bloemfontein South Africa a provides services to farmers across the country. Farm level costs (see Table 1) were based on average cost during the time of calculations and was calculates at R1,163 per cow annually. assumptions made for the difference in costs of traditional AI compared to sex-sorted semen artificial insemination (SSAI) considered are also presented in Table

1. The average live weaner prices for the past 5 years (2019-2024) were obtained from the Red Meat Producers Organisation (RPO), who is the responsible for the promotion of a sustainable and profitable red meat industry in South Africa.

Table 1: Assumptions made for traditional AI and sex sorted AI.

Assumptions	Traditional AI	SSAI
Input cost per cow per year	R1,163	R1,163
Price per semen straw	R100	R400
Hormones	R260	R260
AI cost per cow	R50	R50
Bull calves (%)	50%	10%
Heifer calves (%)	50%	90%
Total AI cost per cow treated in the herd	R410	R710
Total annual cost per cow in herd	R1,573	R1,873

Important to note is that, in the total cost calculation provision is made for annual feed (lick) and vaccinations at a 'per cow' level, as well as the cost associated with AI or SSAI per cow. No provision is made for expenditure such as capital interest, depreciation of facilities and equipment, management, labour and general administrative costs. In the cost per breeding method calculation, the only varying factor is the semen straw cost per cow treated using one of the two methods.

The following formula was used to calculate the cost per calf weaned for both methods (Y):

$$Y= \frac{(A+B+C+D)}{N} \tag{1}$$

Where:

Y= Cost per calf weaned (R)

A= Total annual input cost per cow (R)

B= Total cost per semen straw (R)

C= Medication and hormone cost (R)

D= AI per animal (R)

N= Conception rate per method (%)

Equation 2 was used to calculate the annual input cost per cow:

$$A = \frac{Total\ lick\ and\ feed\ cost + Total\ veterinaty\ cost}{Number\ of\ animals\ in\ herd} \quad (2)$$

Where A represents the annual input price per cow

3. Results and discussion

The differences in the two approaches of breeding measured according to different calving rates are presented in the Table 2.

Table 2: Cost comparison between AI and sex sorted AI.

Assumptions	Traditional AI	SSAI
Total cost per calf born (@60% Pregnancy)	R2,622	R3,122
Total cost per calf born (@66% Pregnancy)	R2,384	R2,838
Total cost per calf born (@70% Pregnancy)	R2,248	R2,676

A sensitivity analysis has been done to show the difference in the cost of a traditional AI calf versus a SSAI calf where different pregnancy percentages were achieved between the two methods (see Table 3). In a case where traditional AI achieves 10% higher pregnancy rates, the additional cost of SSAI is still lower than the gain in value (gender value) of average calves from sex-sorted semen, making it a worthwhile option to consider. Based on the assumptions, at a conception rate of 66% for both traditional AI and SSAI, the difference in cost to produce a calf with a >90% chance of being female is R455.00 higher than the case where 50% of the calves should be heifers. The difference in cost should be considered by beef cattle producers as it poses economic value. Another observation that was made is that as the conception rate in the herd decreases, the cost of SSAI increases. Utilizing SSAI and obtaining a 60% conception rate in a beef cattle herd would result in a higher (R455.00) cost per calf born compared to obtaining a 70% conception rate. This emphasizes the fact that a higher conception rate would ensure a decreased cost of producing a heifer calve which ultimately increases the value gained from SSAI. At a 70% conception rate from SSAI used in breeding cows, the cost of producing a heifer calve would decrease ultimately decrease by 90% (R54.00) compared to obtaining a conception rate of 60% through traditional AI.

Table 3: Production costs for traditional AI and SSAI at different pregnancy percentages.

		SSAI Pregnancy Rate		
		60%	66%	70%
Traditional AI Pregnancy Rate	60%	R500	R216	R54
	66%	R738	R455	R292
	70%	R875	R591	R429

An important observation from Table 2 is that at various conception rates, SSAI would initially cost a beef cattle producer more to produce a calve of a certain gender. However, the gender value of sex-sorted semen is concerned to the value that producers attach to calves of a certain sex. In the case of breeding replacement heifers, SSAI poses the advantage where beef cattle producers can perform individual mating by hand-selecting genetically superior animals to produce heifers from more maternal dams (Rodgers et al., 2012). Where in contrary, more bull calves can be obtained from mating terminal crosses. In some beef cattle production systems, heifers kept for replacement are more valuable than their male counterparts which creates the platform to breed genetically improved heifers that ultimately increases a producer's herd quality. Furthermore, a sensitivity analysis was conducted to calculate the cost per calve born at different conceptions rates per breeding method.

3.1 Value gained by producing more heifer calves.

When calculating the value gained per replacement heifer calve over a bull calve, it can be said that a bull weaner calf marketed directly after weaning would be worth about R 8 400 (210 kg x R40/kg) this based on market conditions at the time of data collection. Heifers kept for replacement purposes at the same time sold for R11 000. In the case where a bull calf at weaning age sells for R8400 it would necessitate to have a breeding objective of producing more females as this will potentially increase the income of a beef cattle producer. Based on the assumptions made, if a 50% ratio of bull to heifer calves is considered, the average calf weaned will be worth about R9 200 to the producer (Table 4).

In contrast, the average value of calves from sex-sorted semen (about 90% more heifers) will increase to approximately R10 740. Therefore, the average value of a calf will be R1 540 higher where sex-sorted semen is used. This is in line with Drake et al. (2020) who found that the income margin gained by selling replacement heifers exceeds those of selling weaner calves directly to the feedlot market. It is important to consider the value that a breeder attaches to heifers, and is strongly dependent on the breeding objectives, breeds as well as time of the year. If there are breeders who value their heifers even higher, the difference in values will be greater, that is, the value that gender-based semen can add to the breeder's operation will be even higher (R 11 000 in the scenario but is subjective to market condition). Overall, the use of sex-sorted semen is profitable, particularly for heifers, the rationale is that in replacement heifers can be bred to improve the herd quality of South African cattle breeders.

When calculating the average income gained per calf sold, at 60% conception rate using traditional AI, a beef cattle producer would earn around R7078 after calf production cost have been deducted. In comparison, at the same conception rate, a beef cattle producer would earn around R7618 on average per calve by using SSAI. Beef cattle producers would receive R540 more per calve when 90% of the calves weaned are replacement heifer calves bred through SSAI. In this scenario, using SSAI would still be a financially better option to utilize within a breeding herd. Furthermore, in an instance where the conception rate increases to 70%, an average income of R7452 would be obtained using traditional AI. At the same conception rate, the average income per calve would increase to R8064 when SSAI is applied in breeding. This indicates a R612 increase in the income when SSAI is used to breed replacement heifers compared to traditional AI.

3.2 Value gained by producing more bull calves.

The following section highlights the cost comparison traditional AI and SSAI, when the breeding objective of a beef cattle breeder is to breed bulls that are to be weaned and sold to the South African feedlot market. Same costs as presented in Table 1. A practical management decision for beef cattle producers who market their calve in the feedlot sector, would be to increase their bull calve production through (male) sorted semen which would increase their profitability. For commercial cattle producers who market feeder calves to feedlots, bull calves are usually heavier at weaning and more valuable in the feedlot market compared to their female counterparts. In feedlots, bull calves grow faster, are more efficient and finish at heavier weights, providing greater profit maximisation (Spies, 2011). The use of SSAI, where 90% bull calves are obtained and sold to the feedlot market would earn cattle breeder increased value per calf sold. On a commercial level, cows in the herd can be inseminated with male sex-sorted semen from high-ranking Average Daily Gain and Feed Conversion sires to produce bull calves for the feedlots. Bull calves are preferred by feedlots compared to heifer calves as they perform better due to having a better feed conversion rate than heifers (Hendriks et al. 2021). Beef cattle producers stand to gain advantage through the implementation of sex-sorted AI as a means of improving their herd and ultimately their profit margins.Tables 4-6 indicates the profit differences between the two breeding methods.

Table 4 Calculation of average price per calf born through AI.

Weaning weight	Price per kg (R)	Weaner price (R)	Gender percentage(%)	Average price per calf in herd (R)
210	41.5	8715	50	
210	38.5	8085	50	
				8400

Table 5 Calculation of average price per calf born through SSAI.

Weaning weight	Price per kg (R)	Weaner price (R)	Gender percentage (%)	Average price per calf in herd (R)
210	41.5	8715	90	
210	38.5	8085	10	
				8652

Based on the assumptions made (Table 4 and Table 5), if a 50% ratio of bull to heifer calves is considered, the average calf weaned will be worth about R8400 to the producer. In contrast, the average value of calves from sex-sorted semen (about 90% more heifers) will therefore increase to approximately R8652. Therefore, the average value of a calf will be R252 higher where sex-sorted semen is used. When calculating the income gained per calf sold, at 60% conception rate using traditional AI, a beef cattle producer would earn around R5738 after calf production cost have been deducted. In comparison, at the same conception rate, a beef cattle producer would earn around R5540 on average per calve. In this scenario, using SSAI would not be a financially better option to utilize within a breeding herd of a South African beef cattle producer as the value per calf decreases after calf production cost have been deducted. A sensitivity analysis has been done to calculate how much more income a beef cattle producer would make when 90% bull calves are produced through SSAI, compared to 50 percent through traditional AI. The sensitivity analysis calculates the income levels at various sexed semen straw costs as beef cattle producers should be aware that in different market conditions, the cost per sexed semen straw could fluctuate and is subject to change (Patra et al.,2023). While in the same scenario, two variables were kept constant which is the conception rate (70%) and the cost of unsexed semen straws (R100). Furthuremore, various weaning weights of bull calves were incorporated into the sensitivity analysis to see which weaning weights would make it financially viable for a beef cattle producer to utalise SSAI over traditional AI after production cost has been deducted. The calculation was done by calculating the gender value per calve for each method, where the weaning weight of heifer calves were kept constant (210 kg), while the weight of bulls varied from 200 kg-230 kg . Hendriks et al. (2021) and Patra et al. (2023) indicated that bull calves often weigh more than heifer calves, and the sensitivity analysis investigated how much more would a beef cattle producer earn per calve through SSAI if a certain weaning weight was obtained at various semen costs.

Table 6 Income comparison by producing a 90% bull calves through SSAI compared to traditional AI

		Weaning weight (kg)			
		200	**210**	**220**	**230**
Semen straw cost (R)	**200**	-R107	**R109**	**R275**	**R441**
	300	-R249	-R33	**R275**	**R299**
	400	-R383	-R176	-R10.50	**R96**
	500	-R535	-R319	-R153	-R47

Table 6 indicates that when a beef cattle producer produces a calve at weaning weighing 200 kg , irrespective of the semen cost, it would not be financially viable for the producer to continue with SSAI, and should rather continue with traditional AI. If the semen straw cost of sexed semen increased to R500 per straw, a producer would make R535 less per calve compared to using traditional AI. When the weaning weight of bulls increase to 210 kg, it will only be financially viable for the beef cattle producer to make use of SSAI when the cost per sexed semen straw is R200 as he would earn R109 more using SSAI compared to traditional AI. However at the same weaning weight off bull calves, when the semen straw cost increases the producer would earn less by using SSAI, with the better option being to continue with traditional AI. Seidel and DeJarnette (2022) observed similar price trends in the application of SSAI semen straws for calve breeding in the US. Important to note is that the optimal weight where more income is gained through SSAI compared to traditional AI is when a weaning weight of 230 kg per bull calve is obtained, and the market cost for sexed semen varies between R100-R400. At a 230 kg weaning weight, once the semen straw cost increases to 500 per straw a beef cattle producer would make a loss of R47 by using SSAI, and in such cases traditional AI should be utalised. These observations are in line with Walsh et al. (2021) who indicated that the cost of sexed semen is one of the key drivers of the financial viability of the breeding method.

4. Conclusion

From a farm management perspective, SSAI improves the quality of heifers bred, as cattle producers can inseminate genetically superior cattle with SSAI, to obtain replacement heifers that have certain traits that are favourable for high performing replacement heifers. This study developed a model which can be used beef cattle producers to determine the income to be generated based on the breeding method applied on the farm. This model allows beef cattle producers to adjust the variable inputs based on their breeding objectives and other on-farm costs. Breeding objectives could include breeding more heifers for replacement purposes of breeding more bulls with the intent of becoming stud bulls. With beef cattle producers having various breeding objectives regarding the desired sex of their offspring, where bull calves and heifer calves provide a difference in economic value gained by each calf. The utalisation of SSAI becomes a financially viable method of breeding for beef cattle producers with objectives of breeding more bull calves for the feedlot market. Increased weaning weights of approximately 230 kg per bull calve poses a great financial advantage for beef cattle producers as more income would be generated compared tonusing traditional AI. However, in the case of producing replacement heifers, given the of SSAI poses greater financial advantage as a higher income is generated per replacement heifer calve at various conception rates compared to using traditional AI. With precision management strategies becoming more crucial in driving farm profitability, it is of at most importance that South African cattle breeders apply precision techniques to ensure sustainable production AI, should be one of the breeding methods that are considered.

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IFMA24: Resilience through Innovation

DETERMINING THE POTENTIAL GAIN FROM IMPROVED GRAZING MANAGEMENT DECISIONS IN PASTURE-BASED DAIRY PRODUCTION SYSTEMS

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Academic Paper

Abstract

Climate influences pasture-based dairy production systems, underpinning variability in forage production throughout and between years. The potential pasture production lost from sub-optimal pasture management as farmers seek to manage their system in what can be variable pasture growth conditions, is unclear. Understanding potential gains in pasture utilisation from improved management in commercial farm situations could guide future efforts to address constraints. This study assessed how grazing management affects pasture production on south-eastern Australian dairy farms under variable conditions using climate data, a biophysical dairy model, commercial farm scenarios and stochastic simulation. The potential average gain from improved grazing management decisions was estimated to be up to AU$531/ha for a farm located in west Gippsland, Victoria. Even partial improvement could be beneficial given pasture-based dairy farms in the region are typically 100-200 hectares in size. The approach described here could be applied in other dairy production areas using locally relevant information to assess whether pursuing improvements in grazing management is economically worthwhile in different target environments. If the lack of information on pasture availability and likely growth patterns is a barrier to improving grazing management, digital pasture measurement technologies may have a role in addressing this gap.

Keywords: Pasture, Dairy, Grazing, Variability, Management, Decision-making

Introduction

Improving the productivity of agricultural systems is crucial for sustainable food production and the long-term economic viability of farming. The recent 'global roadmap' by the Food and Agriculture Organisation (FAO 2023) has set a target of increasing agriculture's total factor productivity by 1.7% per annum by 2050. Long-term total factor productivity growth for the Australian dairy industry falls short of this target, averaging an estimated 1.3% increase annually from 1978–79 to 2020–21 (ABARES 2023). Further increases in productivity on dairy farms are therefore important. Efficiency gains made on-farm will ultimately contribute to increased total factor productivity and benefit individual farm businesses seeking to be profitable.

In pasture-based dairy production systems, growing and utilising more forage on the available land area leads to efficiency gains and presents an opportunity for improvements in farm profit. While several factors that influence potential forage growth, such as soil type and climate, are outside farmers' control, management decisions can also influence the efficiency of these farm systems. For example, farmers choose when and how intensively pastures will be grazed and this will affect the amount of pasture grown relative to the potential for that year, and for subsequent grazing cycles. Farmers routinely make these decisions with little or no information and the variability in pasture growth within and between years can lead to difficulties in consistently implementing optimal management strategies.

Previous research suggests that sub-optimal grazing management routinely occurs in practice. For example, a New Zealand study focussing on perennial ryegrass-based pastures (McCarthy *et al.* 2014) found that 49% of pastures on dairy farms were grazed too soon according to leaf stage criteria; an indicator of the optimal time for grazing (Fulkerson and Donaghy 2001). Additionally, the recommended post-grazing residuals of 3.5-4.5 cm compressed height, equating to a pasture mass of 1500-1700 kg dry matter (DM)/ha, were not achieved on 48% of occasions (McCarthy *et al.* 2014). These metrics, relating to grazing timing and intensity, can affect subsequent growth of perennial ryegrass. For perennial ryegrass pastures in Canterbury, New Zealand, Chapman (2016) estimated a 12% greater regrowth annually when pastures were grazed at the 3-leaf stage compared to the 1.5-leaf stage. Similarly, 20% greater regrowth was measured in plots defoliated at the 3-leaf stage, rather than the 1.5-leaf stage in a 1-year simulated grazing experiment in Tasmania, Australia (Turner *et al.* 2015). Another experiment in Tasmania found that defoliating at the 2-leaf stage rather than the 3-leaf stage resulted in a 6% lower pasture production (Rawnsley *et al.* 2014). A further consideration associated with the timing of grazing is the impact on the nutritive value of the pasture. Grazing at earlier leaf stages can mean cows are consuming pasture with a higher nutrient density, although the potential nutritional benefit has been found to be outweighed by lower pasture DM yield and poorer persistence of pastures particularly when pastures were also defoliated to a low residual (Pembleton *et al.* 2017).

Both over- and under-grazing can reduce pasture regrowth, as demonstrated by the quadratic relationship between residual stubble height and pasture production established by Lee *et al.* (2008) who measured irrigated swards defoliated to 20, 40, 60, 80 or 100 mm in successive simulated grazing events over a 6-month period in Tasmania. In their study, total pasture production was 11% and 18% lower at the 20 mm and 100 mm residual stubble height treatments respectively, compared to the 60 mm treatment. In a grazing trial, Garcia and Holmes (2005) found a 20% lower herbage accumulation rate when pasture was grazed to <1300 kg DM/ha, compared to when residual pasture mass was 1500-2300 kg DM/ha. Results of these studies suggest there are likely to be tangible negative impacts when sub-optimal grazing occurs.

The short duration of field studies such as those described above are unable to account for variability in pasture growth over several years, limiting our understanding of the impact of sub-optimal grazing management in pasture growth years that differ from those studied and over time. Similarly, using average values as presented in Chapman (2016) may miss critical insights into on-farm impacts for individual years in highly variable pasture growth environments. There is evidence in both Australia and New Zealand that there can be substantial inter-annual variability in pasture growth (Chapman *et al.* 2009, Vogeler *et al.* 2016). In these environments, the prevailing conditions will affect how much potential pasture growth is possibly lost each year under sub-optimal grazing management. There is potential to use biophysical modelling as Chapman *et al.* (2009), Vogeler *et al.* (2016) and others have done and use the variability in growth detected in this type of analysis as the basis for further modelling to study the impact of sub-optimal grazing management practices over several production years.

A further aspect to consider when seeking to understand the impact of sub-optimal grazing management is the incorporation of commercial farming scenarios. An important finding from the McCarthy *et al.* (2014) study was that each farm in their study had instances where optimal grazing management regarding grazing timing and intensity did and did not occur. Of note, there were differences between farms in the frequency at which pastures were grazed too early, on time or too late and how often pastures were over or under grazed. Applying data collected on commercial farms regarding the incidence of achieving grazing targets for the timing and intensity of grazing alongside modelled data for a target environment may provide insight into what the realistic on-farm impact of sub-optimal grazing management could be.

The aim of this study was to establish the potential impact of grazing management decisions on pasture production on south-eastern Australian dairy farms under variable climatic conditions.

Materials and methods

1. *Study location and pasture growth simulations*

Accumulation rates of perennial ryegrass (*Lolium perenne* L.), the main species currently used in pasture-based dairy production systems in south-eastern Australia, were simulated for a 30-year period at Ellinbank, located in the Gippsland dairy region of Victoria, Australia (lat. -38.2456, long. 145.9347). Simulations were conducted in DairyMod (Johnson *et al.* 2008, Version 5.6.5) using historical patched point meteorological data obtained from the publicly available Scientific Information for Land Owners (SILO) database of Australian climate information (Jeffrey *et al.* 2001). Daily weather data from the database imported into DairyMod included minimum and maximum temperatures (°C), rainfall (mm), evaporation (mm), solar radiation (MJ/m^2), relative humidity (%), vapour pressure and potential evapotranspiration (mm). Within DairyMod, the soil, pasture and management parameters were defined. The default parameters for perennial ryegrass and soil parameters of medium organic matter and medium hydrology type were used. The simulation was run as a single-paddock simulation with non-limiting nitrogen fertiliser application. In the simulation, the paddock was assumed to be grazed when pasture reached 2.5 t DM/ha and grazed to a residual of 1.5 t DM/ha within a day. This aligns with the pre- and post- grazing targets used in Australian research studies (Clark *et al.* 2015, Thamaraj *et al.* 2008) and practical grazing management guidelines. Practical grazing management guidelines indicate that pasture utilisation reduces when pregrazing pasture masses go above 2.5 t DM/ha or canopy closure occurs (Fulkerson 2007). The recommended post-grazing pasture mass is approximately 1.5 t DM/ha for perennial ryegrass (Chapman *et al.* 2012).

Model outputs from 1st January 1993 to 31st December 2022, representing thirty years of simulated data, were used in subsequent analysis. Daily net positive pasture accumulation rates (kg/ha per day) were averaged for each month within each year. These values were used to generate monthly empirical input distributions to capture the variability between years. The input distributions were generated using the @Risk DecisionTools software (Version 8.4.0 Palisade Corporation, NY). The @Risk software was then used to conduct a Monte Carlo simulation involving 10,000 iterations, resulting in a range of possible pasture accumulation outcomes, represented as output distributions, on a monthly and annual basis.

2. *Estimating the effect of grazing timing on pasture growth*

The impact of continually grazing prior to the emergence of the third leaf was estimated using a similar approach to Chapman (2016). In common with Chapman (2016), our study used the data from Chapman *et al.*, (2012) to obtain the percentage of each leaf contributing to the total available pasture mass available at the next grazing following defoliation. However, our study used distributions of pasture accumulation rates as described above rather than using average accumulation rates. Leaf appearance intervals can vary according to light, temperature, water, and nutrient supply, which can all differ between years. As multi-year leaf appearance interval data for our study site was not available, proportions of the potential pasture grown were estimated according to the leaf stage the pasture was assumed to have reached prior to defoliation, and the contribution of this leaf stage to total pasture accumulation based on Chapman *et al.* (2012), (Table 1), The estimated proportions were applied to monthly pasture accumulation values to generate estimated growth in the month if pastures were consistently grazed at a 1.5, 2 or 2.5 leaf stage, rather than grazing at the 3-leaf stage.

Table 1: Estimated proportion of DM grown if pasture is grazed earlier than the 3 leaf stage assuming an average leaf appearance interval of 10 days

	Proportion of DM grown relative to potential at 3 leaf stage	
Leaf stage comparison	(all months except Oct-Nov)	(Oct-Nov)
1.5 v 3	0.85	0.95
2 v 3	0.9	0.975
2.5 v 3	0.96	0.99

3. Modelling the on-farm impact of sub-optimal grazing

Seven on-farm grazing management scenarios for Ellinbank, Gippsland were established based on data from McCarthy *et al.* (2014) on the frequency that pastures were grazed early, on target or late (based on leaf stage) and whether pastures were over-grazed, under-grazed or grazed to the recommended target on individual dairy farms in their study (Figure 1).

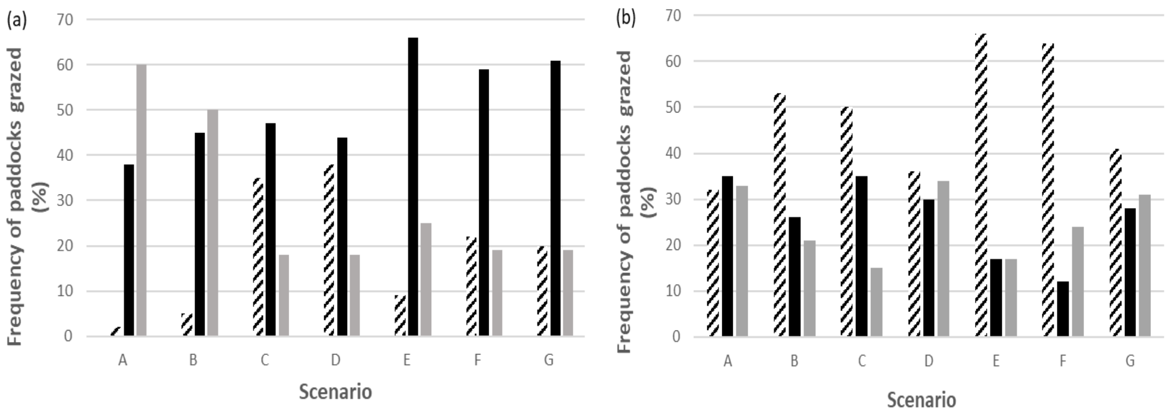

Figure 1: Frequency of paddocks (a) grazed at ≤ 2-leaf (diagonal lines), between 2 and 3-leaf (black) and ≥ 3-leaf regrowth stage (grey) and (b) where post-grazing herbage mass of pasture was <1500 (diagonal lines), 1500-1700 (black) and >1700 (grey) kg DM/ha for the 7 scenarios tested. *Adapted from McCarthy et al. (2014).*

The frequency that pastures were grazed early (≤ 2 leaf stage), on target (2-3 leaf stage) and late (≥ 3 leaf stage) on each farm in the McCarthy *et al.* (2014) study were applied to the corresponding monthly pasture accumulation estimates for that leaf stage in the Ellinbank environment. The compounding effect of grazing intensity was investigated by proportionally applying a potential pasture accumulation loss where pastures were over- or under- grazed for each scenario. As inconsistent effects of grazing intensity on pasture regrowth can be found in the literature (Lee *et al.* 2008), input distributions were defined for potential losses based on the range of results obtained in published field studies on dairy pastures in Australia (Garcia and Holmes 2005, Lee *et al.* 2008). These ranged from 0 to 20% and 0 to 18% loss for over-grazing and under-grazing respectively. Uniform distributions whereby there was equal probability that the regrowth loss following over or under grazing could take any value between 0 and the defined upper limit were used.

The seasonal economic values currently used in the Australian Forage Value Index (Leddin *et al.* 2018) for the Gippsland region were used to estimate potential economic losses from sub-optimal grazing. The economic values applied were 0.37, 0.41, 0.42, 0.35, 0.33 AU$/kg DM for summer (Dec-Feb), autumn (Mar-May), winter (Jun-Jul), early spring (Aug-Sep) and late spring (Oct-Nov) respectively (Dairy Australia 2024).

A simulation involving 10,000 iterations using the @Risk software was then used to generate output distributions of the potential impact of sub-optimal grazing.

Results

Effect of grazing timing on pasture production in the Ellinbank environment

In the Ellinbank environment, average annual pasture DM production based on 30 years of historical climate data and where optimal grazing management is assumed was estimated to be approximately 13,500 kg DM/ha/year with a standard deviation of 1,700 kg DM/ha/year (Figure 2). The average annual pasture grown decreased by an estimated 1,000 and 1,600 kg DM/ha/year if pastures were grazed at the 2- or 1.5-leaf stage respectively, rather than at the 3-leaf stage. The likelihood that pasture production in a single year was higher than 13,500 kg DM/ha was 49% under optimal grazing management but declined to 26% if consistently grazed at the 2-leaf stage and 14% at the 1.5 leaf stage.

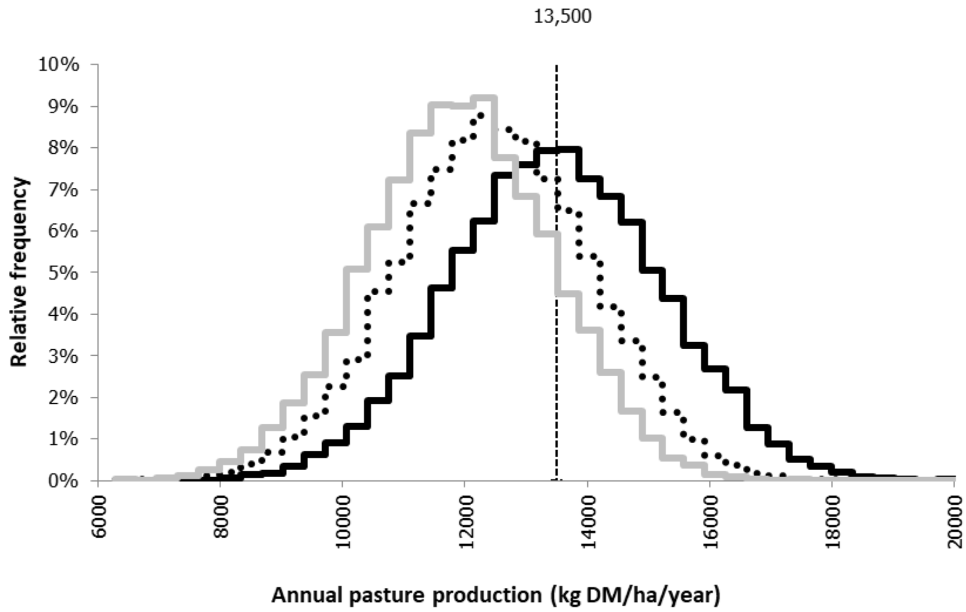

Figure 2: Distribution of pasture production in the Ellinbank environment under optimal grazing management (black solid line), where pastures are grazed consistently at the 2-leaf stage (dotted line) and where pastures are grazed at the 1.5 leaf stage (grey line).

Estimating the on-farm impact of sub-optimal grazing

The estimated average annual pasture production of the 7 Ellinbank scenarios (Table 2) was 600-900 kg DM/ha lower than the average pasture production of 13,500 kg DM/ha/year modelled under a variable climate and optimal management in the Ellinbank environment when grazing timing alone was included. Where grazing intensity was also included, pasture regrowth was estimated to be reduced by a further 400-700 kg DM/ha. Overall, the grazing management implemented in the scenarios tested resulted in an estimated 1100-1400 kg DM/ha/year lower annual pasture production than what could be achieved under more optimal management.

These decreases in pasture production reduced the likelihood that pasture grown above the estimated average of 13,500 kg DM/ha under optimal management in the Ellinbank environment, would occur (Table 2). The likelihood that pasture production would exceed 13,500 kg DM/ha was reduced by 12-21 and 25-32 percentage units where grazing timing only and grazing timing and intensity respectively were considered compared to what would be expected under more optimal management.

Table 2: Average pasture production and likelihood (%) of annual pasture production exceeding 13,500 kg DM/ha/year for each of the grazing management scenarios in the Ellinbank environment

Scenario	Average pasture grown (kg DM/ha/year) including effect of grazing timing only	Average pasture grown (kg DM/ha/year) including effect of grazing timing and intensity	Likelihood (%) of farm exceeding 13,500 kg DM/ha/year	
			Based on grazing timing	Based on grazing timing and intensity
A	12,900	12,200	37	21
B	12,700	12,100	31	18
C	12,700	12,100	31	17
D	12,900	12,200	36	20
E	12,600	12,200	28	20
F	12,600	12,100	29	19
G	12,800	12,400	35	24

Where grazing timing alone was considered, the average potential cost of sub-optimal grazing for the Ellinbank scenarios was estimated to be 208-346 AU$/ha. The scenarios that had the lowest incidence of grazing earlier (A, D and G) had the highest average pasture production of the 7 scenarios (Table 2) and therefore the lowest economic penalty for not consistently achieving the target timing for grazing (Figure 3). Scenarios A, D anfootd G also had less between-year variability in estimated economic loss compared to those where pastures were assumed to be grazed early (≤ 2 leaf stage) on more occasions.

The average cost of sub-optimal grazing when both grazing timing and intensity was included ranged from 418-531 AU$/ha. Although the average difference between scenarios was lower than when grazing timing alone was considered, the variability in outcomes between scenarios increased when grazing intensity was also included (Figure 3). The 2 scenarios with the largest variability between years (A and B) were those where high post-grazing residuals (>1700 kg DM/ha) occurred more often than the other scenarios. While the scenarios that achieved their target pasture masses post-grazing more often had the least between-year variability, this did not necessarily translate into the lowest average cost overall.

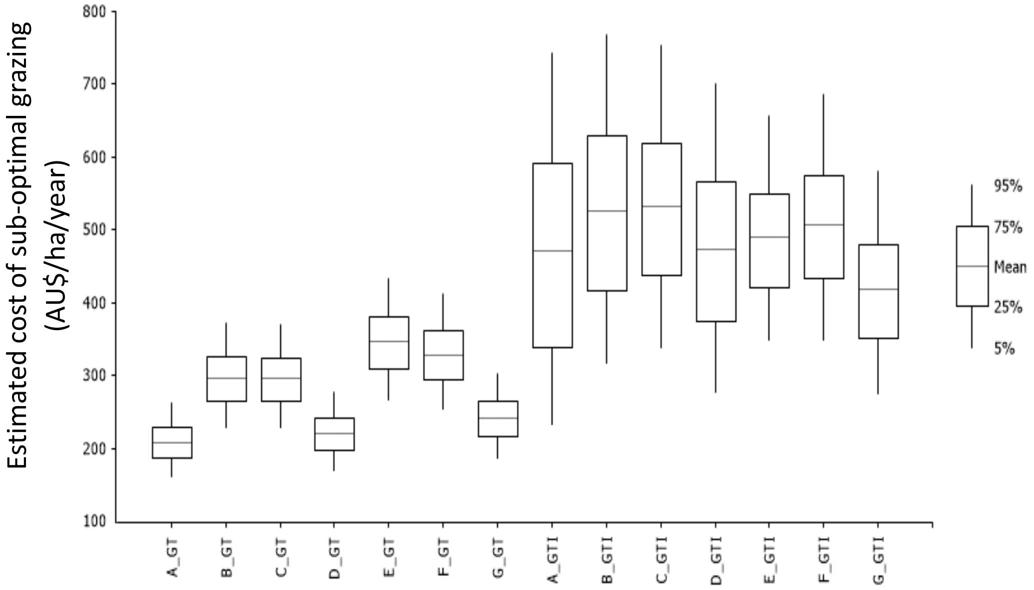

Figure 3: Estimated cost of sub-optimal grazing when grazing timing alone (GT) or grazing timing and intensity (GTI) were accounted for in the 7 test scenarios.

Discussion

In the analysis presented, annual pasture production ranged from 7,500 to 19,500 kg DM/ha indicating a wide range of variability in growth can occur in Ellinbank that is outside the control of the farmer. This aligns to the findings of Perera *et al.* (2020) who reported a 10 t DM/ha range in pasture DM yield in this environment between 1960 and 2015. In our study, 99.5% of annual pasture production values were in the range of 8,000-18,000 kg DM/ha reported by Perera *et al.* (2020).

When sub-optimal grazing management was imposed in the context of this variable production, initially via estimating pasture regrowth if pastures were continually defoliated at or prior to the 2-leaf stage, reductions in annual pasture production were predicted. On average, estimated annual pasture production was 1,600 kg DM/ha lower when pastures were assumed to be grazed at the 1.5-leaf stage compared to the 3-leaf stage. This was slightly less than the 2,000 kg DM/ha difference estimated by Chapman (2016) using a similar method for dairy pastures in Canterbury New Zealand and lower than the 3,000 kg DM/ha measured in a single year simulated grazing field study in Tasmania, Australia (Turner *et al.* 2015). The estimated annual average pasture production in our analysis was 4,000 and 5,300 kg DM/ha/year lower than

Turner *et al.* (2015) and Chapman (2016) respectively, which may partly explain the differences in magnitude observed.

Despite reductions in average annual pasture production, our study demonstrated that when pastures are grazed early, there would still be years where pasture production would be above the average estimated under optimum management. However, as expected, the likelihood of this decreased the earlier pastures were grazed.

The predictions of average lower annual pasture production by up to 1400 kg DM/ha/year in the test scenarios compared to the estimated optimum is considerable, particularly when scaled to a whole farm. For example, the size of farms in Gippsland surveyed in an industry benchmarking program for the region, range from 72-423 ha (Agriculture Victoria 2023). Even at the lower end of this range, up to 101 t DM/year could be foregone through suboptimal management, while a farm of 423 ha in the environment studied could forego 592 t DM/year. These estimates should be considered the upper bounds of what could be potentially foregone as the complexity of pasture-based dairy production systems may mean farmers cannot always achieve grazing management targets. Pastures may not be consistently grazed at what theory predicts is the optimum time or at the desired intensity for several reasons including balancing the needs of the pasture with the grazing cow (Wilkinson *et al.* 2020), the desire to 'transfer' pasture across seasons (Chapman *et al.* 2016) and implementing management for plant survival when pastures are waterlogged or in drought (Donaghy *et al.* 2021). However, the results suggest that improving grazing management to reduce the gap between current practice and the potential will have a tangible impact at the farm-level. The size of the impact will depend on a farm's individual circumstances. By simulating different but realistic combinations of grazing management practices in the same climate, our study demonstrated that decisions made about the timing and intensity of grazing events could have different economic consequences. The differences were both in the estimated value of pasture foregone though sub-optimal management and the variability between years. According to these findings, improving grazing management could assist farmers in maintaining or increasing the profitability of their pasture-based dairy production systems.

The approach we have used could also be applied to perennial ryegrass-based systems in other dairy environments. Farmers and their advisors could assess the frequency at which targets for grazing timing and intensity are achieved on their farm and how much this could be adversely affecting pasture growth in their environment. If the expected reduction in pasture production from current management is deemed to be significant enough, strategies to overcome the barriers to improving grazing management on their farm should be explored. There may be a case to seek more pasture measurement data to better inform management decisions. Emerging digital pasture measurement technologies offer the prospect of providing farmers with the information they need at the desired frequency for decision-making. If pasture measurement information influences decisions that result in an increase in the number of times grazing management targets are met, results of this study suggest there are benefits to be gained. This aligns with the findings of Beukes *et al.* (2019) who reported improvements in the profitability of New Zealand dairy farms when farmers assessed their pastures regularly.

Conclusion

The potential average gain from improved grazing management decisions in the Ellinbank area of Gippsland, south-eastern Australia was estimated to be up to AU$531/ha. If farmers could capture even part of this improvement, it would be beneficial to their farm systems as pasture-based dairy farms in the region are typically 100-200 hectares. Farmers and their advisors could be guided by the approach used here to test whether there may be opportunities in their unique circumstances to enhance their grazing management in an economically beneficial way. If the lack of information on the status of pastures is an identified barrier to improving grazing management, digital pasture measurement technologies may have a role in addressing this gap if the benefits outweigh the costs.

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IFMA24: Resilience Through Innovation

RESILIENCE, PRODUCER SENTIMENT, AND RELATED FARM CHARACTERISTICS

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Abstract

At the 2024 Purdue Top Farmer Conference, a survey exploring farm resilience, producer sentiment, and growth expectations was conducted, yielding insights into the perspectives of America's leading farmers. This study compares survey responses from 52 agricultural producers from the Top Farmer Conference, against national surveys using identical survey instruments. Analysis of the survey data is performed using t-tests and correlation coefficients to test associations between resilience, growth expectations, and sentiment among attendees compared to national respondents. Top Farmer Conference participants displayed a more optimistic outlook on the agricultural economy and higher expectations for farm growth. Attendees display similar resilience levels to the national averages, despite lower diversification, suggesting these producers choose to use specialization as an intentional business strategy. Despite lacking direct measures of risk preference and managerial abilities due to the survey's condensed nature, predictive classification models estimate these attributes, suggesting superior managerial skills among conference attendees, but not significantly higher levels of risk aversion. This research highlights the interaction between resilience, producer sentiment, and farm growth expectations for leading agricultural producers. Estimates of managerial acumen and risk preference provide further depth to comparisons of Purdue Top Farmer Conference attendees to the average U.S. producer.

Key Words: producer sentiment, resilience, Top Farmer Conference

Introduction

Each year in early January, Purdue University hosts the Top Farmer Conference where academic speakers, agribusiness affiliates, and farmers convene to discuss current issues and trends in agricultural markets. Discussion at this year's conference included an outlook of the U.S. economy, developments of biofuel markets and their impact on production agriculture, corn and soybean outlooks, and policy implications of the forthcoming 2024 Farm Bill. In addition to these discussions, participants at this year's conference were invited to complete a brief survey assessing farm resilience, producer sentiment, and farm growth expectations.

Using survey instruments identical to those used to assess producer sentiment in the Purdue-CME Group Ag Economy Barometer, and those used to assess resilience and farm growth in Lippsmeyer et al. (2024), producer responses from the Top Farmer Conference were compared to responses from a national survey. The conference had 230 attendees, 118 of which attended in-person and the remaining 112 participated online. A total of 52 completed survey responses from agricultural producers were collected at the conference with an additional 31 non-producer responses collected, but not used in this analysis as their responses likely are not reflective of farmer's perceptions. T-tests are used to identify differences in mean survey responses between results from Lippsmeyer et al. (2024) and producer survey responses from the Top Farmer Conference. Further comparisons examine correlation coefficients between resilience, farm growth, and producer sentiment, assessing whether associations between variables are stronger or weaker for Top Farmer Conference attendees than those identified in the national surveys.

Lippsmeyer et al. (2024) investigates the interaction between producer sentiment, farm resilience, risk preference, managerial ability, and farm growth expectations, uncovering statistically significant relationships among these variables. Findings reveal that producers characterized by higher resilience levels also possess more ambitious growth expectations for their farms and maintain a more optimistic outlook on the agricultural economy. Furthermore, resilient producers exhibit a greater propensity for risk-taking and demonstrate superior managerial skills.

Because the survey instrument used for the Top Farmer Conference was a condensed version of the original survey, questions on risk preference and managerial abilities were not included. Although this data is lacking, by implementing predictive classification models using data from the strategic risk survey implemented in Lippsmeyer, et al. (2024), we predict producer risk preferences and managerial abilities for Top Farmer Conference participants. Two classification algorithms, a multinomial logistic regression and a random forest model, are implemented and compared to ensure robustness of results.

The survey respondents from the 2024 Purdue Top Farmer Conference, though not a random sample, offer unique insights into how some of America's leading farmers compare to respondents of national surveys. We expect conference attendees are better managers, have more optimistic sentiment, higher resilience, and lower risk aversion than producers in Lippsmeyer et al. (2024). Survey data and results of predictive modeling are used to test these hypotheses.

Producer Sentiment

The Purdue University – CME Group Ag Economy Barometer is a nationwide measure of the health of the U.S. agricultural economy. The index is comparable to the University of Michigan Consumer Sentiment Index, but is specified to measure sentiment toward the agricultural economy rather than broader economic conditions felt by U.S. households. Each month, the Ag Economy Barometer uses index values to assess the health of the aggregate agricultural economy, producers' sentiment towards current conditions, and sentiment towards the future of the agricultural economy. While results are particularly insightful for domestic producers, fluctuations in Ag Economy Barometer values may also be indicative of broader economic pressure on U.S. agricultural producers. Questions included in the barometer focus on farm profitability, farmland values, key commodity prices, seed, fertilizer, and feed ingredient prices – all of which are heavily influenced by global market conditions, thus making results relevant to global market participants and researchers.

In December 2023, the Ag Economy Barometer recorded a reading of 114, with the Index of Current Conditions slightly lower at 112 and the Index of Future Expectations slightly higher at 115 (Mintert and Langemeier, 2024). For comparison, the highest value for the Ag Economy Barometer was 183 in October of 2020 while the lowest was 85 in March 2016. The sentiment spike in October of 2020 was attributed to a combination of high commodity prices amid record yields and government program payments from the second round of CFAP payments (Mintert and Langemeier, 2020). The Index of Current Conditions showed similar trends with the highest reading of 202 in Winter of 2020 and the lowest reading of 72 in April of 2020, directly after the onset of the COVID-19 pandemic. The highest value for the Index of Future Expectations was 186 during October of 2020 and the lowest was 89 in March of 2016.

The Farm Capital Investment Index gauges producer perceptions of the suitability of the current time for making large farm investments including purchasing machinery or updating buildings. In December 2023 the index stood at 43, changing only by one point compared to the previous month. The average value of the Farm Capital Investment Index over the past five years has been 52, which suggests that producers believe it has been a relatively unfavorable time to make large farm investments. The highest value of the Farm Capital Investment Index was 93 in Winter of 2020 (when the federal funds rate was approximately 0.09%). Since March 2022 when the Fed began its series of 11 interest rate hikes, the Farm Capital Investment Index has ranged between 31 and 45 with the lowest reported value of 31 points in September 2022, November 2022, and most recently in April 2024.

In contrast, the Farm Capital Investment Index for Top Farmer Conference attendees reported a value of 66. So, while respondents believed the current period might not be ideal for large farm investments, Top Farmer Conference attendees were significantly more optimistic compared to their counterparts in the nationwide survey, even more so than most producers have been over the past five years. Similar trends were also apparent for the Ag Economy Barometer Index with a reading of 139 and the Index of Current Conditions at 191 for Top Farmer Conference participants.

There are several potential explanations for this disparity in producer sentiment. First, higher sentiment, particularly for the Index of Current Conditions, may be due to the higher-than-expected corn and soybean yields across the Midwest, particularly in Indiana and Ohio, despite early-season drought conditions. Drought conditions were present throughout Indiana between May and August 2023 (National Drought Mitigation Center, 2023), but yield reports from the 2023 season show record high yields for both corn and soybeans (USDA NASS, 2024). Since the conference attendees are predominantly from the Midwest, their sentiment following a comparatively successful season is much more positive than that of producers who experienced less favorable growing conditions in 2023. Other possible explanations include some degree of selection bias associated with the sample from the 2024 Purdue Top Farmer Conference. Rejesus, et al., (2008) find that younger producers as well as those that are more risk seeking, more educated, and have larger farming operations tend to prefer receiving information from either risk management experts or marketing clubs/other farmers. Further research finds similar results that less risk averse producers often engage more cooperatively and join producer groups (Sulewski & Kłoczko-Gajewska, 2014). In corroboration with our survey results, these conclusions provide reason to assume conference attendees, who have actively chosen to engage in an interactive setting with peers and professionals, may have lower risk aversion, higher educational attainment, and have larger farms. Moreover, an implicit understanding of the farming operations of conference attendees through interaction suggests larger farm size and higher income levels may influence sentiment levels. These differences likely buffer producer sentiment of conference attendees relative to the national producer sentiment levels reported in the December 2023 Ag Economy Barometer survey.

Table 1: Producer Sentiment – The Ag Economy Barometer

	December 2023 Nationwide Survey n = 401	**January 2024 Top Farmer** n = 53	**t-test** P-value
Ag Economy Barometer Index	114	139	0.041
Indices of Current Conditions	112	191	0.000
Indices of Future Expectations	115	113	0.830
Barometer Questions			
Would you say that your farm operation today is financially better off, worse off, or about the same compared to a year ago?			
Better Off	14%	45%	0.000
Worse Off	44%	19%	0.000
Do you think that a year from now your farm operation will be better off financially, worse off, or just about the same as now?			
Better Off	16%	21%	0.397
Worse Off	29%	42%	0.098
Turning to the general agricultural economy, do you think that during the next twelve months there will be good times financially, or bad times?			
Good Times	22%	11%	0.025
Bad Times	56%	49%	0.377
Do you think it is more likely that US agriculture during the next five years will have widespread good times or widespread bad times?			
Good Times	31%	30%	0.856
Bad Times	44%	36%	0.276
Thinking about large farm investments – like buildings and machinery - generally speaking, do you think now is a good time or bad time to buy such items?			
Good Times	15%	21%	0.351
Bad Times	72%	55%	0.020

Resilience to Strategic Risk

Resilience to strategic risk reflects a farm's capacity to adapt to changes and endure adverse market conditions, namely those that alter business strategy. Our survey asked a series of six questions aimed at assessing resilience via a farm's agility and absorption capacity. These questions were adapted from Sull (2009) and ask about the use farm financial metrics, diversification, balance sheet strength, routine procedures, goals and objectives, and assessing new opportunities.

Agility and absorption capacity are often viewed as two distinct strategies through which farm managers build resilience to strategic risk. Agility encompasses a farm’s ability to spot and exploit changes in the market in a timely fashion and absorption is the ability to withstand changes or shocks in input and output markets (Sull, 2009). At the Purdue Top Farmer Conference, resilience to strategic risk was confirmed to be of significant interest, with 98% of survey respondents expressing either moderate or high interest in learning more about strategic risk, the impact of strategic risk on their operations, and strategies for building farm resilience.

In April 2023, the Purdue Center for Commercial Agriculture (CCA) conducted a nationwide survey to better understand the average commercial producer's resilience to exogenous market shocks. Supplemental questions pertaining to farm characteristics were also posed. Survey results were used to assess producer resilience levels on a nationwide basis. At the Purdue Top Farmer Conference, the same survey questions were posed to assess the resilience levels of attendees, yielding strikingly similar results (Table 2). Statistical tests comparing the resilience of the two groups found the aggregate measures of resilience to be virtually identical. However, nuanced differences are apparent when resilience is broken down by component survey question. The most notable discrepancies were observed in responses regarding farm diversification and balance sheet strength.

From the April 2023 survey, 55% of respondents reported that their farm enterprises were more diversified than five years ago. In contrast, only 42% of Top Farmer participants indicated increased diversification in their enterprises over the past five years. Farm diversification is considered a key metric for resilience, as it reduces reliance on any single enterprise. By diversifying, farms reduce dependence on any singular revenue stream, thus reducing risk from any given enterprise. Yet, specialization remains an attractive business strategy for many, containing greater risk, but boosting opportunities to garner economies of scale and increase profit margins. The lower diversification rate among Top Farmer Conference participants was relatively unsurprising given that attendees were primarily Midwestern farmers, specializing in corn and soybean production.

Given that resilience scores are cumulative, and diversification was lower for Top Farmer participants, yet overall resilience levels were consistent across groups, it was apparent these producers excelled in another metric of resilience. That metric was financial performance, measured by balance sheet strength. Notably, 100% of attendees at the Purdue Top Farmer Conference indicated they had a strong balance sheet in a self-assessment question.

Table 2: Resilience to Strategic Risk

Resilience to Strategic Risk	**April 2023 Nationwide Survey** n = 403	**January 2024 Top Farmer** n = 52	**t-test** P-value
Our farm has established goals, objectives, and core values.			0.397
Strongly Agree	36%	23%	
Agree	54%	58%	
Disagree	9%	19%	
Strongly Disagree	2%	0%	
Our farm looks for opportunities that new enterprises may provide.			0.066
Strongly Agree	32%	27%	
Agree	51%	58%	
Disagree	14%	13%	
Strongly Disagree	3%	2%	
We regularly assess our advantages and disadvantages compared to other farms.			0.000
Strongly Agree	19%	23%	
Agree	51%	45%	
Disagree	24%	30%	
Strongly Disagree	5%	2%	
We have low per unit fixed costs relative to our most efficient competitors.			0.129
Strongly Agree	18%	9%	
Agree	54%	57%	
Disagree	22%	32%	
Strongly Disagree	6%	2%	
Our farm enterprise is more diversified today than it was 5 years ago.			0.748
Strongly Agree	20%	2%	
Agree	35%	40%	
Disagree	36%	53%	
Strongly Disagree	9%	6%	
We have a strong balance sheet.			0.685
Strongly Agree	39%	50%	
Agree	51%	50%	

	Disagree	7%	0%	
	Strongly Disagree	3%	0%	
Cumulative Resilience to Strategic Risk				
	Low (6-15)	15%	17%	0.705
	Medium (16-20)	68%	70%	0.817
	High (21-24)	17%	13%	0.471

Farm Growth Expectations

In conjunction with questions on resilience and producer sentiment, participants were asked about their annual farm growth expectations. Responses to this question from Top Farmer Conference attendees were compared to responses from the Purdue CCA resilience survey (Table 3). Of respondents, 11% from the nationwide survey indicated plans to reduce farm size, 34% intended to maintain their farm size, and 55% aimed to grow their operations in the next five years. Of the 55% expecting to grow their operation over the next five years, 42% expect to grow their operations up to 10% annually, and 13% expect to grow at a rate greater than 10% annually. In contrast, at the Top Farmer Conference, a mere 2% of participants planned to reduce the size of their farms, 23% intended to maintain their current size, and 75% planned to expand their operations in the coming five years. Of the 75% expecting to grow their operation over the next five years, 62% expect to grow up to 10% annually, and 13% expect to grow at a rate greater than 10% annually. These trends show that not only do producers attending the Top Farmer Conference exhibit a greater propensity to continue farming, but a significantly larger proportion of this group expects to their operation's size to grow compared to counterparts in the nationwide survey.

There is some debate regarding plausibility of growth rates for farms expecting to grow greater than 10% annually over the next five years, as these goals are particularly ambitious. However, growth to these magnitudes is not unheard of in U.S. agriculture, as seen with consolidation and growth of hog production between 1997 and 2017 (Davis, et al., 2022, p. 5). Growth in farm size for crop producer has been consistently reported on various Census of Agriculture reports, with large farms accounting for a greater percentage of U.S. farm value of production through time (MacDonald & Hoppe, 2018). The degree to which farms are growing remains uncertain as data is not publicly available at the farm level. However, from the survey data in Lippsmeyer et al. (2024) the 13% of farms expecting at least 10% growth annually have on average 1,730 acres in crop production (with the largest farm operating approximately 14,400 acres). These farms are clearly representative larger farms, begging the question of if U.S. production agriculture is on the same consolidation trajectory as seen in domestic hog production – with the largest farms progressively getting larger. While we do not aim to draw any conclusions regarding farm growth or consolidation in U.S. crop production, rather provide discussion of plausibility of such high growth rates for a subset of U.S. commercial producers. These shifts are likely attributable to larger businesses having lower "payout" percentages, thus higher savings retention rates and higher sustainable growth rates (Boehlje, 2013).

Table 3: Farm Growth Expectations and Identification of Risk Sources

Farm Growth	**April 2023 Nationwide Survey** n = 403	**January 2024 Top Farmer** n = 52	**t-test** P-value
What is the planned annual growth rate you have for your farm over the next 5 years?			
Growth (10%+)	13%	13%	0.912
Growth (Up to 10%)	42%	62%	0.006
Maintain	34%	23%	0.238
Reduce Size	11%	2%	0.000
Identification of Risk Sources			
Which of the following risks would you say is most threatening to your operation? (Check up to two items)			
Financial Risk	25%	12%	0.005
Legal Risk	7%	3%	0.109
Marketing Risk	26%	32%	0.939
Production Risk	20%	16%	0.015
Strategic Risk	5%	13%	0.659
Human Risk	17%	23%	0.000

Methods for Predictive Classification

In addition to evaluating resilience, farm growth, and producer sentiment, the April 2023 nationwide survey inquired about farm management practices and risk preferences, uncovering positive correlations among these characteristics (Lippsmeyer, et al., 2024). Due to the abbreviated nature of the survey conducted at the Purdue Top Farmer Conference, it was not possible to directly measure producer managerial abilities and risk aversion. To compensate for this limitation, predictive classification models were developed, utilizing data from the April 2023 survey. Random forest and ordinal logistic regression classification models were used to estimate the most likely managerial ability and risk aversion for respondents (Kuhn and Johnson, 2016). These predictive models, calibrated using the April 2023 survey data, were employed to estimate the managerial abilities and risk preferences of the Top Farmer Conference attendees.

To assess validity of the classification models, we test model accuracy by dividing the count of correct predictions for the model divided by the total count of predictions (Baldi, et al., 2000). Accuracy levels exhibited variation by model iterations. Each model was run a total of 500 iterations to obtain representative metrics. Average accuracy levels for predicting risk preference were 0.33 and 0.30 for the ordered logistic regression and random forest model, respectively. Average accuracy of managerial ability was slightly lower, with 0.24 for the ordered logistic regression and 0.17 for the random forest model. The low accuracy observed in the predictive models can be attributed to the complexity of the dependent variable, which is characterized by Likert scales with seven discrete levels. This range of outcomes presents a significant challenge in forecasting each individual level accurately, thereby affecting the model's overall predictive efficacy. However, even though marginal differences between one level and the next are difficult to discern, the predictions are likely still valid for generalizing low versus high managerial abilities.

Results

Lippsmeyer et al. (2024) document the existence of statistically significant, positive relationships between producer sentiment, farm growth expectations, and farm resilience. Analogous relationships are apparent in the Top Farmer Conference survey data, with larger magnitudes (Table 4). These relationships present varying degrees of statistical significance across correlation coefficients, likely attributable to the limited sample size.

Table 4: Correlations Across Variables – Kendall's Tau

April 2023 Nationwide Survey n = 403		
	Producer Sentiment	Farm Resilience
Farm Resilience	0.071*	1
Farm Growth Expectation	0.089**	0.199***
January 2024 Top Farmer n = 52		
	Producer Sentiment	Farm Resilience
Farm Resilience	0.145	1
Farm Growth Expectation	0.159	0.214*
Significance Levels: p < .01 '*' p < .05 '**' p < .1 '*'**		

Results from both predictive modeling strategies—random forests and ordered logistic regression—suggest that the managerial capabilities of producers who attended the Top Farmer Conference were superior to those of producers included in the nationwide survey (Table 5). Predictive results display some spread but draw a consensus that a notably smaller proportion of producers are expected to possess below-average managerial abilities.

Olsson (1988) explores the synergies among managerial ability, farm performance, and risk preference, suggesting that these characteristics frequently co-vary, with the poorest managers often having the most risk averse attitudes. Producers characterized by avoidance of risk, insufficient reinvestment in the farming operation, and rundown operation which have used up productive resources are labeled "defensive strategists" (Olsson, 1988). However, there also exists a subset of producers with the lowest levels of risk aversion (most risk seeking) which still exhibit poor farm performance. These producers are categorized as "gamblers" and often take on excessively risky investments while failing to fully consider the implications of such risks adequately, are poor managers, and often end up bankruptcy (Olsson, 1988). Modeling outcomes predict that producers from the Top Farmer Conference exhibit both a lower incidence of strong risk aversion (between 0% to 1%) and a relatively small proportion predicted to show the most risk-seeking behavior compared to respondents from the nationwide survey.

Table 5: Predictive Estimates – Managerial Ability and Risk Preference

	April 2023 Nationwide Survey n = 403	**January 2024 Top Farmer** n = 52	
		Ordered Logit	**Random Forest**
How would you rate your attitude towards risk?			
Strongly Risk Averse	11%	0%	1%
Moderately Risk Averse	61%	95%	86%
Slightly Risk Averse	28%	5%	13%
Managerial Ability			
Below Average	13%	0%	4%
Average	61%	88%	67%
Above Average	26%	12%	29%

Conclusions

This analysis has compared and contrasted producer sentiment, resilience, and farm growth expectations between attendees at the Purdue Top Farmer Conference and respondents to nationwide surveys of commercial agricultural producers. Comparisons across producer groups are made using t-tests and correlation coefficients.

Producer sentiment of Top Farmer Conference attendees had significantly more optimistic readings, with the Index of Current Conditions at 191. In comparison, the nationwide Index of Current Conditions for December of 2023 (just a few weeks prior) was 115. These results indicate that producers at the Purdue Top Farmer Conference had much more optimistic outlooks towards the state of the agricultural economy.

Differences in the Farm Capital Investment Index were also apparent between groups, with an index value of 66 for attendees at the Top Farmer Conference December 2023, versus the nationwide December 2023 index value of 43. Based on index values, producers at the Top Farmer Conference have much more positive perceptions of the suitability of the current time for making large farm investments. Similar trends were apparent for farm growth expectations, with 75% of producers at the Top Farmer Conference expecting to grow their operation over the next five years, versus only 55% of producers expecting to grow their operation based on responses from the nationwide survey.

Aggregate resilience levels were uniform across groups, which was somewhat surprising considering Lippsmeyer et al. (2024) finds resilience and producer sentiment are positively correlated. The primary driver behind this result is lower diversification levels among conference attendees. Although diversification is a recognized risk mitigation strategy, pursuing specialization can also serve as a deliberate business tactic. Specialization has the potential to reduce fixed operational costs, augment production efficiencies, and bolster profitability. Consequently, a marginal reduction in resilience might be considered an acceptable compromise by producers, who opt for a business strategy that embraces higher risk in exchange for the prospect of increased returns.

Managerial ability and risk aversion were also shown to be related to producer sentiment, growth, and resilience in Lippsmeyer et al. (2024). Using survey data from Lippsmeyer et al. (2024) predictive models were developed to estimate managerial ability and risk aversion levels for attendees at the Top Farmer conference.

Predicted outcomes provide further insight into these producer's characteristics and competencies relative to those from the nationwide sample. Model estimates predict that most producers are unlikely to show the highest levels of risk aversion or the lowest levels of managerial ability. This would suggest that fewer producers who attended the Top Farmer Conference are likely to be categorized as "gamblers" or "defensive strategist" by Olsson (1988), nor exhibit pitfalls commonly associated with either.

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IFMA24: Resilience through Innovation

ECONOMIC CONSEQUENCES OF UPGRADING ANIMAL WELFARE STANDARDS IN THE EUROPEAN UNION ON THE EXAMPLE OF THE BAN ON THE USE OF FARROWING CRATES IN PIG PRODUCTION

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Abstract

The main objective of this study is to evaluate the economic effects of the proposed EU pig breeding ban on the usage of farrowing crates. Selected EU Member States' agricultural surveys and expert consultations served as the foundation for the impact evaluation. Four scenarios were used to further aggregate the data to determine the sectoral impact on the EU-27. Results indicate, that the EU's restriction on farrowing crates is predicted to have a negative impact on sow population and piglet output since it will increase the need for sow space, impair production efficiency, and require a substantial amount of investment.
The switch to alternative farrowing systems will result in increased variable costs during the farrowing stage. The lower density, caused by the higher space allocation per sow in free farrowing systems (6.5m2 in free farrowing with temporary confinement and 7m2 in systems without confinement), will cause fixed expenses to rise proportionally to the drop in the sow herd. The installation of free farrowing and reconstruction of existing buildings. Depending on the scenario studied, investment costs range between EUR 3.5 and 6.2 billion, indicated in 2021 values.

Key words: EU pig production, farrowing crates, free farrowing systems, phasing out cages, animal welfare, economic consequences

1

Introduction: Due to the social pressure represented by the 'End the Cage Age' Initiative in Europe, there is an ongoing discussion at the level of the European Commission and in EU Member States about the possibility of raising animal welfare standards beyond the level set in the current legislation (2008/120/EC Council Directive) (European Commission 2012, 2021). This study focuses on the anticipated changes to the EU's animal welfare regulations, particularly the introduction of a ban on the use of cages in livestock production. This ban is expected to be a response by the European Commission to the 'End the Cage Age' Initiative (European Commission, 2023). The amendment of the current animal welfare legislation, as outlined in 2008/120/EC Council Directive, will incorporate new legislative provisions proposed by the EU Commission. The proposed ban on the use of cages in EU livestock farming will include a transition period, the duration of which will be determined, following the re-lease European Food Safety Authority (EFSA) (Rojek, 2023) opinion, expected in 2024.

Sweden has already completely banned the use of farrowing crates, becoming the first and only Member State to do so since 1994, in advance of new legislation. Another nation where the argument resulted in legislation was Austria, which in 2012 instituted minimum space limitations for sows that exceeded EU regulations. By 2033, Austria wants all sows to be housed in free-farrowing cages that are at least 5.5 m2 in size, with a maximum 5-day confinement period following farrowing. In Germany and Denmark, similar discussions have occurred. In Germany, the sow-confinement period was decided to be reduced to a maximum of 5 days after farrowing in 2019 (with a 15-year transition period), with a minimum space requirement of 6.5 m^2 area.

There is a substantial body of literature (as presented in Potori et al. 2023) discussing the technical performance and economic efficiency of free-farrowing systems. The results are sometimes ambiguous and case-specific, but a majority indicate the lower performance of free-farrowing systems (e.g., higher mortality of piglets, lower number of litters, higher culling-out percentage of sows, higher feed intake, and higher costs) compared to crate-based solution. At the same time, there is a lack of complex analyses of the economic results for switching to the free pig farrowing systems across different countries. We intend to fill in this gap.

Methodology:

The impact assessment was carried out in three stages: 1) farm-level analyses based on farm surveys and expert consultations in selected EU Member States; 2) scenario analysis which included 4 alternative scenarios; and 3) aggregation (scaling-up) of the scenario analysis into the EU-27 sectoral impact.

The survey was carried out using a variety of approaches, including online or paper questionnaires, in-person or phone interviews. The major purpose was to collect data that characterised the pig farrowing segment of the production system, as well as to understand farmers' intentions and preferences for alternative free-farrowing methods. Farmers can now announce an 'exit' from pig production or transfer to pig fattening.

Initially, the survey was supposed to be performed in all 27 member states of the EU. However, after evaluating the EU pig industry statistics, countries with a tiny, less than 0.3% part of the EU sow herd (Cyprus, Estonia, Luxembourg, Malta, Slovakia, and Slovenia) were taken out, as was Sweden, which has entirely transitioned. The questionnaire was distributed through farmer organisations.

The results of the farm survey served as a foundation for the assessments, which were further enriched by additional data and information gathered from various sources, including review of the literature on the efficiency of different farrowing systems, data from farmers' organizations in the EU Countries, opinions from a group of pig production experts representing Wageningen University (Netherlands), the InterPIG global network, and Warsaw University of Life Sciences (Poland), as well as pig production companies experienced in transition.

The reference serving as the basis for all comparisons was a housing system with farrowing crates at the current space at the farm (every farm has a bit different space allowance in farrowing pen. The alternative housing systems considered were: free farrowing pen **with temporary confinement** (up to 5 days) and **6.5 m^2 space allowance**; free farrowing pen with **no confinement** and **7 m^2 space allowance**. In the survey, farmers were offered the choice to transition into pig fattening or to announce their withdrawal from pig production (Exit).

Key parameters used for the assessments, with values for existing systems with farrowing crates = 100%, included:

- piglet mortality: +15% (in free farrowing pen 6,5m^2 with confinement), and +20% (in free farrowing pen 7 m^2 with no confinement);

- number of litters per sow/year: -1.9%;
- mortality of sows: +5%;
- culling-out percentage: +15%;
- feed consumption during the lactation period (28 days): +7.3%;
- labour input: +1 minute/sow/day during lactation in system with confinement, +2 minutes/sow/day in system with no confinement;
- Veterinary-medicine costs: +7.5%;
- average basic cost of new farrowing pen: EUR 1700, with a depreciation period of 15 years, plus the costs of reconstructing existing buildings, averaging to EUR 1800 per pen, but depending on the scenario and the region (EU-East/EU-West), ranging from EUR 1623 to EUR 2146, depreciated over 25 years;
- depreciation of the existing buildings in 25 years.

All 4 scenarios depict a hypothetical situation following the transition to alternative housing systems. The scenarios are described below:

Baseline – using CRATES: assumes piglet production with the use of farrowing crates based on technical and production parameters from the farm survey.

Scenario S1 conf: "All farms move into the free farrowing system with temporary confinement". In this scenario it is assumed that all farms in the sample will stay in production, and all will switch into the free farrowing system with temporary confinement [pen size 6.5m2].

Scenario S2 no-conf "All farmers will move to a free farrowing system with no-confinement". In this scenario it is assumed that all farms in the sample will stay in production, and all will switch into the free farrowing system with no confinement [pen size min. 7m2].

Scenario S3 exit "All farm declarations of a switch to alternative housing systems were included". In this scenario all declarations regarding farmers' decisions were taken into account (see table 1). Considered options were: 1) switch to free farrowing system with temporary confinement; 2) switch to the free farrowing system with no confinement; 3) switch to production of fatteners only; 4) resigning from pig production (the respective number of sows was removed from the sample).

Scenario S4 modified "Farm declarations to alternative housing systems were MODIFIED". It is highly possible that several farmers who declared their intention to leave, did so because they were frustrated by the anticipated regulatory changes. The more

4

in-depth examination of the group of farmers who made these assertions supports such a conclusion. Therefore, in this scenario, we 'modified' initial declarations from scenario S3, assuming that, in reality, the decisions will be more rational and the number of 'exits' will be less than declared in the survey (see table 1). Declarations of shifting to free farrowing or pig-fattening remained unchanged compared to Scenario S3. Only farm exits were rationalised.

Table 1. Farmer declarations of the transition path under the scenarios S3 and S4 [expressed in % of sows herd affected – not the number of farms*]

	Switch to free farrowing with confinement 6.5m^2	Switch to farrowing system with no-confinement 7m^2	Switch to Pig Fattening	Exit from production
$S3_{exit}$	60.2%	4.3%	5.1%	30.4%
$S4_{modified}$	94.5%	4.3%	0.3%	0.8%

* The percentage of farm declarations to resign was much higher than the corresponding percentage of sows affected by these decisions. This is because farmers who declared exits were mostly from small farms.
Source: authors' elaboration based on the farm survey.

The findings of the farm-level calculations were aggregated to the EU sector level. Results were weighted based on the structure of sow-herd in the EU Member States and the percentage of sows maintained in crates as of 2021 (Table 2).

Table 1. Characteristics of the sow herd in the EU, 2021

Country	**SOWS' number [2021, thousand heads]**	**Share in the Total EU**	**% Sows in crates**
Spain	2,684.9	24.7%	99%
Germany	1,583.0	14.6%	99%
Denmark	1,235.0	11.4%	95%
France	928.0	8.5%	96%
Netherlands	910.0	8.4%	98%
Poland	654.1	6.0%	95%
Italy	551.0	5.1%	99%
Belgium	386.3	3.6%	95%
Romania	298.9	2.7%	99%
Hungary	240.7	2.2%	99%
Portugal	229.6	2.1%	99%
Austria	224.1	2.1%	95%
Ireland	144.8	1.3%	99%
Czechia	126.4	1.2%	95%
Sweden	120.7	1.1%	0%
Croatia	104.0	1.0%	95%

Country	SOWS' number [2021, thousand heads]	Share in the Total EU	% Sows in crates
Greece	100.0	0.9%	99%
Finland	93.0	0.9%	60%
Bulgaria	65.8	0.6%	99%
Lithuania	44.3	0.4%	95%
Latvia	39.7	0.4%	95%
Slovakia	37.2	0.3%	99%
Cyprus	31.0	0.3%	95%
Malta	3.7	0.0%	99%
Luxembourg	3.1	0.0%	99%
Estonia	25.7	0.2%	95%
Slovenia	14.2	0.1%	95%
TOTAL EU	10,879.1	100.0%	96.2%
EU-West	9,228.2	84.8%	96.1%
EU-East	1,650.9	15.2%	96.6%
7 largest pig producing countries (SP, DE, DK, FR, NL, IT, PL)	8,546.0	78.6%	97.7%

Source: authors' elaboration based on EUROSTAT data.

Results

Our findings indicate that the ban on farrowing crates is expected to result in a decrease in sow population and piglet output in the EU due to increased sow space requirements, a reduction in production efficiency, and significant demand for investments. In the most probable scenario S4, assuming a gradual transition by sow farmers, the number of sows is projected to decrease by approximately by 31,4%, resulting in around 7.5 million heads (Figure 1) and number of piglets weaned by 34%.

The transition to alternative farrowing systems will lead to increased variable costs related to the farrowing period. These higher costs resulted from several factors, including increased feed consumption by sows during lactation in larger pens with free movement (+7.5%), elevated expenses related to sow replacement (with a 15% rise in sow-culling rates), an increase in labour costs necessary for the maintenance of free farrowing pens (by 1-2 additional minutes per day during lactation), an increase in vet-medical costs (+7.5%), and a decrease in production due to slightly elevated piglet mortality (+15% with confinement and + 20% with no-confinement), along with a reduced number of litters per sow per year (-1.9%). The lower density, resulting from the larger space allowance per sow in free farrowing systems (approximately 6,5m^2 in free farrowing with temporary confinement and 7m^2 in systems without confinement), will also cause fixed costs per unit (per sow or piglet) to rise in proportion to the decline in the sow herd.

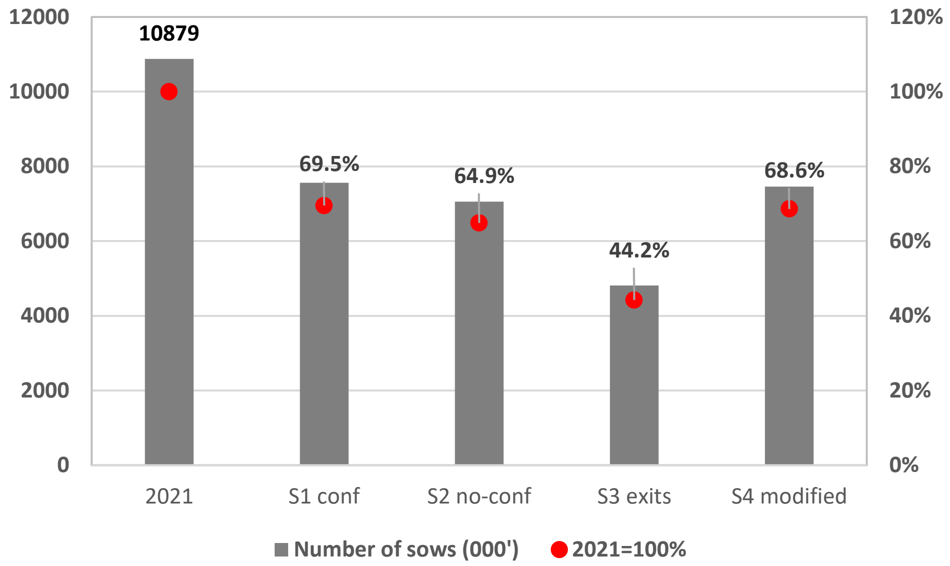

Figure 1. The total number of sows in the EU-27 (in % relation to the base scenario and in thousand heads).

Source: authors' elaboration based on the study results.

Depending on the scenario, those costs rise by 38% per piglet weaned in scenario S3exits, and up to 51% in scenario S2no-conf. An increase in production costs per piglet weaned related to farrowing period from EUR 11.1 to approximately EUR 15.6 (+40%) is projected in Scenario S4modified (Figure 2). The abovementioned, increased costs which are related only to a farrowing period contribute in total to ca. 6-10% of increase of the total costs of production per piglet.

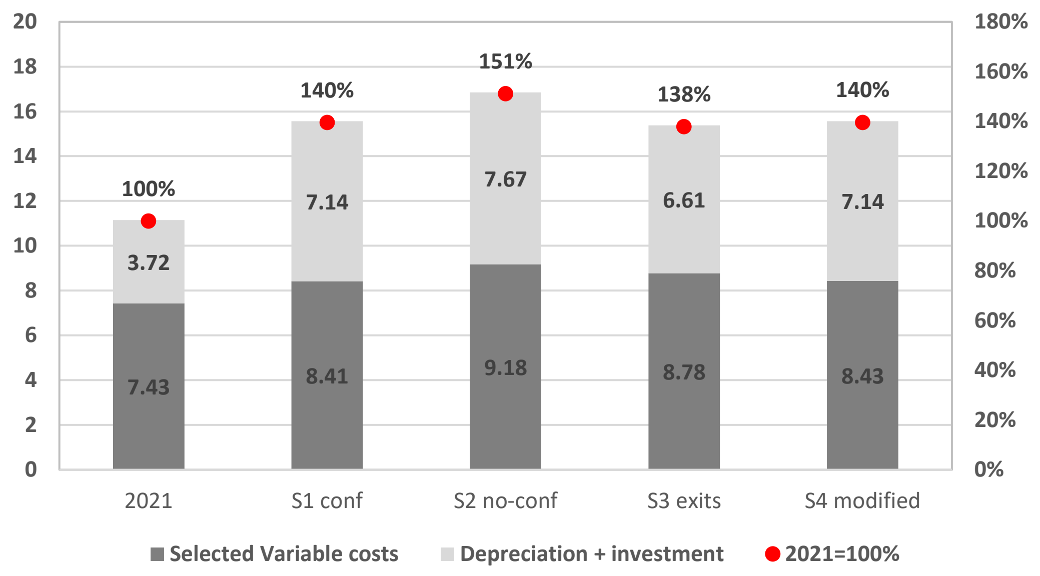

Figure 2. Change in the total selected costs per piglet weaned (selected variable costs + depreciation of new investment and existing buildings) in EU Member States [euro per sow; %] Source: authors' elaboration based on the study results.

Due to lower production efficiency and smaller average sow herds in Eastern European countries, the increase in production costs is expected to be more pronounced in the EU-13, or 'new' Member States.

The implementation of free farrowing systems on pig farms will necessitate investments in new pens and the reconstruction of the existing buildings. Depending on the scenario analysed, investment costs range from around EUR 3.5 to 6.2 billion, expressed in 2021 prices (Figure 3).

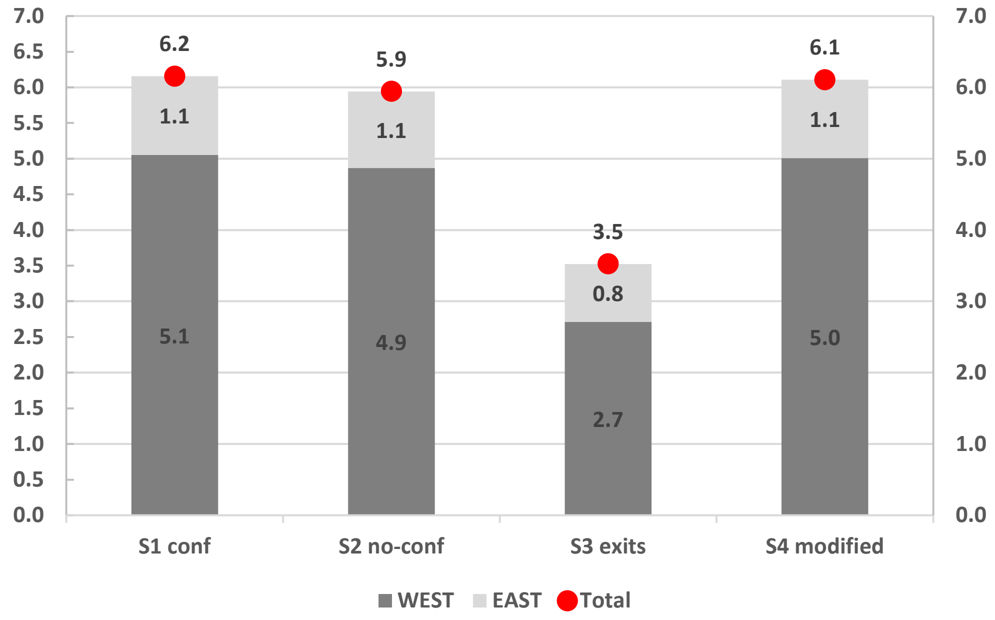

Figure 3. Total costs of investment in new pens in the EU-27 across EU-West and EU-East [billion EUR] Source: authors' elaboration based on the study results.

The vast majority of pig farmers surveyed across the EU held negative opinions regarding the prohibition of farrowing cages, and they gave low scores to the policy's impact on the well-being of piglets and sows (figure 4). Farmers stressed the difficulty of simultaneously achieving three welfare goals in production without compromising each other: the welfare of the sows, the welfare of the piglets, and the welfare of the workers. It is evident that the primary benefit of free farrowing systems is the sows' ability to express natural behaviour. However, maintaining the welfare of piglets in free farrowing pens is much more challenging, with concerns including increased mortality, more frequent injuries, and deteriorating hygienic conditions, as reported in numerous studies. On the other hand, the greater the freedom for sows increases the risk of injury and requires more time from personnel. In addition to these concerns, pig breeding companies and organizations expressed serious apprehensions about the massive capital investments necessary to replace current pens and renovate flooring. They emphasized the need of training and financial support to farmers.

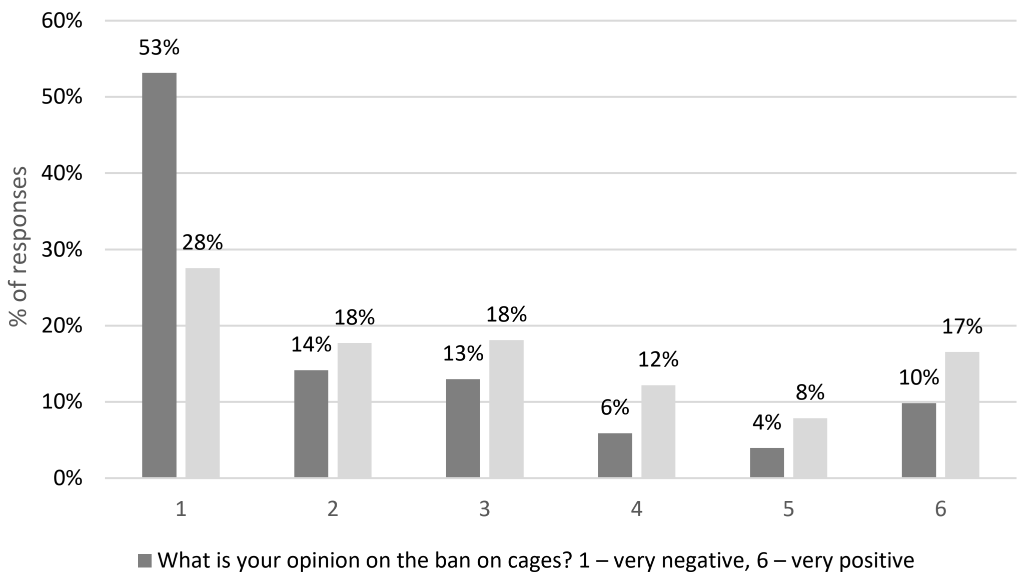

Figure 4. Farmers opinion on the transition to the free farrowing systems

Source: authors' elaboration based on the study results.

Conclusion: The transition from cage-farrowing systems for sows is widely accepted and plans for implementing reforms at the level of the European Commission are well advanced. However it should be emphasized that beyond the actual improvement in the welfare of sows, there are lingering concerns, including increased production costs, higher piglet mortality rates, and heightened risks to employees. These challenges can be mitigated through adjustments in the technological production process, However, in the opinion of sector organisations, such adjustments require time and training. It is essential to consider providing financial assistance to support farms in making a smooth transition to the new systems, as well extended transition period to ensure a painless shift.

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Resilience Through Innovation: Push and pull factors of hill country farming change: the case study of hill country farming in Aotearoa New Zealand

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Academic Paper

This work is original research carried out by Angela McFetridge and Dr. Katherine Dixon.

PUSH AND PULL FACTORS IN HILL COUNTRY FARMING CHANGE: THE CASE OF AOTEAORA NEW ZEALAND

Abstract:

In Aotearoa/New Zealand, more than half of sheep and beef farming occurs in hill country. To understand how beef and sheep farmers balance the tension of farming amidst multiple challenges and balance resilience, we conducted 53 interviews with hill country farmers. In this work, we consider factors that pull change and those that push change in these farming environments. Farmers discussed challenges posed by market pull agents, such as carbon farming, and push agents who through government influenced change, create expectations of behaviour change from farmers for the benefit of positive environmental outcomes. Farmers considered bearing the financial and non-financial costs within change, and to create change. Farmers also expressed second order challenges about attracting the next generation of hill country farming, including farm succession and farm employees.

Key words: hill country, farming, sustainable agriculture, qualitative interviews, changing landscapes

Introduction

Hill country landscapes (Lynn et al., 2009) are important to Aotearoa/New Zealand for cultural, primary production, tourism and recreational reasons (Cottrell 2016; Kerr, 2016). These landscapes make up more than half of Aotearoa New Zealand's agricultural land, supporting the majority of the country's sheep and beef farms (Fransen et al., 2022). These dynamic hill country landscapes present significant opportunities for a world class model of sustainable agriculture whereby carbon capture, waterway management and conservation of native biodiversity are part of a financially productive farm business model. Hill country farming is an important contributor to the Aotearoa/New Zealand economy through global lamb and beef exports (Moot & Davison, 2021), recently evidenced during the Covid-19 pandemic and the increased demand for red meat (New Zealand Ministry for Primary Industries, 2022b).

However, during the last two decades the resilience of the hill country farming industry, isolated rural communities, and farmers themselves has been tested by a suite of systemic changes. Through market pull, there has been competition for land-use from dairy and forestry industries, and currently, the Aotearoa/New Zealand Emissions Trading Scheme (ETS) has incentivised the conversion of farm land to "carbon forest" (Price Waterhouse Coopers, 2020). These market forces have pulled and influenced rapid increases in hill country land prices which in turn put pressure on family farm succession (Nuthall & Old, 2017). Moreover, the direct and indirect impacts of climate change and a suite of new government regulations have created an environment aiming to push change into farming practices and farmer behaviour (Crofoot, 2016; Harrison, 2016; Kerr, 2016; Scrimgeour, 2016).

Industry leaders initiated the Hill Country Futures Research Programme (HCF) to shape the future of hill country farming. Spanning five years, this multidisciplinary initiative prioritized resilient forages and farmers, crucial for safeguarding New Zealand's hill country farms and rural communities. Led by Beef + Lamb New Zealand (B+LNZ), the programme received funding and support from B+LNZ, The New Zealand Ministry for Business, Innovation & Employment (MBIE), PGG Wrightson Seeds, and RAGT NZ. The paper focuses on a social component of the HCF and presents empirical findings derived from qualitative interview data.

Methods

To ensure a geographic spread of representative interviewees across Aotearoa/New Zealand, local network-connectors were used to select hill country farmers for interview. We conducted 53 interviews with 85 farmers across the North and South-island (Figure 1).

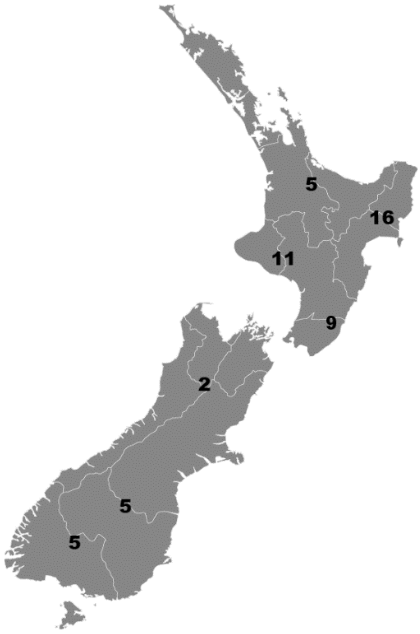

Figure 1. The areas where interviews were conducted across both islands of Aotearoa/New Zealand and number of interviews shown. Because of farms cross regional boundaries, the total number of interviews per region could not be confirmed and numbers shown are estimates of area.

Interviewees were between 18 to 79 (average 50) years old; 31% were women; and 7% self-identified as Māori (Table 1). Māori are Aotearoa/New Zealand's indigenous population.

Table 1. There were 53 interviews across both islands, attended by 85 farmers.

	Interviewees	Interviews
North island (N-INT000)	69	41
South island (S-INT000)	16	12
TOTAL	**85**	**53**

A semi-structured questionnaire to guided interviews and enable a conversational approach. The questions and prompts (in parentheses), relevant to the research presented here are:

- Tell us a bit about yourself and how you came to be on this farm?
- Describe your operation (size, land classes, stock types, management, staff etc).
- How do you see the future of hill country farming (in your region)? (Where are things heading?)

- What is your vision for hill country farming in 2030? (Best case and worst case?) (Drivers? Barriers/enablers?)

Interviews were conducted between July 2020 and March 2021. The average duration of the interviews was 90 minutes. Interviews took place at a location convenient to interviewees, such as their farm office or home. All interviews were recorded and transcribed, and interviewees were sent transcriptions for verification prior to analysis. This research was assessed and approved by the New Zealand Ethics Committee (NZEC19_47).

Analysis

Initial analysis was conducted by five researchers using the online software, Web Qualitative Data Analysis (WebQDA) (*About WebQDA*, 2022). We used an inductive research approach for qualitative data analysis, to allow for the authentic farmer voice and to identify thematic unity in the data.

The themes presented here relay the interviewees perspectives of changes to hill country farming in Aotearoa/New Zealand. Testimonies were analysed to identify topics under the two broad themes of ‘hope/optimism for the future’ and ‘concerns for the future’.

Limitations of this research include an under-representation of Māori farmers in the sample. The findings presented here do not represent Te Ao Māori. Further research would seek greater participation by Māori, as both researchers and participants.

Findings and discussion

We identified that there were themes that could be organized into factors 2 key factors: market driven forces which are pulling change, and policy driven factors which pushing change through these landscapes. There were perspectives which supported change and concerns about the pace of change. Similarly, there were perspectives about the scale of change.

Farmers were asked to describe their farmland, producing descriptions of the hill country. For example,

> “We’ve got 7,500 acres in total […] divided into three different areas: about 1100 acres of that is paddocks; the remainder is steep […] rolling hill country [with]

> elevations between 600 and 950 metres for the hill country, and the pastures are between 300 and probably 500 metres.” (S-INT020b).

Several farmers reflected on how farmers in the context of things have changed, are changing, or need to change. For instance, one farmer noted the impact of historic change in the landscape, explaining that their land is “hill country and it’s highly erodible”. “Probably looking back now you wouldn’t have cleared what you’ve cleared, but we have, so now we have to remediate” (N-INT070b). Other changes to the land were the result of direct government push and market pull changes to farming practices:

> “We’re going through a whole lot of environmental stuff at the moment with [what] we’re retiring [and] fencing off waterways, utilising some of the rubbish areas for carbon, planting them out, which then in turn we’ll develop them and change them over to a native base and then be able to collect the carbon up till then, which then in turn will fund the native base.” (N-INT133).

Within both push and pull change, there were examples within each which revealed that one was not more favourable than the other. Each example highlighted that there are important contextual considerations.

Market push change.

Some changes were driven by a market push through governmental policies and regulations. Most farmers supported the principles, however, there was scepticism about policy details and practical implementation. For example, one farmer noted that the proposed regulations for planting and fencing around waterways to protect water quality was “a good idea”, but also highlighted that diversity in the landscape required flexibility and should be "practical and [applied] in the right situations” (N-INT151). Another farmer said they “don’t mind doing some planting” (S-INT060) but queried the absence of learning from historical second order problems, such as planting willow trees near waterways. Some farmers, acknowledge the requirement for change, though, through market push tactics, the change is slower: “we appreciate that we have an impact on the environment, and we do need to change…[but] we can’t do it overnight – these are complex biological systems” (N-INT076). Farmers identified that changes within their farm gates raised consideration of second order impacts associated initial change. Other farmers embraced change as part of guardianship: “Successful farmers have always been mindful of leaving the farm or leaving the land in a better state than what they found it. It's in your best interest to look after the place and improve it" (S-INT083).

Market pull change

Farmers were concerned about the ETS and its current revenue from carbon farming well more than sheep and beef farming profits. Through this association, farmers identified this threat to hill country farming and rural communities. Farmers referenced the rapid and large-scale transition of sheep and beef farming to carbon farming through exotic forestry, in many cases, *Pinus radiata*[1]. One farmer thought that planning to "save the world's climate by blanket planting farmland […] to store carbon is just bizarre. I think it's going to screw the country personally" (N-INT120). Another farmer feared the impact that forestry would have on the ability of future generations to be hill country farmers: "That's my fear for this future. My children will benefit from growing up here, but will their children, if they want that? Will that be an option for them, or will this farm have been converted into a [exotic] pine forest?" (N-INT163). One farmer objected to the pine trees, but not the idea of using forestry to store carbon, noting that "I wouldn't mind so much if some of it was planted in native trees, and reverted to native bush" (N-INT115). Similarly:

> "[The] worst-case scenario is that it's all in stinking bloody monoculture trees that end up being chopped down and dragged out with bulldozers, and put on a ship and sent to China, and made into pallets and used three times, and burnt. That's great for the world, isn't it?" (S-INT059), and:

> "It would be nice to keep it and keep the hill country as it is; I don't want to see it get all denuded […or] covered in plants that are not supposed to be there. To me, I think it's senseless that we're planting trees that don't belong in New Zealand, on the country like that. I'd love to see a climatic zone that if we put forestry in it grows in that area; it doesn't go in […other] areas; [and] it's not allowed in […some] areas." (S-INT020b)

Conversely, several farmers supported the concept of using fast-growing exotic species to reduce their carbon footprints if there were no farming disadvantages. For example, one farmer

[1] In Aotearoa/New Zealand, *Pinus radiata* is an exotic tree which is predominantly used for production forestry and carbon sequestration (NZFFA, 2024). In some parts of Aotearoa/New Zealand it is wilding conifers such as *Pinus radiata* are identified as a plant pest (Department of Conservation, 2024).

relayed that they could select the areas of their land that are low-yield, “plant them in pine trees, achieving what you need to do with your footprint and intensifying the good parts so as you’re not losing any stock” (N-INT133). However, other farmers saw sense in the idea of using forestry on some areas of their land by:

> “planting a variety of exotic and native trees on marginal land [where] the amount of grazing you get off some of that stuff is pretty minimal anyway, so why not retire it and reduce that erosion; even if it's a bit of carbon farming. Like, why not jump on that bandwagon and get a bit of benefit out of it[?]” (N-INT151).

Farmer initiated change

Farmers recognised the cumulative impacts of anthropogenic change and how they might affect farming and people’s way of life. Despite various agents initiating change from outside the farm gate, farmers were observant and showed care about environmental impacts inside their farm gates. For instance, one interviewee feared the impacts from nutrient runoff on their water supply: “I don’t want to have a creek where I can’t have a drink out of it. […] We like clean water, and we have that now. But I am pretty worried about that in the future.” (S-INT014a). Another farmer feared the effects of changing climate on the frequency and extreme variations in seasons and the weather: “That’s one thing with our weather, it is becoming more extreme. There’s no question. It’s hotter for longer, drier, wetter” (N-INT128).

Balancing second order impacts of change

Farmers’ aspirational hopes for the future of land-use in hill country acknowledged the dependencies between farming practice and financial matters. For example:

> “I would love to see green farms, native bush, less weeds, [and] profitable farms as well, because as soon as you start making money, farmers can spend money to fence bush off, or can improve their rivers […] you can’t borrow money to do that.” (S-INT057)

One farmer explained that “one of our biggest things is having the capital to put into the work that’s needed. We’ve got beautiful land, but it needs drainage. It all costs so much. We can never do what we want to do” (N-INT035a). As global ecological and climate change progresses, farmers said they felt under pressure to minimise their operation’s impact, while rectifying previous generations’ impact. Some farmers explained the costs of social expectation as financial and psychological: “It feels like we’ve been out here farming for a hundred years and then all of a sudden, it’s on one generation to get things right. There’s a cost to that” (N-INT160). Also: “There’s a lot of pressure financially, environmentally, and their mental wellbeing is potentially quite poor at the moment” (S-INT083). In terms of future farm maintenance, one farmer commented: “[it] would be hard to do anything. Interest rates would be too high, so you wouldn’t be able to borrow any money” (S-INT014a).

The increase of land prices was significant for farmers. For some, the land costs influenced uncertainty for the future. For example: “I do think land values have gone too high […] a lot of people are probably borrowed up a bit too much. I wouldn’t be going and borrowing a lot of money now […] not knowing what I can do with that land” (S-INT020a). Some farmers explained that foreign land ownership and the perceived financial benefits of forestry in the ETS influences rising land prices: “Forestry and overseas investment […] for someone trying to have a crack at getting into farm ownership, those two things just make it pretty much impossible I think” (N-INT031b). The rising costs of land and operations were affecting farm succession, creating difficulties for some families who want to keep the farm in the family. For example: “I think what might happen is the traditional owner operator might not exist, which would be a real shame. It would become more corporate farming” (S-INT083). Additionally:

> “Family farms, we’ve somehow got to pay out siblings. The farm has gone up ridiculously in value over the years to unsustainable levels. You can’t buy a farm and pay it off with the profits of the farm […] You cannot pass the debt on like we’ve been passed on.” (N-INT146a);

> “We would like farm succession to be able to move on, so it’s not just going to be corporates who get to farm in the future, because of the unsustainable land prices and future. It’s got to be realistic that we can put another generation of family farmers back into the farms, because that’s where the passion is…” (N-INT146).

Having financial pathways for new farmers to get a foot in the industry amidst rising costs of land and operations was seen as important:

> “I don’t think there will be so many opportunities like we’ve had. I think for young people that don’t have the ‘in’ with their parents owning a farm, I think it’s just going to be more and more corporate, which is unfortunate.” (N-INT162).

The need to have a degree of economic security to afford succession has also been identified in other countries (for example, Pilgeram & Amos, 2014).

Conclusions

In this research, the farmers themselves provided many of the conclusions. Achieving farmers' hopes for the future of hill country farming hinged on the interfacing between markets, environmental outcomes, and communities. In recognising "financial pressure is what drives a lot of the poor farming practices" (N-INT146a), one farmer wanted a "fair system" that "rewards those who have already done good work and penalises the ones who just keep pushing the boundary" (N-INT146a). In this research, we have seen market pull factors create change at pace and scale. Implementing market pull concepts to farmers are paid the true costs of producing food would enable environmental stewardship of hill country. One farmer explained:

> "I would say price is the main thing with our products; if we can get a good price it makes the whole thing much easier […] there's not a lot we can do about the climate. Price is the main thing; price of product. Then we can be good guardians of the land." (S-INT077)

Appropriate financial mechanisms to support farmers in making the changes they need to make to ensure resilient farming into the future have the potential to not only enable sustainable environmental decisions but may also aid continued family ownership of hill country farms and the longevity of rural communities. One such mechanism could be "removing barriers that landowners face in accessing funding and information" for private investment in biodiversity that also enhances carbon sequestration and climate resilience (New Zealand Minister of Climate Change, 2022). .

Farmers emphasized the importance of profit in hill country farming; "if you want to keep hill country farming going […it] has to be profitable" (S-INT020a). Farm profits were linked to the successful future of hill country farming and rising land prices For example, one farmer said: "we've certainly got to keep putting money in, pumping it in, because that's going to be the answer for a lot of things" (S-INT057).

> "To me, […my vision] would be improving the farm to the point where you can earn enough money, and obviously the prices are alright, and all that. You're earning enough money to then put the money into fencing and planting trees and

> shelters. The dream to me is a beautiful farm set up… troughs; rivers fenced off; riparian planting; hedges everywhere." (S-INT100)

Financial stability in hill country farming was a prerequisite for environmental sustainability, some went further by suggesting that a lack of funds leads to damaging practices. One farmer explained that "they always say that […] you've got to be black to be green; […if] you're not as financially productive as you want to be, it is tough to sort of go down that track" (S-INT077). This suggests there could be second order impacts on rural social and economic health. The importance of financial enablers in sustainable farming is not unique to Aotearoa/New Zealand, with farmers in the northern hemisphere also identifying it (for example, see Yeo, 2019).

Overall, farmers focused on the human aspects of farming. Whether it was about their local communities and public institutions, the reputations of farming, the ability for family-run farms to persist into the future, or the ability to continue to farm in the context of environmental and land-use change, people were at the centre of their ideal futures. Farmer responses to change depended on whether they felt a locus of control over the change or whether change happened to them. Much of the visceral reaction from the farmers we interviewed came from change that happened to them. Pride currencies, however, emerged when farmers owned their own change, with a higher locus of control.

We recommend that policies relating to forestry incentivised by carbon credits are compatible with the definition of nature-based solutions for climate mitigation. We feel that farmers would endorse this recommendation. They value the benefits of habitat restoration which can extend beyond climate change mitigation through the visible pride currencies of increasing indigenous biodiversity. For example, noticing increasing numbers of native birds and recovering native vegetation. Restoring habitats around existing waterways can improve water quality for the farming family, livestock, and others downstream, and can also provide some protection against landslips (Department of Conservation, 2020). This in turn increases the resilience of hill country farming in Aotearoa/New Zealand across multiple capitals.

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IFMA24: Resilience through innovation – Production sub theme

VEAL - A PRACTICAL (OVER)VIEW FROM A DUTCH VEAL FARMER'S PERSPECTIVE

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Applied paper (3400 words) for IFMA 2024 on:

- Overview of the Dutch veal sector and a practical visualization and functioning of a veal farm

- Insights from research and networking projects that focus on veal calf rearing and fattening

Abstract

The Dutch veal sector is a large, but challenged one. It has grown since the late 20th century and is now moving into a new era with new expectations beyond simply the economic one. Veal farmers need to deal with increasing legislative changes as well societal and environmental demands. Van Beijnum VOF is a veal farm close to a Natura 2000 region and is fully immersed in this change as a result. Future perspectives therefore include incurring large and expensive investments, ending the operations, either by enrolling in buy-out schemes or by selling. Wageningen University is, partly also encouraged by the Dutch Ministry of Agriculture to research and look into possibilities for (the) veal (sector), resulting in a range of projects that are currently ongoing or starting.

Key words: veal, history, future, practice, challenges, opportunities

1. Overview of the Dutch veal sector

Historical development

The Dutch veal sector has grown rapidly in the years between 1960 and 2019, from about 400.000 to 1.65 million of animals slaughtered each year. The veal sector has grown thanks to large demand in Europe for veal meat as well as the efficiency of the chain, which is also dominated by a few large stakeholders, typically integrated. This means that such a stakeholder has business in every aspect of the sector, ranging from owning farms and animals to transport, feed and slaughterhouses. About 60% of all veal farmers are contracted by such an integrator, while 40% are considered a free entrepreneurs. Despite this, these entrepreneurs are still dependent on integrations with regards to purchase of feed and slaughterhouse, see figures 1 and 2.

Figure 1 (left). Depending on the feeding regime, milk powder and derivates, concentrates and other feedstuffs are delivered by integrators and feed companies in bulk. Figure 2 (right). Calves are transported in specialized transport vehicles.

The veal sector finds it origin and has always been strongly connected with the dairy sector in the Netherlands. Rather than seeing the (predominantly) bull calves and surplus heifer calves (not used for replacement) as a waste product, the veal sector has emerged to increase the value of these animals coming from the dairy sector. The primary function of a (dairy) cow on a dairy farm however, is to produce milk. This focus may impact the quality of calves that arrive on a veal farm as they are the result of choices made by a farming system that focuses on milk production and longevity, but also health and not on the characteristics of the future veal calf.

Roughly half of the calves that are fattened in the Netherlands originate from outside the country borders. These animal are transported to collection centers, sorted by their characteristics like breed, age, gender and weight before being transported further. The majority (up to 90%) of veal meat is subsequently exported to Italy, France and Germany. The Dutch consumer rarely has veal on their menu.

Typology of veal

Veal fattening farms can have different distinctions; mainly depending on the choice of starting (setup) age and fattening/finishing age ranging from young calves (so-called nuka's; an abbreviation from what translates from Dutch to 'sober calves') of minimal 14 days and 36kg. The main distinction however, is determined by whether calves are fattened to rose or white (meat) veal. White veal calves are provided milk (next to unlimited concentrate and a form of roughage) throughout the entire fattening phase and iron levels of the feed is strictly monitored to obtain a specific meat color and texture. This, in contrast to rose calves that have a more unstrained, free feeding choice. There are sector and legally driven rules for this distinction regarding maximum age, related housing requirements (m^2/animal) and blood iron (Hb) levels. Animals slaughtered at an age less than 8 months are classified as calves, above 12 months as beef; in between is dependent on national interpretation of the delivered animal. The quality, in broadest sense of the meat, influences the market value: total yield (kg), leanness/fat, conformation and Hb. A system of numbers (1-5 or 1-10) and letters (EUROP) is used to label a carcass on its quality. Not new, but being considered more, is increasing the value of the surplus (especially) bull and heifer calf as dairy farmers receive a higher price for an animal with a more beef potential. Beef breeds are therefore often cross-bred by dairy farmers (Belgian Blue, Angus, Limousin, to name a few).

Future outlook

The economic success of the veal sector comes with a side note. The veal sector has been investing in increased animal welfare, health and sustainable production especially compared to half a century ago – when animals were held in truly detrimental conditions. But points of concern still exist and will probably remain, such as high antibiotic use, housing and welfare levels. The Netherlands is a small country with a relatively large number of farm animals. Topics like animal welfare, environmental impact, circularity and public health with regards to the Dutch veal sector are therefore rapidly subject of societal, sometimes polarized debate. Several changes are thus expected for the coming years among which, an increase in minimum transport age resulting in keeping calves longer on the dairy farm. Other changes are taking place towards a more animal worthy husbandry system, housing requirements (larger surface areas or comfort standards) and compliance to environmental requirements on nitrogen and greenhouse gas emissions, resulting in less farms overall. This trend has been visible already since the start of this century, see figure 3. These challenges are not unique to the veal sector, hence changes that happen in the dairy sector will influence the veal sector as well.

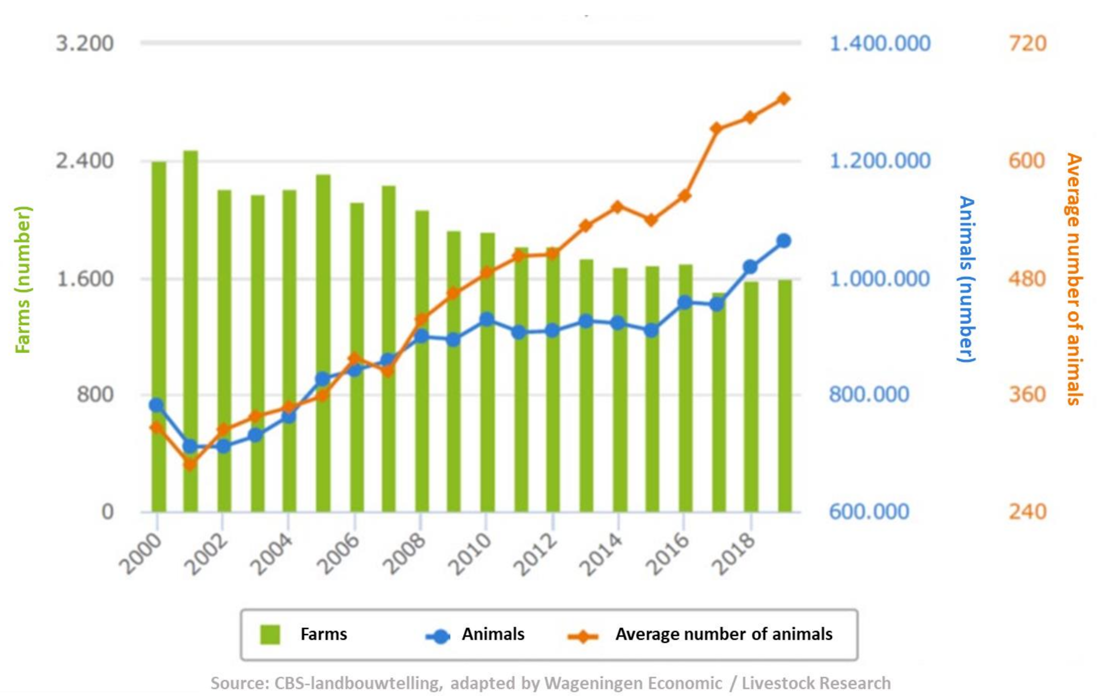

Figure 3. Development of veal farms up to 2019. (average) Animal numbers per farm increased, due to increased numbers of animals and reduction of amount of farms.

The relatively high supply versus (declining) demand for veal, puts a pressure on margins and ultimately also on the farmer’s income. Currently, prices for veal meat are good, but young animal purchase prices are also higher - often depending on time of year. Despite this, farmers experience a lack of vision towards the future and this is accompanied by a low potential and willingness to invest in becoming more sustainable.

(Consulted source: ‘Scenariostudie Kalverketen’, 2021)

4

2. "Van Beijnum V.O.F." white veal farm

Farm background

The author of this document is strongly involved with the management; rearing and fattening of a 850 heads white veal herd in a farm in Bennekom, province of Gelderland - The Netherlands. A family farm that has evolved from a mixed farm with dairy cows, poultry, pigs and arable land to a veal fattening farm over 60 years, see figure 4.

Figure 4. The farm throughout the years. Change from mixed farming (left) to a veal only focus (right)

A practical visualization and functioning

The farm is what could be described as a typical white veal farm, a high density of animals in closed barns. Sometimes arbitrarily referred to as intensive systems or intensive production. There is none to very little relation with land use (crop production for use or space for animal roaming) and overall availability. The total hectares of the land and buildings together is less than 3 hectares. As a result, manure produced by the animals needs to be removed from site to be either used by arable farms or on grassland or processed.

Animals are owned by a contractor, meaning that the main task for the veal farmer is to care for the animals and provide proper housing and not deal with the purchase and sales of animals and feed, logistics, farm advising and planning to and from collection sites or slaughterhouses. There is a relative large degree of freedom in how to exactly manage the animals, dependent on the restrictions and requirements that (larger) contractors uphold. This has pros and cons: less hassle from all peripheral tasks, and income is fixed – which is good is less favorable economic times, but does not allow to profit from better times.

An all-in, all-out system is maintained in which an entire barn of animals is both received and filled as well as put on transport to the slaughterhouse after the fattening period of about 27-30 weeks of age. This brings about some risks of having multiple and mixing many animals from different locations but has the major benefit of increasing uniformity and less work load. In this system, animals are kept individually, though not secluded from each other in the first 1 to 2 weeks, see figure 5. This allows for properly monitoring the individual health status, development and behaviour of the calf, and next, to safely after keep them in uniform groups, see figure 6.


Figures 5 and 6. Different rearing stages and growth phases require different management. Figure 5 (left). First weeks, individual housing / feeding. Figure 6. (right) After, in groups.

These uniform groups are based on health status, size and drinking behaviour initially as these parameters influence growth and development, in turn influenced by feeding regime per group. Feeding of each group is identical. A mixture of roughage (i.e. grains, silage) and straw is provided ad libitum via an automated feeding systems, this is illustrated in figure 5 – the blueish tubes. Milk is a composition of whey, fat, water and a powder nucleus providing the missing nutritional elements and protein fitting the animal’s growth phase. The only difference is the amount (liters/calf) per pen which is provided automatically in throughs. Some calves may refuse milk, or drink very little during the fattening period and a strategic choice can be made to move these animals to a feeding regime with less or no milk. Then, these animals develop into (young) rose veal.

Health and performance

Despite the automatic feeding systems, the milk feeding moments: morning and afternoon, are always accompanied to keep a close eye on individual calves. These may need and then receive specific care; ranging from replacement to another pen to treatment in the form of medication. On a regular basis a veterinarian performs a herd health check-up, also to determine whether they're in need of a blanket treatment approach, rather than individual medication. On the other hand, a farm advisor from the integrator performs a herd productivity check-up to adjust feeding regimes and monitor the development of the animals to stay in line with the in previous section mentioned market value parameters (visual observation). The only parameter that is checked on a regular base using blood samples is the blood iron level: Hb. Based on the outcome of this analysis, animals may receive iron supplementation either by injection (individual correction) or via the milk (blanket). This is a balancing act: a too high iron level will result in meat with a more reddish tone (negatively affecting market value), yet too low iron levels will cause performance drops or health issues.

Last but certainly not least, housing plays an important role. To support the development of the calf, a comfortable environment needs to be created with regards to temperature, comfort and ventilation whilst simultaneously avoiding drafts, rigid shifts and odor (ammonia levels). Comfort is a debatable issue as there are factors to consider in the choice of, for instance, the type of slats. Wooden slats provide relative comfort thanks to fast drying of manure and urine but is also quite hard. Animals that experience some sort of physical discomfort, like lesions or impaired locomotion or require rest are moved to a pen where some straw is provided.

Farm goals

The obvious goal is to achieve highest market value, but it is probably clear by now that potential is also partly determined by the type of animal that arrives on the farm. That is beyond the farm's control. After arrival there are still several (management) practices that contribute to the highest market value or other goals that (personally) matter. This farm aims for low mortality and morbidity rates by providing as much individual care as possible. Morbidity is difficult to assess, but mortality rates are rarely higher than 2%, which is a nice score compared to European mortality rates that are somewhere between 3% and 5%, which is (at least by the sector itself) considered low compared to other veal fattening countries. Morbidity expresses mainly the major health issues: diarrhoea and lung/pleura problems, in line with what is seen in the sector overall. This can be mitigated to a certain extent: keep groups of calves together from the start, reduce stress, provide constant and proper feeding (hours), monitor ventilation and address need for care immediately. Less sick calves is a win-win-win situation primarily for the animal, but also for the farmer and ultimately the contractor. Hygiene may also contribute to a good working space. Not only when issues arise, such as changing and disinfecting boots or even compartmenting in case of a salmonella outbreak, but also in general. It's nicer and safer to work under clean conditions.

Future perspective

Several aspects are to be considered with regards to the future perspective of the farm. Succession has not been guaranteed for a long time. There has been sufficient theoretical and personal interest to carry on the business among the people involved on the farm, but the long-term feasibility of this needs to be a point of consideration that may change the overall decision course in the future.

The farm is located in a region that is called the Binnenveldse Hooilanden, a region partly designated as Natura 2000 area (the EU ecological network, subject to legislative enforcement), that due to its nutrient poor characteristics allows for some sensitive vegetation growth (like bluegrass), see figure 7. The consequence is a required nitrogen precipitation (deposition) reduction in the area by up to 80%, as it is now considered too high by the national authorities. Veal farms emit ammonia, so they are considered so-called peak contributors to this problem. There are ways to mitigate ammonia reductions, but they often require large investments (i.e. air scrubbers, which filtrate ammonia from the air). The Dutch government has launched several initiatives, in phases to tackle this problem both nationally as well as regionally.

Amidst all these more secondary aspects, a veal farmer rears and fattens calves in the end for an income. 850 animals is below what is considered a Dutch full time equivalence to be completely self-sufficient, let alone invest to be future resilient. Options therefore are to expand to numbers above 1200 or create incomes on the side, which has always been the case. The relative predictable daily routine and temporary labour peaks related to the production cycles, allow for offsetting risks and expenses by generating income from another job or occupation. Expanding the numbers above 1200 is currently an undesirable choice.

Figure 7. The farm is situated right in front of the 'Binnenveldse Hooilanden' Natura 2000 region, beautiful nature but enforcing a strict environmental preservation policy on N-emissions, impacting agricultural business in a large radius.

The combination of factors: economy, lack of perspective, lack of succession partly and location environmental risks need to be taken into consideration on what to do with this veal farm in its current form as per 2025 and onwards. There are several options available, next to the already described expansion option. As part of their strategy to reduce nitrogen emissions the Dutch government has recently issued a buyout scheme for peak contributors called 'LBV Plus-scheme (an abbreviation from what translates from Dutch to 'National termination-scheme for farms location')-scheme'. This national buy-out scheme offers farmers that don't carry on their business to receive a 120% compensation for their functional barn buildings at the (one of the) precondition(s) to end and never start an agricultural business again in the European Union. The farm could also be set for sale, provided there is market interest by other buyers. These buyers, in turn would then also have to make strategic decisions but may prioritize other

In conclusion, many good things have been done and are still done on the farm and if possible, continuing the veal operation is preferred. All involved on the farm agree that practices on the farm and in the sector can or even should be better, but not without a fair and sustainable future prospect. In case the operation closes, all involved will either work fulltime in their other jobs, or will have to find a (new) job suited for their capabilities. In case the farm is bought, becoming an employee for a new owner is also even an option.

3. Research on calf rearing and veal calf fattening

Wageningen Livestock Research is involved in many ongoing research and development projects regarding calf rearing and fattening from different angles. Often researchers from different disciplines; farming systems, animal welfare, nutrition, emissions, genetics, etc., work together in projects with different stakeholders. These may include farmers, government, sector, market, academics, non-governmental organizations (NGOs) and other interest/stakeholder-groups.

Below are some insights or planned/ongoing activities on a few hot topics currently on different agendas:

Transport (age)

In some European countries such as Germany, calves are already transported at an older age ahead of legislation. The veal sector embraces the idea, as older calves are not transported during their most vulnerable moment of 2 weeks and are potentially more robust. Recently published work by Marcato et al. (Journal of Dairy Science, 2022) looked at transporting calves at 28 days (compared to 14 days) and saw signs/indications of improved robustness. This shift in rearing protocol will require more and better collaboration between dairy and veal farmer where both are rewarded for either effort. This is also slowly picked up by the sector, rewarding dairy farmers for qualitative strong animals, but it’s not fully guaranteed yet. The dairy farmer’s business and calf rearing protocol is impacted by the longer time that surplus calves stay on the farm. This has not been properly assessed and a research proposal has been prepared to make this inventory. The proposal is currently under evaluation.

Resilience and sustainability

As mentioned in an earlier section, the Dutch ministry of agriculture is looking how to work towards a more animal worthy and sustainable husbandry system. Following the first large government research project launched (under the name ‘KPI-K’) for dairy cattle and arable land, this has also recently been launched for the intensive systems: poultry, swine and veal. The aim of the project is to provide critical performance indicators on a large set of sustainability targets, such as animal welfare, economic and social resilience, circularity, biodiversity, water & soil management and climate. Some of these goals do not directly or not even at all affect the veal system, but are looked at nonetheless.

Animal welfare

Society pressure on improving the animal welfare of calves is increasing, despite many efforts to already improve this within the sector. Together with sector stakeholders, several scenarios have been designed with regards to how a future calf rearing facility could look like with different priorities. There's also increasing interest in systems where the calf is held longer with the dairy cow, improving cow-calf contact and enabling new market value potentials. Similar to this, but looking from a different angle is allowing dairy farmers to keep the veal or beef cattle on the own farm, effectively becoming a dual purpose farm instead. Several pilots and studies are going on regarding these concepts.

Market

As indicated before, Dutch rarely consume veal meat – especially white veal. The differentiation of white veal is however what allows for additional value. (niche) Markets are receptive to different product value propositions but requires a marketing push or stimulus by the government or other stakeholders. Wageningen Livestock Research investigates market potential and opportunities to satisfy different consumer desires.

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'Scenariostudie Kalverketen'; 2021 (scenario study towards a different course in the veal value chain; compiled by Lysias Advies, Schuttelaar & Partners and Rebel on behalf of the Dutch Ministry of Agriculture.

IFMA24: Resilience through Innovation

WATER RESILIENCE AND CHANGE OF WATER USE BEHAVIOR

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Abstract

One of the barriers to water resilience is human behavior, which is influenced by a number of contextual and psychological factors. Contextual factors include socioeconomic, technical, institutional, and environmental factors, while behavioral factors include but are not limited to factors associated with the perception of risk, attitudes, and norms. Nonetheless, few studies consider an integrated view of these factors in shaping water use behavior and water resilience. This paper consolidates contextual and behavioral factors influencing water use and resilience. Knowledge gaps, including but not limited to water resilience, can stimulate theoretical and philosophical innovation to reimagine water systems as complex socio-eco-technological systems characterized by nonlinear dynamics and unexpected behavior. Based on the gaps identified, the paper proposes a conceptual model that connects contextual behavioral factors and water resilience and represents potential cause-effect relationships as supported by various behavior approaches and psychological theories. This model proposes an institutional factor to assess the relationship between institutions and stakeholders and contextual factors linked not only for individual water users but also for individuals of water supply organizations based on a review of the literature on water use and water resilience, including but not limited to conservation behavior, psychology, and water use models.

Keywords: Human behavior, Psychology, Innovation, Institutions, Stakeholders, Contextual factors

Introduction

Every day, significant volumes of water are drawn from inland surface water bodies (e.g., rivers, lakes, wetlands, and reservoirs) and aquifers for a variety of reasons, including agriculture, residential, energy generation, and industrial use. Water withdrawal has expanded about twice as quickly as the global population (FAO, n.d.). Agriculture is the most water-intensive industry, accounting for around 69% of worldwide water withdrawals (FAO, 2018). Water scarcity has resulted from drawing water quicker than it is recharged (Moncaleano et al., 2021).

The gap between worldwide water withdrawals and actual water demand is substantial and growing. One explanation for this disparity is inefficient water use, which leads to higher consumption when it might be reduced (Wang et al., 2015; Nazari et al., 2018; Ding et al., 2019; Ghanim, 2019). As a result of over-extraction, rivers and groundwater supplies around the world are running dry (Jorgensen et al., 2009; Graymore et al., 2010; Arto et al., 2016; Bhaduri et al., 2016; Mekonnen & Hoekstra, 2016; Lund et al., 2018).

Water inefficiency also has an impact on the provision of environmental flows, contributing to environmental deterioration and economic instability (Mekonnen & Hoekstra, 2016; Vieira et al., 2017; Piedra-Muoz et al., 2018). Policymakers and water managers have frequently recommended efficient water utilization as a method to reduce the inflated gap between water extractions and water demand.

Resilience remains relevant and widely debated (e.g., Eakin et al., 2017; Folke, 2016; Rodina, 2018), as there is now a growing body of work that aims to situate and (re) contextualize resilience within the complex realities of environmental change and resource governance in various contexts (e.g., Brown, 2016; Meerow et al., Rockström et al., 2014; Rodina et al., 2017; Vale, 2014; Ziervogel et al., 2017)

The pillars of those global and local strategies, such as the Sustainable Development Goals (SDGs) of the United Nations, include increasing water resilience, efficient usage, and changing water use behavior (Cole et al., 2018; Ortigara et al., 2018). Water efficiency and resilience are frequently related to technical factors that affect the performance of water utilities, such as water leakages in water distribution systems, poor management, and irrigation system maintenance (EEA, 2007). Other issues, such as those associated with water psychology, impacting the behavior and decisions of relevant water users, are typically overlooked by policymakers. Mosler (2012) describes behavior as the product of an individual's psychological processing of factors. Therefore, a comprehensive assessment of these factors and their relationships is needed to provide insights into the causes of over-extraction, the interdependence between stakeholders, and the effects on water resilience.

Methodology

This article is based on a systematic scoping review. It presents a quantitative analysis of coded data that was used to identify themes that were investigated in greater detail through a qualitative analysis (i.e., detailed review), including an evaluation of water use behavior and water resilient system characteristics. The scoping study covers the English language peer-reviewed academic literature in the Web of Science and ProQuest scholarly databases that use the phrase "water resilience" in the context of water usage behavior. Second, the analysis delves deeper into the practices, solutions, evidence, and controversies that arise from the literature in order to provide more insights into water use behavior dimensions of water resilience.

Change of water use behavior concept

Contextual factors and Definition of Change in Water Use behavior

Water usage behavior is described as an environmental behavior in the context of water use. Environmental behavior, according to Steg and de Groot (2018), is "any behavior that has a good or bad impact on the environment." Contextual and behavioral factors influence this behavior (Carrus et al., 2010; Graymore et al., 2010; Russell & Fielding, 2010). Perceptions, thoughts, feelings, and beliefs that influence behavior are examples of behavioral factors. These factors, taken together, represent an individual's attitude in relation to conduct (Contzen & Mosler, 2012).

Several theories and models have been used to analyze environmental behavior, such as the theory of planned behavior (TPB) (Ajzen, 1991), the new environmental paradigm (NEP) (Dunlap et al., 2000); the theory of environmentally significant behavior (Stern, 2000); the risk, attitude, norms, abilities, and self-regulation (RANAS) model (Contzen & Mosler, 2012); the norm activation model (NAM) and the theory of values (Steg and de Groot, 2018); the values, beliefs, and norms theory (VBN) (Stern, 2000; Yildirim & Semiz, 2019) (refer Table 1)

Table 1: Models and theories and factors to understand water use behavior

Model or theory	Approach	Factors
The norm activation model (NAM) (Steg & de Groot (2018))	The pro-environmental actions follow from the activation of personal norms, reflecting feelings of moral obligation to perform actions. Experimental studies have shown that NAM variables are causally related.	Personal norms are activated by problem awareness, ascription of responsibility, outcome efficacy, and self-efficacy.
The new environmental paradigm (NEP) (Dunlap & Van Liere (2010) and Russell & Fielding (2010))	The NEP focused on beliefs about humanity's ability to upset the balance of nature, the existence of limits to growth for human societies, and humanity's right to rule over the rest of nature.	Beliefs
Theory of planned behavior (TPB) (Steg & de Groot (2018))	Behavior results from the intention to engage in specific behavior. The TPB assumes that socio-demographics and values influence behavior indirectly via attitudes, subjective norms, and	Attitudes, subjective norms, and perceived behavioral

	perceived behavior. Attitudes express a positive or negative stance toward a behavior; subjective norms, normative factors represent convictions about the incidence of a behavior and how the social network thinks about the behavior; perceived behavioral control ability factors represent the aptitudes and individual beliefs.	
Theory of values (Steg & de Groot (2018))	Values include beliefs about the desirability or undesirability of certain end-states that transcend specific situations. Values serve as guideline principles for the evaluation of people and behaviors.	Key values for pro-environmental behavior. These are separated into two dimensions: Self-transcendence, altruism, and biospheric. Self-enhancement; egoistic and hedonic.
The theory of environmentally significant behavior (Stern (2000))	This theory assesses the definitions, classifies the precursors of environmental behavior, evaluates the links between environmental concern and behavior, and identifies the factors that determine environmentally significant behavior.	Causal variables: attitudinal, personal capabilities; contextual factors; habit and routine.
The value-belief-norm theory (VBN) (Steg & de Groot (2018); Russell & Fielding (2010); Stern (2000); Contzen & Mosler (2012); Dietz (2014)).	This theory is an extension of the NAM and links the values theory, the norm activation theory (NAM), and the new environmental paradigm (NEP). A causal chain of values (biospheric, altruistic, and egoistic), beliefs, and personal norms trigger the behavior.	Values; beliefs on relationships between humans and the natural environment reflected by ecological worldview norms.

	Beliefs consist of personal worldviews of concerns or perceptions about the consequences of human actions that may harm the environment; norms relate to moral obligations to engage in an environmental behavior; values are central to any decision-making process and guide behavior and attitudes.	
Risk, attitude, norm, abilities, self-regulation (RANAS) (Steg & de Groot (2018); Contzen & Mosler (2012)).	This model systematically identifies, measures, and integrates behavioral and contextual factors to assess behavior at an individual scale. The RANAS model derives the factors on the basis of quantitative data. Behavioral outcomes: behavior, intention, and habit. Risk: perceived vulnerability. Attitude: instrumental beliefs, affective beliefs. Normative: descriptive, injunctive, and personal norms. Ability: action knowledge, self-efficacy, maintenance efficacy, recovery efficacy. Self-regulation: action control/planning, coping planning, remembering, commitment.	Risk, attitude, ability; self-regulation.

Sources: Author's compilation from different sources

To explain and affect behavior, the RANAS model incorporates the most important behavioral theories. It has two major benefits: first, it can be tailored to a wide range of behaviors in a wide range of contexts and populations, and second, it provides a standard template of questions for measuring behavioral components and analyzing behavior. This allows for the comparison of multiple sites or scenarios (Dreibelbis et al., 2013). Water, sanitation, and hygiene (WASH) behaviors such as handwashing and adoption of household water treatment technology have been assessed using risk, attitude, norms, abilities, and self-regulation (Contzen & Mosler, 2012; Mosler, 2012; Dreibelbis et al., 2013; Lilje & Mosler, 2018; Daniel et al., 2019; Nunbogu et al., 2019). Knowledge, beliefs, and emotions are RANAS characteristics that are linked to an individual's water usage psychology and influence the practice of behavior in the context of water use (Mosler & Contzen, 2016). Indeed, this model integrates behavioral components such as risk and self-regulation, both of which are important for regulating and grasping varied activities.

The TPB is one of the theories incorporated into the RANAS and has been widely used to investigate and understand environmental behaviors, including water use and its associated factors (Harland et al., 1999; Stern, 2000; Steg & Vlek, 2009; Russell & Fielding, 2010; Mosler, 2012; Fu & Wu, 2014; Yuriev et al., 2020).

The term "values" refers to "concepts or beliefs about desirable end states or behaviors that transcend specific situations and guide the evaluation of behavior and are ordered by relative importance" (Dietz et al., 2005). Values can have an immediate impact on beliefs, conventions, and behavior. Beliefs influence norms, and norms influence conduct (Roobavannan et al., 2018). In the realm of environmental behavior, values are factors that are associated with environmental concern and may influence individual decisions. These are the values of altruism, biosphericity, egoism, and hedonism (Stern, 2000; Dietz et al., 2005; Steg & de Groot, 2018). Personal norms provide a solid foundation for individuals' pro-environmental actions (Stern, 2000).

Stern (2000) established the VBN theory of environmentalism by combining values theory, NEP, and NAM. It is represented by a causal chain that incorporates values, beliefs, and norms, as well as its variables (see Figure 1). Since individual behavior is essential to analyze the psychology of why people use water efficiently or not, behavioral studies have mainly focused on individual users, e.g., how consumers react to water resilience measures and regulations (Graymore & Wallis, 2010; Lee et al., 2011; Scott et al., 2014; Jorge et al., 2015; Wang et al., 2015; Vieira et al., 2017; Kneebone et al., 2018; Nazari et al., 2018; Benedict & Hussein, 2019; Kapetas et al., 2019; Koh, 2020). Several stakeholders, including farmers and households from rural communities, have been considered.

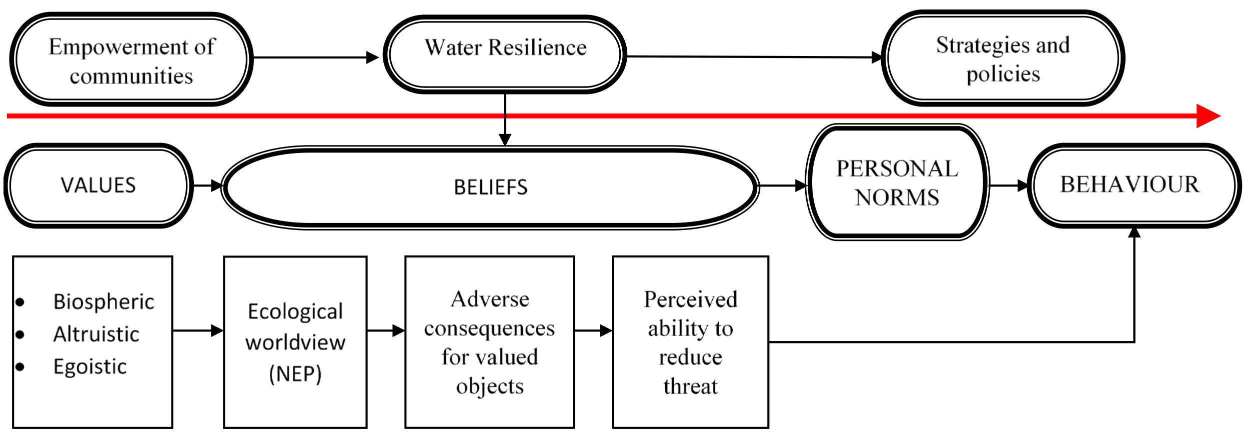


Figure 1: Integrated theories and models of water use behavior and water resilience
Sources: Author's compilation and Adopted from Dietz et al. (2005) & Srern (2000)

Individuals' background characteristics and their physical environment are referred to as contextual factors (Dreibelbis et al., 2013). These have varying effects on behavioral aspects and can either assist or hinder behavior (Contzen & Mosler, 2012). Contextual elements include social, economic, technological, environmental, and institutional origins, acquired skills, immediate personal circumstances, economic resources, capacities, regulations, resilience, and so on.

Determinants are behavioral characteristics that can instantly influence individual behavior (Jager & Joachim Mosler, 2007; Dreibelbis et al., 2013). These are also activities and habits that can be immediately observed, as well as variables that influence people's mindsets. The contextual factors studied in the context of water resilience are social, economic, environmental, technical, and institutional (Jorgensen et al., 2009; Millock & Nauges, 2010; Russell & Fielding, 2010; Lee et al., 2011; Willis et al., 2013; Scott et al., 2014; Hussien & Memon, 2016; Vieira et al., 2017; Kneebone et al., 2018; Nazari et al., 2018; Benedict & Hussein, 2019; Kapetas et al., 2019; Koh, 2020). Table 2 outlines the social, technical, Institutional, and Environmental factors for water use behavior and resilience.

Table 2: Social, technical, Institutional, and Environmental factors**.**

	Sources	**Remark**
Socioeconomic factors		
• Age • Gender • Education level • Information • Networking • Household characteristics • Population density	Beal et al. (2013). Tang et al. (2013); Attari (2014); Chang et al. (2016); Dean et al. (2016); Piedra-Muñoz et al. (2018); Khair et al. (2019); Russell & Fielding (2010); Dreibelbis et al. (2013); Benito et al. (2019); Zhang & Xu (2019); Russell et al. (2020).	-Key socio-demographic factors that contextualize water use. -Age, education level, information, and networking are strongly associated with knowledge about water use, which is a core component of solving water-related problems. These factors have been shown to be important in predicting water use.
Technical factors		
• Training • Data availability	Dean et al. (2016); Nazari et al. (2018); Russell et al. (2020).	-Training facilitates a better understanding of water usage and knowledge of good water management practices and better-informed decisions.

• Elaboration of water use behavior plans • Infrastructure and technology readiness • Performance of utilities in terms of financial • Capacity to supply water demand		-These factors have been shown to be important in predicting water use.
Institutional and Environmental		
• Goals to guide • Enable and constrain the actions of individuals. • Firms, households, and other decision-making units • Shaping human interactions around water use • Coordinating activities	Vitola & Senfelde (2015); Lynne et al. (1991); Stern (2000); Geels (2004); Kapetas et al. (2019); Ostrom (1990); Aligica (2006); Koehler et al. (2018); Khair et al.(2019); Dean et al. (2016).	-These may activate values and shape the beliefs of individuals and can change the behavior of many toward water use. -The environmental factors refer to geographical experiences that are connected with associative learning. -Institutional factors involve institutional relationships between water users and the water supply systems and regulations.

• Designing and implementing policies • Facilitates information and promotes incentives to encourage people to use water appropriately		

Sources: Authors' compilation from different sources.

A conceptual model to understand water use behavior and resilience

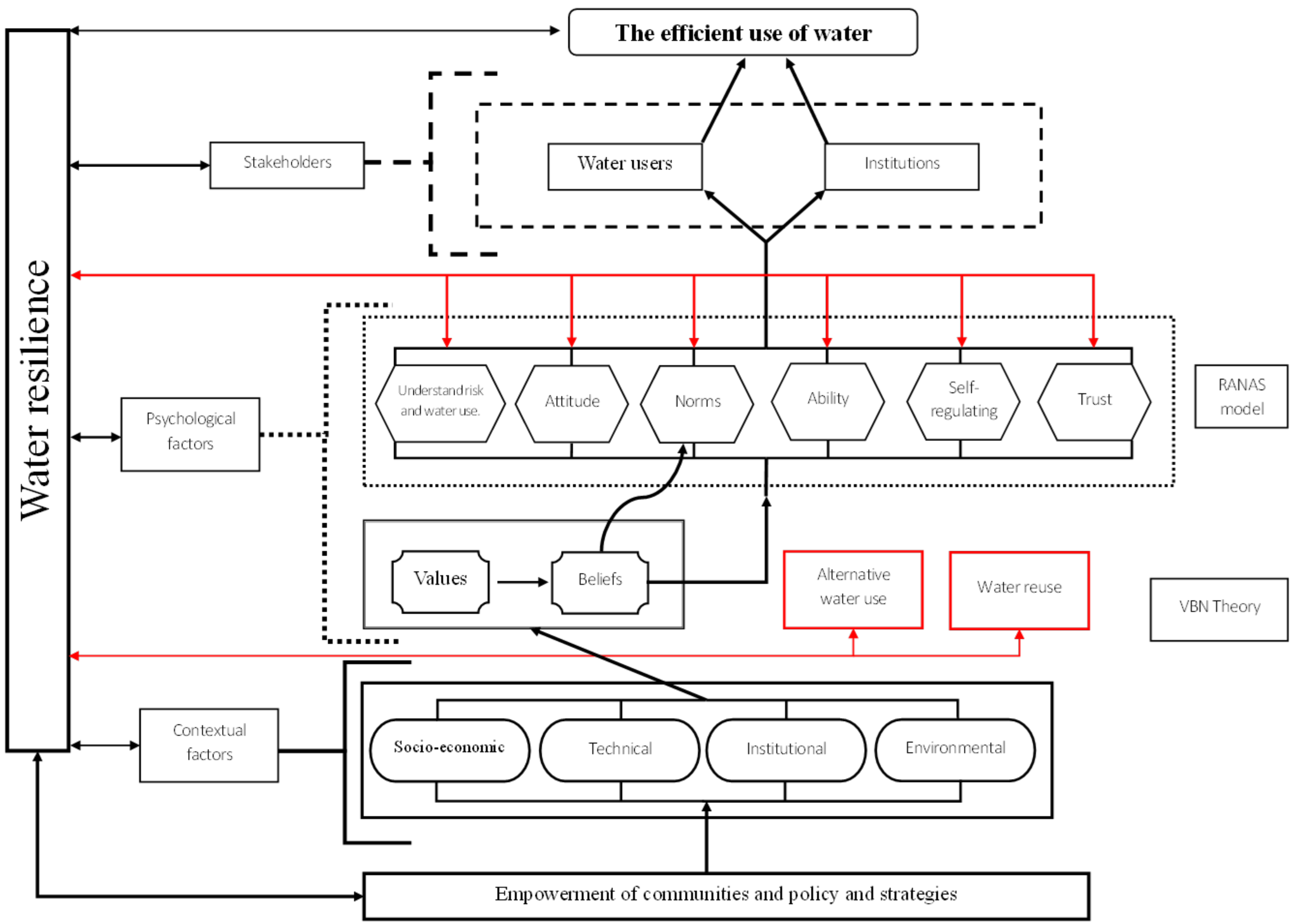
Existing approaches for measuring and understanding environmental behavior are used as a guide and source of inspiration. These include the model of behavior change (Contzen & Mosler, 2012) that has been used for the water and sanitation sector in developing countries (Mosler, 2012); the framework of Steg & Vlek (2009) for understanding and promoting pro-environmental behavior; the research of Carrus et al. (2010) for studying the socio-psychological and contextual predictors to assess sustainable water consumption and the causal chain of factors across the environmental significant behavior (Stern, 2000). The ability of systems (social or biophysical) to tolerate or cope with risks, shocks, or stressors (whether climate change impacts, social crises, economic shocks, or catastrophic occurrences) while maintaining certain critical functions or structures is well acknowledged. Definitions of resilience have been expanded to incorporate the concept of adjusting to change in order to achieve more desired states (Folke, 2016; Rodina, 2018).

A causal hierarchy of contextual and behavioral elements is posited in order to argue that context influences psychological and behavioral characteristics, which influence individuals' environmental behavior. All of these elements work together to determine the behavioral outcome in terms of water efficiency. The model consists of three major components: contextual variables, behavioral (or psychological) factors, and water consumers, water resilience, and stakeholders (refer to Figure 2). Resilience thinking has been widely debated and (re)defined as a method for conceiving social-ecological systems as complex adaptive systems (Rodina et al., 2017).

The efficient use of water behavior is a result of the psychological processing of factors intrinsic to an individual and involves the execution of responsible pro-environmental actions (Steg & de Groot, 2018; Steg and Vlek, 2009; Mosler, 2012). The behavior involves curtailment actions that are associated with resource conservation and efficiency actions that are related to the installation of water efficiency technology and water resilience (Russell & Fielding, 2010; Beal et al., 2013). These actions can include harvesting water by using rain barrels, both of which have positive impacts on water use due to less water consumption and withdrawals. In terms of specific dimensions of water resilience, arguments have been made for increased flexibility in the water sector and increased reliance on nature as a flexible option with multiple benefits—from flood risk mitigation to improving water supply and quality (Bell et al., 2017).

Figure 2: Contextual and psychological factors within the conceptual framework of water use behavior and water resilience

Sources: Author's compilation based on different sources


The efficient use of water
Water resilience
Stakeholders
Water users
Institutions
Psychological factors
Understand risk and water use.
Attitude
Norms
Ability
Self-regulating
Trust
RANAS model
Values
Beliefs
Alternative water use
Water reuse
VBN Theory
Contextual factors
Socio-economic
Technical
Institutional
Environmental
Empowerment of communities and policy and strategies

13

Knowledge Gap in Water Use Behavior and Water Resilience

Water systems around the world are embedded in inflexible infrastructure legacies and design paradigms that are slow to adapt to change (Bell et al., 2017; Brown et al., 2009; White, 2010). Despite mounting evidence that transformation is required, the water sector has struggled to implement genuinely new and revolutionary approaches. There are still significant gaps between the policy aims of increasing water resilience. Knowledge gaps, including but not limited to "water resilience," have the ability to promote theoretical and philosophical innovation in order to reimagine water systems as complex socio-eco-technological systems characterized by nonlinear dynamics and unexpected behavior.

The ability to "return to a new normal" by efficiently coping with negative repercussions or rapid-onset disasters, the ability to adapt to new conditions effectively, and the ability to accommodate dramatic shifts are all examples of resilience. In this setting, the demand for novel resilience concepts, methodologies, and guidance has risen rapidly in recent years, with a particular emphasis on catastrophe risk reduction, which is strongly linked to infrastructure resilience and climate adaptation. Even though the topic has been widely explored in theoretical research, remarkable instances of resilience practice in the water sector are scarce.

The conceptual model proposes to close the identified gaps in a variety of methods (as indicated above). The model evaluates WUE behavior using an extension of the RANAS model to include aspects related to institutions based on current psychological models and theories such as RANAS and VBN. In addition, the model concept provides a "flexible" strategy that can be used, adjusted, or expanded to additional water use contexts (via water use behavior and water resilience). The incorporation of institutional factors also allows for the interpretation of the water use behavior of individuals in water supply organizations as well as relationships between water consumers and water supply organizations. Several authors have highlighted additional crucial governance characteristics for resilience, such as polycentric governance, and others are disputing the advantages of decentralized forms of governance in terms of increased resilience to water-related stressors (Pahl-Wostl et al., 2012; Rijke et al., 2013).

The factors and WUE must be measured in order to explain and identify the linkages within the conceptual model between components and their influence on (in) efficient water use. For each element, a set of factors is identified, such as socio-demographic variables, attitude and perception variables, and water consumption and availability. These factors can then be measured using RANAS-inspired surveys, interviews, and field measurements of water usage and supply (e.g., rainfall) fluxes (Daniel et al., 2019). Overall, the water resilience literature is quite broad, focusing on various water sectors, dimensions, or dangers, posing both conceptual and practical issues for water administration.

Water resilience concept

Definition of Water Resilience

As previously said, resilience, specifically water resilience, is a difficult subject to express when discussing environmental sustainability. It's simple to come up with an accurate, concise description; it's more difficult to construct a definition that incorporates all our planet's worldwide water concerns in the twenty-first century. Academics around the world will continue to debate what resilience means to them, and no one definition is likely to emerge anytime soon. However, water resilience" can be defined as a society's ability to adapt to changes in the availability of water resources forced upon it by changing weather patterns or socio-ecological factors, and its ability to respond to these long-term changes in water use in an uncertain future (WTS, 2023).

Approaches to Achieve Water Resilience/ Factors underlying Water Resilience

A large number of attributes are important for or contribute to increased resilience in the water-related system. Some authors argue that resilient systems are those capable of adapting to a wide range of potential climate scenarios (Howard et al., 2010). Medd & Chappells (2007) advocate for higher resilience among water providers by increasing network interconnectivity on a local or regional grid level to improve supply-demand balance. Cross-sectoral collaboration, according to Dunn et al. (2016), is a crucial element of successful urban transitions toward resilient urban water management in Rotterdam.

The analysis reveals that the peer-reviewed academic literature on water resilience is still highly fragmented by sector, echoing the fragmentation of the water industry as a whole. While much of the literature on water resilience focuses on infrastructure resilience, there is still a lack of understanding of the factors, practices, and governance principles that help increase the resilience of people, communities, and the environment to water-related risks. Despite calls for water security and resilience to be primarily governance concerns, the literature remains slanted toward technocratic management of infrastructural aspects of water sector resilience building. As a result, there is a risk that the prevalent technocratic, infrastructure-centered thinking regarding water resilience may successfully block potentially transformative movements toward more flexible, adaptive, and ultimately more resilient forms of water management.

In terms of governance dimensions, stakeholder engagement, and involvement are typically viewed as activities that aid in obtaining buy-in or social acceptance for resilience-building actions that governments and water management primarily determine. This suggests that equity and participation are viewed as vital only later in the resilience-building process and are not necessarily highlighted or understood in relation to early planning and decision-making stages. This can be quite troublesome, as many claim that stakeholder engagement and participation are critical to resilient water systems. There is limited evidence for innovation or change in the water sector towards climate-sensitive, resilient, and equitable water governance outside of the modestly growing literature on adaptive and polycentric governance and work on using water-sensitive principles in water planning. There are presently very few examples of effectively applied creative methods to water resilience in the literature. This provides an opportunity for both researchers and water planners to question traditional models of governance and propose prospects for water sector transformation. The characteristics of water resiliency systems are summarized in Table 3.

Table 3: Characteristics of Water Resilience Systems

Characteristics of Water Resilience Systems	
Category	**System characteristics**
Built/natural systems design characteristics	Robust
	Having redundancy
	Able to recover quickly
	Having buffer capacity
	Multi-functional systems
Social system characteristics	Collaborative
	Involving social learning
	Decentered
	Participatory
	Involving diverse knowledge
	Able to deal with uncertainty
	Equitable
	Resourceful
	Legitimate
	Transparent
General system properties (may apply to social, built, or ecological systems)	Adaptive
	Interconnected
	Flexible
	Having diversity
	Transformative
Institutional and governance characteristics and practices that increase resilience.	
Unspecified	Papers that did not discuss or specify any institutional or governance processes as necessary or important for building resilience.
Collaborative processes	Example: Ericksen (2015) argues for collaborative watershed governance,

	involving coordination between watershed groups, institutions, agencies at different governance scales, and policymakers as key for building resilience.
Stakeholder engagement	Example: Kirchoff and Dilling (2016) argue that collaboration, coordination, and deliberation among diverse stakeholders across scales are critical for adaptive and resilient water governance.
Government-led (top-down)	Example: Watson et al. (2017) discuss a case of building resilience to water scarcity in Australia as an institutional and regulatory effort; that is, resilience can be enhanced through government-led policy and incentives.
New cross-sectoral institutions/ arrangements	Salinas Rodriguez et al. (2014) discuss resilience in the context of water-sensitive urban design and highlight the need for new programs or alliances at the municipal level that cross beyond traditional water departments and institutions to be able to address complex and interconnected challenges.
Inclusive governance	Example: Kirchoff & Dilling (2016) argue that one of the features of adaptive, resilient water governance is diverse and representative participation, collaboration, and deliberation.
Community/civil society-led	Example: Altaweel et al. (2010) discuss resilience building to changes in freshwater in

	rural Alaska as a community effort, stressing community decision-making processes and strong social relationships as central to increased social resilience.
Equity	Example: Gooch & Rigano (2010) identified a lack of equity as a barrier to community-scale social resilience in a study from northern Queensland, presumably implying that equity enables or strengthens social resilience.
Transparent Governance	Akamani (2016) argues for analytic deliberation (i.e., well-structured dialogue involving scientists, resource users, and the interested public, informed by analysis of key information about environmental and human-environment systems) as a way to address the need for inclusive and integrative institutional mechanisms for the transparent and evidence-based negotiation of trade-offs among stakeholders in the water governance process for resilience.
Capacity building	Green et al. (2013) stress both institutional and local capacity building as key to the resilience of transboundary treaties in the Okavango river basin.
Multi-level governance	According to Lu et al. (2013), among the characteristics of urban resilience to flooding risk (in Rotterdam) is multi-level coordination in decision-making between national, provincial and local governments.

Participatory processes	Green et al. (2013) further argue that meaningful public participation—the exchange of information and input that occurs at a time and place convenient to local citizen volunteers—is key for institutional resilience.
Integrated governance	Caniglia et al. (2016) see fragmentation as a barrier to adaptive and resilient governance and, therefore, argue for integration and open communication between the different actors or agencies.
Adaptive governance	Clarvis et al. (2014) apply resilience to re-conceptualize water law as a complex adaptive system and argue that legal frameworks should be more adaptive and flexible to meet new and diverse challenges.
Accountability	Johannessen & Wamsler (2017) discuss what resilience in urban water systems means and highlight accountability (and notably improved accountability in urban water systems) as an enabling factor of socioeconomic resilience as it helps build trust and enhance human agency and thus facilitate easier transition processes towards water sensitive cities.
Mix of centralized and decentralized processes	Rijke et al. (2013) provide important insights regarding the need for a mix of centralized and decentralized, and formal and informal governance approaches to support effective governance of water infrastructure during different stages of adapting to drought and

	transitioning to a water-sensitive city that is resilient to immediate and gradual change.
Social legitimacy	Cosens & Williams (2012) identify social legitimacy (public acceptance of governmental action) as a significant gap in thinking about social resilience. Specifically, they argue that decisions about whether to use adaptive management, what to monitor, and how to make incremental adjustments must be made in a manner that fosters legitimacy.

Sources: Authors' compilation from different sources

Conclusions

Several factors have hampered the success of numerous efforts to adopt water-resilience measures. One reason for higher-than-expected demand and inefficient water usage is human behavior, which is related to a lack of an integrated assessment of behavioral and environmental factors influencing water use behavior.

The research found a number of contextual and psychological elements driving the behavior based on a comprehensive review. Based on current models and theories, a conceptual model was constructed that includes both groups of components and offers linkages between water consumers and institutions to better explain (in)efficient water usage. Involving water managers makes it easier to examine the institutional linkages that exist between water consumers and water management. This will reveal the impact of institutions or organizations on water consumers' behavior and vice versa.

Local observations and social surveys should offer the necessary data to build the model and assess the elements impacting behavior. The article also highlighted the importance of water consumers and institutions participating in the water use chain in making decisions and implementing actions that affect water resilience. The concentration on end users, such as homes, sometimes implies that other stakeholders in the water supply chain, such as institutional stakeholders (organizations/water managers), are mostly disregarded. Linking water resilience knowledge with stakeholder perceptions would lead to a more thorough assessment of water resilience and change in water use behavior. Some of the suggestions to effectively align water resilience with water use behavior are :

Empowered communities- Active community engagement and participation; effective communication of government programs and policies; promotion of social cohesiveness and strong community networks and support for civil society institutions

Policies /strategies- Incorporation of expert and technical knowledge, local knowledge, and culture into decision-making; incorporation of social, environmental, and economic costs and benefits into decision-making; a long-term strategy is in place to guide projects and programs that build on water resilience over time, political leadership promotes resilience as a priority issue in government decision-making, proactive coordination around downstream/upstream; between/within government agencies, promotion of clear stakeholder roles and responsibilities; Effective enforcement of economic regulations for water;

Much more research is needed, however, to understand better the intricate interplay between the technical, ecological, and societal elements of complex water systems, as well as the governance implications of water resilience and water use behavior alignment.

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IFMA24: Resilience through Innovation

WATER RESILIENCE AND CHANGE OF WATER USE BEHAVIOR

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Abstract

One of the barriers to water resilience is human behavior, which is influenced by a number of contextual and psychological factors. Contextual factors include socioeconomic, technical, institutional, and environmental factors, while behavioral factors include but are not limited to factors associated with the perception of risk, attitudes, and norms. Nonetheless, few studies consider an integrated view of these factors in shaping water use behavior and water resilience. This paper consolidates contextual and behavioral factors influencing water use and resilience. Knowledge gaps, including but not limited to water resilience, can stimulate theoretical and philosophical innovation to reimagine water systems as complex socio-eco-technological systems characterized by nonlinear dynamics and unexpected behavior. Based on the gaps identified, the paper proposes a conceptual model that connects contextual behavioral factors and water resilience and represents potential cause-effect relationships as supported by various behavior approaches and psychological theories. This model proposes an institutional factor to assess the relationship between institutions and stakeholders and contextual factors linked not only for individual water users but also for individuals of water supply organizations based on a review of the literature on water use and water resilience, including but not limited to conservation behavior, psychology, and water use models.

Keywords: Human behavior, Psychology, Innovation, Institutions, Stakeholders, Contextual factors

Introduction

Every day, significant volumes of water are drawn from inland surface water bodies (e.g., rivers, lakes, wetlands, and reservoirs) and aquifers for a variety of reasons, including agriculture, residential, energy generation, and industrial use. Water withdrawal has expanded about twice as quickly as the global population (FAO, n.d.). Agriculture is the most water-intensive industry, accounting for around 69% of worldwide water withdrawals (FAO, 2018). Water scarcity has resulted from drawing water quicker than it is recharged (Moncaleano et al., 2021).

The gap between worldwide water withdrawals and actual water demand is substantial and growing. One explanation for this disparity is inefficient water use, which leads to higher consumption when it might be reduced (Wang et al., 2015; Nazari et al., 2018; Ding et al., 2019; Ghanim, 2019). As a result of over-extraction, rivers and groundwater supplies around the world are running dry (Jorgensen et al., 2009; Graymore et al., 2010; Arto et al., 2016; Bhaduri et al., 2016; Mekonnen & Hoekstra, 2016; Lund et al., 2018).

Water inefficiency also has an impact on the provision of environmental flows, contributing to environmental deterioration and economic instability (Mekonnen & Hoekstra, 2016; Vieira et al., 2017; Piedra-Muoz et al., 2018). Policymakers and water managers have frequently recommended efficient water utilization as a method to reduce the inflated gap between water extractions and water demand.

Resilience remains relevant and widely debated (e.g., Eakin et al., 2017; Folke, 2016; Rodina, 2018), as there is now a growing body of work that aims to situate and (re) contextualize resilience within the complex realities of environmental change and resource governance in various contexts (e.g., Brown, 2016; Meerow et al., Rockström et al., 2014; Rodina et al., 2017; Vale, 2014; Ziervogel et al., 2017)

The pillars of those global and local strategies, such as the Sustainable Development Goals (SDGs) of the United Nations, include increasing water resilience, efficient usage, and changing water use behavior (Cole et al., 2018; Ortigara et al., 2018). Water efficiency and resilience are frequently related to technical factors that affect the performance of water utilities, such as water leakages in water distribution systems, poor management, and irrigation system maintenance (EEA, 2007). Other issues, such as those associated with water psychology, impacting the behavior and decisions of relevant water users, are typically overlooked by policymakers. Mosler (2012) describes behavior as the product of an individual's psychological processing of factors. Therefore, a comprehensive assessment of these factors and their relationships is needed to provide insights into the causes of over-extraction, the interdependence between stakeholders, and the effects on water resilience.

Methodology

This article is based on a systematic scoping review. It presents a quantitative analysis of coded data that was used to identify themes that were investigated in greater detail through a qualitative analysis (i.e., detailed review), including an evaluation of water use behavior and water resilient system characteristics. The scoping study covers the English language peer-reviewed academic literature in the Web of Science and ProQuest scholarly databases that use the phrase "water resilience" in the context of water usage behavior. Second, the analysis delves deeper into the practices, solutions, evidence, and controversies that arise from the literature in order to provide more insights into water use behavior dimensions of water resilience.

Change of water use behavior concept

Contextual factors and Definition of Change in Water Use behavior

Water usage behavior is described as an environmental behavior in the context of water use. Environmental behavior, according to Steg and de Groot (2018), is "any behavior that has a good or bad impact on the environment." Contextual and behavioral factors influence this behavior (Carrus et al., 2010; Graymore et al., 2010; Russell & Fielding, 2010). Perceptions, thoughts, feelings, and beliefs that influence behavior are examples of behavioral factors. These factors, taken together, represent an individual's attitude in relation to conduct (Contzen & Mosler, 2012).

Several theories and models have been used to analyze environmental behavior, such as the theory of planned behavior (TPB) (Ajzen, 1991), the new environmental paradigm (NEP) (Dunlap et al., 2000); the theory of environmentally significant behavior (Stern, 2000); the risk, attitude, norms, abilities, and self-regulation (RANAS) model (Contzen & Mosler, 2012); the norm activation model (NAM) and the theory of values (Steg and de Groot, 2018); the values, beliefs, and norms theory (VBN) (Stern, 2000; Yildirim & Semiz, 2019) (refer Table 1)

Table 1: Models and theories and factors to understand water use behavior

Model or theory	**Approach**	**Factors**
The norm activation model (NAM) (Steg & de Groot (2018))	The pro-environmental actions follow from the activation of personal norms, reflecting feelings of moral obligation to perform actions. Experimental studies have shown that NAM variables are causally related.	Personal norms are activated by problem awareness, ascription of responsibility, outcome efficacy, and self-efficacy.
The new environmental paradigm (NEP) (Dunlap & Van Liere (2010) and Russell & Fielding (2010))	The NEP focused on beliefs about humanity's ability to upset the balance of nature, the existence of limits to growth for human societies, and humanity's right to rule over the rest of nature.	Beliefs
Theory of planned behavior (TPB) (Steg & de Groot (2018))	Behavior results from the intention to engage in specific behavior. The TPB assumes that socio-demographics and values influence behavior indirectly via attitudes, subjective norms, and	Attitudes, subjective norms, and perceived behavioral

	perceived behavior. Attitudes express a positive or negative stance toward a behavior; subjective norms, normative factors represent convictions about the incidence of a behavior and how the social network thinks about the behavior; perceived behavioral control ability factors represent the aptitudes and individual beliefs.	
Theory of values (Steg & de Groot (2018))	Values include beliefs about the desirability or undesirability of certain end-states that transcend specific situations. Values serve as guideline principles for the evaluation of people and behaviors.	Key values for pro-environmental behavior. These are separated into two dimensions: Self-transcendence, altruism, and biospheric. Self-enhancement; egoistic and hedonic.
The theory of environmentally significant behavior (Stern (2000))	This theory assesses the definitions, classifies the precursors of environmental behavior, evaluates the links between environmental concern and behavior, and identifies the factors that determine environmentally significant behavior.	Causal variables: attitudinal, personal capabilities; contextual factors; habit and routine.
The value-belief-norm theory (VBN) (Steg & de Groot (2018); Russell & Fielding (2010); Stern (2000); Contzen & Mosler (2012); Dietz (2014)).	This theory is an extension of the NAM and links the values theory, the norm activation theory (NAM), and the new environmental paradigm (NEP). A causal chain of values (biospheric, altruistic, and egoistic), beliefs, and personal norms trigger the behavior.	Values; beliefs on relationships between humans and the natural environment reflected by ecological worldview norms.

	Beliefs consist of personal worldviews of concerns or perceptions about the consequences of human actions that may harm the environment; norms relate to moral obligations to engage in an environmental behavior; values are central to any decision-making process and guide behavior and attitudes.	
Risk, attitude, norm, abilities, self-regulation (RANAS) (Steg & de Groot (2018); Contzen & Mosler (2012)).	This model systematically identifies, measures, and integrates behavioral and contextual factors to assess behavior at an individual scale. The RANAS model derives the factors on the basis of quantitative data. Behavioral outcomes: behavior, intention, and habit. Risk: perceived vulnerability. Attitude: instrumental beliefs, affective beliefs. Normative: descriptive, injunctive, and personal norms. Ability: action knowledge, self-efficacy, maintenance efficacy, recovery efficacy. Self-regulation: action control/planning, coping planning, remembering, commitment.	Risk, attitude, ability; self-regulation.

Sources: Author's compilation from different sources

To explain and affect behavior, the RANAS model incorporates the most important behavioral theories. It has two major benefits: first, it can be tailored to a wide range of behaviors in a wide range of contexts and populations, and second, it provides a standard template of questions for measuring behavioral components and analyzing behavior. This allows for the comparison of multiple sites or scenarios (Dreibelbis et al., 2013). Water, sanitation, and hygiene (WASH) behaviors such as handwashing and adoption of household water treatment technology have been assessed using risk, attitude, norms, abilities, and self-regulation (Contzen & Mosler, 2012; Mosler, 2012; Dreibelbis et al., 2013; Lilje & Mosler, 2018; Daniel et al., 2019; Nunbogu et al., 2019). Knowledge, beliefs, and emotions are RANAS characteristics that are linked to an individual's water usage psychology and influence the practice of behavior in the context of water use (Mosler & Contzen, 2016). Indeed, this model integrates behavioral components such as risk and self-regulation, both of which are important for regulating and grasping varied activities.

The TPB is one of the theories incorporated into the RANAS and has been widely used to investigate and understand environmental behaviors, including water use and its associated factors (Harland et al., 1999; Stern, 2000; Steg & Vlek, 2009; Russell & Fielding, 2010; Mosler, 2012; Fu & Wu, 2014; Yuriev et al., 2020).

The term "values" refers to "concepts or beliefs about desirable end states or behaviors that transcend specific situations and guide the evaluation of behavior and are ordered by relative importance" (Dietz et al., 2005). Values can have an immediate impact on beliefs, conventions, and behavior. Beliefs influence norms, and norms influence conduct (Roobavannan et al., 2018). In the realm of environmental behavior, values are factors that are associated with environmental concern and may influence individual decisions. These are the values of altruism, biosphericity, egoism, and hedonism (Stern, 2000; Dietz et al., 2005; Steg & de Groot, 2018). Personal norms provide a solid foundation for individuals' pro-environmental actions (Stern, 2000).

Stern (2000) established the VBN theory of environmentalism by combining values theory, NEP, and NAM. It is represented by a causal chain that incorporates values, beliefs, and norms, as well as its variables (see Figure 1). Since individual behavior is essential to analyze the psychology of why people use water efficiently or not, behavioral studies have mainly focused on individual users, e.g., how consumers react to water resilience measures and regulations (Graymore & Wallis, 2010; Lee et al., 2011; Scott et al., 2014; Jorge et al., 2015; Wang et al., 2015; Vieira et al., 2017; Kneebone et al., 2018; Nazari et al., 2018; Benedict & Hussein, 2019; Kapetas et al., 2019; Koh, 2020). Several stakeholders, including farmers and households from rural communities, have been considered.

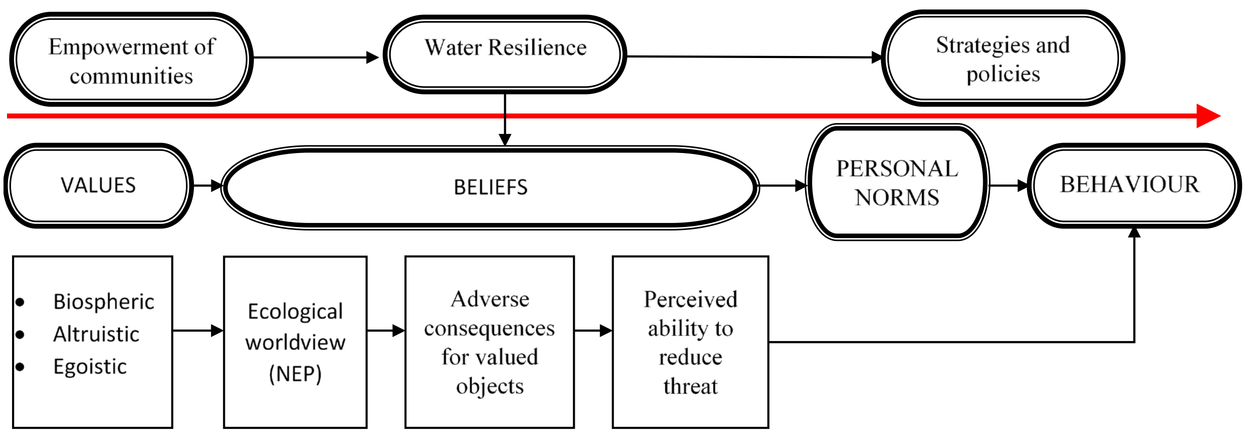


Figure 1: Integrated theories and models of water use behavior and water resilience
Sources: Author's compilation and Adopted from Dietz et al. (2005) & Srern (2000)

Individuals' background characteristics and their physical environment are referred to as contextual factors (Dreibelbis et al., 2013). These have varying effects on behavioral aspects and can either assist or hinder behavior (Contzen & Mosler, 2012). Contextual elements include social, economic, technological, environmental, and institutional origins, acquired skills, immediate personal circumstances, economic resources, capacities, regulations, resilience, and so on.

Determinants are behavioral characteristics that can instantly influence individual behavior (Jager & Joachim Mosler, 2007; Dreibelbis et al., 2013). These are also activities and habits that can be immediately observed, as well as variables that influence people's mindsets. The contextual factors studied in the context of water resilience are social, economic, environmental, technical, and institutional (Jorgensen et al., 2009; Millock & Nauges, 2010; Russell & Fielding, 2010; Lee et al., 2011; Willis et al., 2013; Scott et al., 2014; Hussien & Memon, 2016; Vieira et al., 2017; Kneebone et al., 2018; Nazari et al., 2018; Benedict & Hussein, 2019; Kapetas et al., 2019; Koh, 2020). Table 2 outlines the social, technical, Institutional, and Environmental factors for water use behavior and resilience.

Table 2: Social, technical, Institutional, and Environmental factors**.**

	Sources	**Remark**
Socioeconomic factors		
• Age • Gender • Education level • Information • Networking • Household characteristics • Population density	Beal et al. (2013). Tang et al. (2013); Attari (2014); Chang et al. (2016); Dean et al. (2016); Piedra-Muñoz et al. (2018); Khair et al. (2019); Russell & Fielding (2010); Dreibelbis et al. (2013); Benito et al. (2019); Zhang & Xu (2019); Russell et al. (2020).	-Key socio-demographic factors that contextualize water use. -Age, education level, information, and networking are strongly associated with knowledge about water use, which is a core component of solving water-related problems. These factors have been shown to be important in predicting water use.
Technical factors		
• Training • Data availability	Dean et al. (2016); Nazari et al. (2018); Russell et al. (2020).	-Training facilitates a better understanding of water usage and knowledge of good water management practices and better-informed decisions.

9

• Elaboration of water use behavior plans • Infrastructure and technology readiness • Performance of utilities in terms of financial • Capacity to supply water demand		-These factors have been shown to be important in predicting water use.
Institutional and Environmental		
• Goals to guide • Enable and constrain the actions of individuals. • Firms, households, and other decision-making units • Shaping human interactions around water use • Coordinating activities	Vitola & Senfelde (2015); Lynne et al. (1991); Stern (2000); Geels (2004); Kapetas et al. (2019); Ostrom (1990); Aligica (2006); Koehler et al. (2018); Khair et al.(2019); Dean et al. (2016).	-These may activate values and shape the beliefs of individuals and can change the behavior of many toward water use. -The environmental factors refer to geographical experiences that are connected with associative learning. -Institutional factors involve institutional relationships between water users and the water supply systems and regulations.

• Designing and implementing policies • Facilitates information and promotes incentives to encourage people to use water appropriately		

Sources: Authors' compilation from different sources.

A conceptual model to understand water use behavior and resilience

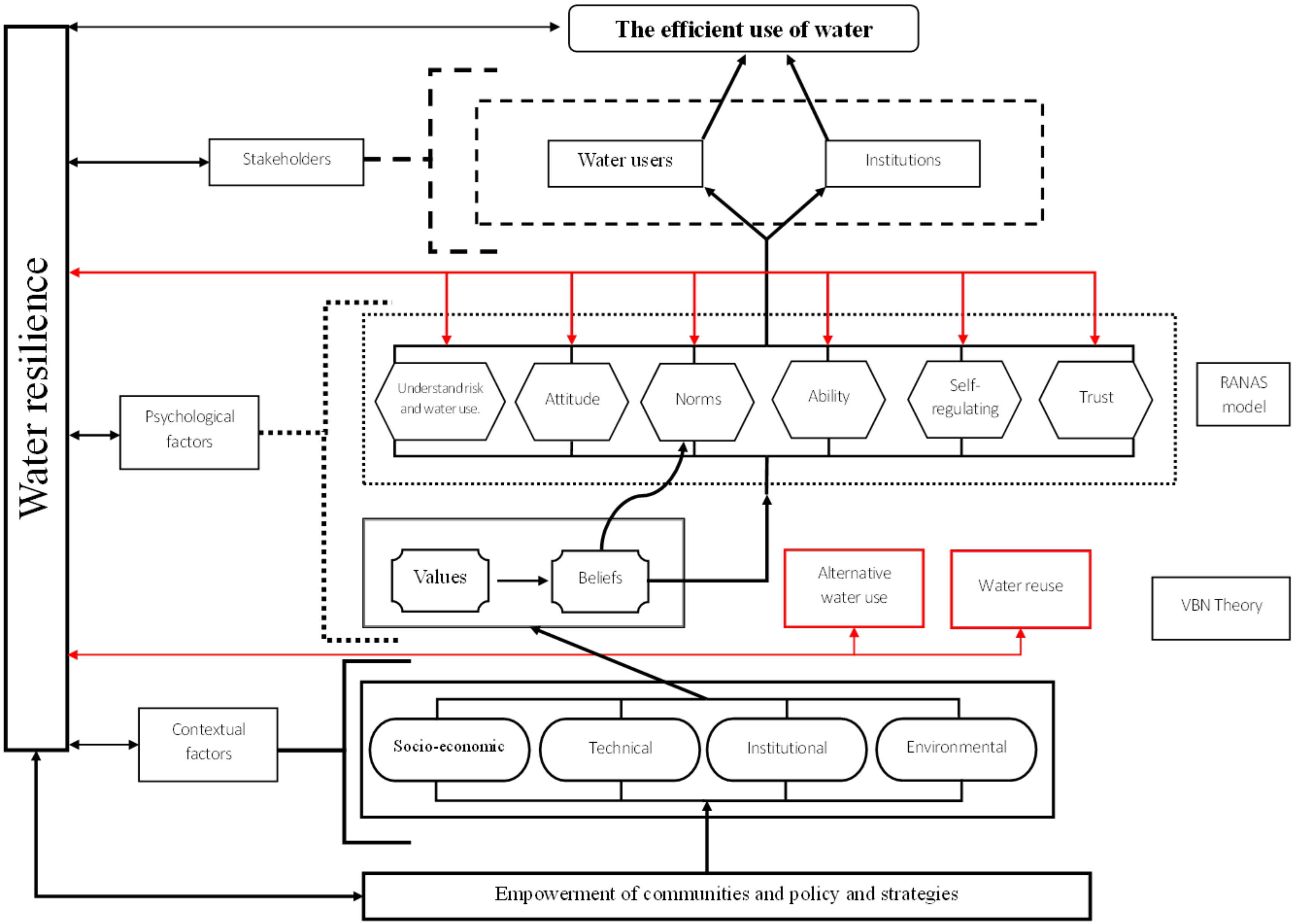
Existing approaches for measuring and understanding environmental behavior are used as a guide and source of inspiration. These include the model of behavior change (Contzen & Mosler, 2012) that has been used for the water and sanitation sector in developing countries (Mosler, 2012); the framework of Steg & Vlek (2009) for understanding and promoting pro-environmental behavior; the research of Carrus et al. (2010) for studying the socio-psychological and contextual predictors to assess sustainable water consumption and the causal chain of factors across the environmental significant behavior (Stern, 2000). The ability of systems (social or biophysical) to tolerate or cope with risks, shocks, or stressors (whether climate change impacts, social crises, economic shocks, or catastrophic occurrences) while maintaining certain critical functions or structures is well acknowledged. Definitions of resilience have been expanded to incorporate the concept of adjusting to change in order to achieve more desired states (Folke, 2016; Rodina, 2018).

A causal hierarchy of contextual and behavioral elements is posited in order to argue that context influences psychological and behavioral characteristics, which influence individuals' environmental behavior. All of these elements work together to determine the behavioral outcome in terms of water efficiency. The model consists of three major components: contextual variables, behavioral (or psychological) factors, and water consumers, water resilience, and stakeholders (refer to Figure 2). Resilience thinking has been widely debated and (re)defined as a method for conceiving social-ecological systems as complex adaptive systems (Rodina et al., 2017).

The efficient use of water behavior is a result of the psychological processing of factors intrinsic to an individual and involves the execution of responsible pro-environmental actions (Steg & de Groot, 2018; Steg and Vlek, 2009; Mosler, 2012). The behavior involves curtailment actions that are associated with resource conservation and efficiency actions that are related to the installation of water efficiency technology and water resilience (Russell & Fielding, 2010; Beal et al., 2013). These actions can include harvesting water by using rain barrels, both of which have positive impacts on water use due to less water consumption and withdrawals. In terms of specific dimensions of water resilience, arguments have been made for increased flexibility in the water sector and increased reliance on nature as a flexible option with multiple benefits—from flood risk mitigation to improving water supply and quality (Bell et al., 2017).

Figure 2: Contextual and psychological factors within the conceptual framework of water use behavior and water resilience

Sources: Author's compilation based on different sources



The efficient use of water
Water resilience
Stakeholders
Water users
Institutions
Psychological factors
Understand risk and water use.
Attitude
Norms
Ability
Self-regulating
Trust
RANAS model
Values
Beliefs
Alternative water use
Water reuse
VBN Theory
Contextual factors
Socio-economic
Technical
Institutional
Environmental
Empowerment of communities and policy and strategies

13

Knowledge Gap in Water Use Behavior and Water Resilience

Water systems around the world are embedded in inflexible infrastructure legacies and design paradigms that are slow to adapt to change (Bell et al., 2017; Brown et al., 2009; White, 2010). Despite mounting evidence that transformation is required, the water sector has struggled to implement genuinely new and revolutionary approaches. There are still significant gaps between the policy aims of increasing water resilience. Knowledge gaps, including but not limited to "water resilience," have the ability to promote theoretical and philosophical innovation in order to reimagine water systems as complex socio-eco-technological systems characterized by nonlinear dynamics and unexpected behavior.

The ability to "return to a new normal" by efficiently coping with negative repercussions or rapid-onset disasters, the ability to adapt to new conditions effectively, and the ability to accommodate dramatic shifts are all examples of resilience. In this setting, the demand for novel resilience concepts, methodologies, and guidance has risen rapidly in recent years, with a particular emphasis on catastrophe risk reduction, which is strongly linked to infrastructure resilience and climate adaptation. Even though the topic has been widely explored in theoretical research, remarkable instances of resilience practice in the water sector are scarce.

The conceptual model proposes to close the identified gaps in a variety of methods (as indicated above). The model evaluates WUE behavior using an extension of the RANAS model to include aspects related to institutions based on current psychological models and theories such as RANAS and VBN. In addition, the model concept provides a "flexible" strategy that can be used, adjusted, or expanded to additional water use contexts (via water use behavior and water resilience). The incorporation of institutional factors also allows for the interpretation of the water use behavior of individuals in water supply organizations as well as relationships between water consumers and water supply organizations. Several authors have highlighted additional crucial governance characteristics for resilience, such as polycentric governance, and others are disputing the advantages of decentralized forms of governance in terms of increased resilience to water-related stressors (Pahl-Wostl et al., 2012; Rijke et al., 2013).

The factors and WUE must be measured in order to explain and identify the linkages within the conceptual model between components and their influence on (in) efficient water use. For each element, a set of factors is identified, such as socio-demographic variables, attitude and perception variables, and water consumption and availability. These factors can then be measured using RANAS-inspired surveys, interviews, and field measurements of water usage and supply (e.g., rainfall) fluxes (Daniel et al., 2019). Overall, the water resilience literature is quite broad, focusing on various water sectors, dimensions, or dangers, posing both conceptual and practical issues for water administration.

Water resilience concept

Definition of Water Resilience

As previously said, resilience, specifically water resilience, is a difficult subject to express when discussing environmental sustainability. It's simple to come up with an accurate, concise description; it's more difficult to construct a definition that incorporates all our planet's worldwide water concerns in the twenty-first century. Academics around the world will continue to debate what resilience means to them, and no one definition is likely to emerge anytime soon. However, water resilience" can be defined as a society's ability to adapt to changes in the availability of water resources forced upon it by changing weather patterns or socio-ecological factors, and its ability to respond to these long-term changes in water use in an uncertain future (WTS, 2023).

Approaches to Achieve Water Resilience/ Factors underlying Water Resilience

A large number of attributes are important for or contribute to increased resilience in the water-related system. Some authors argue that resilient systems are those capable of adapting to a wide range of potential climate scenarios (Howard et al., 2010). Medd & Chappells (2007) advocate for higher resilience among water providers by increasing network interconnectivity on a local or regional grid level to improve supply-demand balance. Cross-sectoral collaboration, according to Dunn et al. (2016), is a crucial element of successful urban transitions toward resilient urban water management in Rotterdam.

The analysis reveals that the peer-reviewed academic literature on water resilience is still highly fragmented by sector, echoing the fragmentation of the water industry as a whole. While much of the literature on water resilience focuses on infrastructure resilience, there is still a lack of understanding of the factors, practices, and governance principles that help increase the resilience of people, communities, and the environment to water-related risks. Despite calls for water security and resilience to be primarily governance concerns, the literature remains slanted toward technocratic management of infrastructural aspects of water sector resilience building. As a result, there is a risk that the prevalent technocratic, infrastructure-centered thinking regarding water resilience may successfully block potentially transformative movements toward more flexible, adaptive, and ultimately more resilient forms of water management.

In terms of governance dimensions, stakeholder engagement, and involvement are typically viewed as activities that aid in obtaining buy-in or social acceptance for resilience-building actions that governments and water management primarily determine. This suggests that equity and participation are viewed as vital only later in the resilience-building process and are not necessarily highlighted or understood in relation to early planning and decision-making stages. This can be quite troublesome, as many claim that stakeholder engagement and participation are critical to resilient water systems. There is limited evidence for innovation or change in the water sector towards climate-sensitive, resilient, and equitable water governance outside of the modestly growing literature on adaptive and polycentric governance and work on using water-sensitive principles in water planning. There are presently very few examples of effectively applied creative methods to water resilience in the literature. This provides an opportunity for both researchers and water planners to question traditional models of governance and propose prospects for water sector transformation. The characteristics of water resiliency systems are summarized in Table 3.

Table 3: Characteristics of Water Resilience Systems

Characteristics of Water Resilience Systems	
Category	**System characteristics**
Built/natural systems design characteristics	Robust
	Having redundancy
	Able to recover quickly
	Having buffer capacity
	Multi-functional systems
Social system characteristics	Collaborative
	Involving social learning
	Decentered
	Participatory
	Involving diverse knowledge
	Able to deal with uncertainty
	Equitable
	Resourceful
	Legitimate
	Transparent
General system properties (may apply to social, built, or ecological systems)	Adaptive
	Interconnected
	Flexible
	Having diversity
	Transformative
Institutional and governance characteristics and practices that increase resilience.	
Unspecified	Papers that did not discuss or specify any institutional or governance processes as necessary or important for building resilience.
Collaborative processes	Example: Ericksen (2015) argues for collaborative watershed governance,

	involving coordination between watershed groups, institutions, agencies at different governance scales, and policymakers as key for building resilience.
Stakeholder engagement	Example: Kirchoff and Dilling (2016) argue that collaboration, coordination, and deliberation among diverse stakeholders across scales are critical for adaptive and resilient water governance.
Government-led (top-down)	Example: Watson et al. (2017) discuss a case of building resilience to water scarcity in Australia as an institutional and regulatory effort; that is, resilience can be enhanced through government-led policy and incentives.
New cross-sectoral institutions/ arrangements	Salinas Rodriguez et al. (2014) discuss resilience in the context of water-sensitive urban design and highlight the need for new programs or alliances at the municipal level that cross beyond traditional water departments and institutions to be able to address complex and interconnected challenges.
Inclusive governance	Example: Kirchoff & Dilling (2016) argue that one of the features of adaptive, resilient water governance is diverse and representative participation, collaboration, and deliberation.
Community/civil society-led	Example: Altaweel et al. (2010) discuss resilience building to changes in freshwater in

	rural Alaska as a community effort, stressing community decision-making processes and strong social relationships as central to increased social resilience.
Equity	Example: Gooch & Rigano (2010) identified a lack of equity as a barrier to community-scale social resilience in a study from northern Queensland, presumably implying that equity enables or strengthens social resilience.
Transparent Governance	Akamani (2016) argues for analytic deliberation (i.e., well-structured dialogue involving scientists, resource users, and the interested public, informed by analysis of key information about environmental and human-environment systems) as a way to address the need for inclusive and integrative institutional mechanisms for the transparent and evidence-based negotiation of trade-offs among stakeholders in the water governance process for resilience.
Capacity building	Green et al. (2013) stress both institutional and local capacity building as key to the resilience of transboundary treaties in the Okavango river basin.
Multi-level governance	According to Lu et al. (2013), among the characteristics of urban resilience to flooding risk (in Rotterdam) is multi-level coordination in decision-making between national, provincial and local governments.

Participatory processes	Green et al. (2013) further argue that meaningful public participation—the exchange of information and input that occurs at a time and place convenient to local citizen volunteers—is key for institutional resilience.
Integrated governance	Caniglia et al. (2016) see fragmentation as a barrier to adaptive and resilient governance and, therefore, argue for integration and open communication between the different actors or agencies.
Adaptive governance	Clarvis et al. (2014) apply resilience to re-conceptualize water law as a complex adaptive system and argue that legal frameworks should be more adaptive and flexible to meet new and diverse challenges.
Accountability	Johannessen & Wamsler (2017) discuss what resilience in urban water systems means and highlight accountability (and notably improved accountability in urban water systems) as an enabling factor of socioeconomic resilience as it helps build trust and enhance human agency and thus facilitate easier transition processes towards water sensitive cities.
Mix of centralized and decentralized processes	Rijke et al. (2013) provide important insights regarding the need for a mix of centralized and decentralized, and formal and informal governance approaches to support effective governance of water infrastructure during different stages of adapting to drought and

	transitioning to a water-sensitive city that is resilient to immediate and gradual change.
Social legitimacy	Cosens & Williams (2012) identify social legitimacy (public acceptance of governmental action) as a significant gap in thinking about social resilience. Specifically, they argue that decisions about whether to use adaptive management, what to monitor, and how to make incremental adjustments must be made in a manner that fosters legitimacy.

Sources: Authors' compilation from different sources

Conclusions

Several factors have hampered the success of numerous efforts to adopt water-resilience measures. One reason for higher-than-expected demand and inefficient water usage is human behavior, which is related to a lack of an integrated assessment of behavioral and environmental factors influencing water use behavior.

The research found a number of contextual and psychological elements driving the behavior based on a comprehensive review. Based on current models and theories, a conceptual model was constructed that includes both groups of components and offers linkages between water consumers and institutions to better explain (in)efficient water usage. Involving water managers makes it easier to examine the institutional linkages that exist between water consumers and water management. This will reveal the impact of institutions or organizations on water consumers' behavior and vice versa.

Local observations and social surveys should offer the necessary data to build the model and assess the elements impacting behavior. The article also highlighted the importance of water consumers and institutions participating in the water use chain in making decisions and implementing actions that affect water resilience. The concentration on end users, such as homes, sometimes implies that other stakeholders in the water supply chain, such as institutional stakeholders (organizations/water managers), are mostly disregarded. Linking water resilience knowledge with stakeholder perceptions would lead to a more thorough assessment of water resilience and change in water use behavior. Some of the suggestions to effectively align water resilience with water use behavior are :

Empowered communities- Active community engagement and participation; effective communication of government programs and policies; promotion of social cohesiveness and strong community networks and support for civil society institutions

Policies /strategies- Incorporation of expert and technical knowledge, local knowledge, and culture into decision-making; incorporation of social, environmental, and economic costs and benefits into decision-making; a long-term strategy is in place to guide projects and programs that build on water resilience over time, political leadership promotes resilience as a priority issue in government decision-making, proactive coordination around downstream/upstream; between/within government agencies, promotion of clear stakeholder roles and responsibilities; Effective enforcement of economic regulations for water;

Much more research is needed, however, to understand better the intricate interplay between the technical, ecological, and societal elements of complex water systems, as well as the governance implications of water resilience and water use behavior alignment.

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IFMA24: Resilience through Innovation

AGRICULTURAL PRODUCTION OF BIOMASS FOR GREEN BIOREFINING CAN POSITIVELY AFFECT ENVIRONMENT AND CLIMATE

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Abstract

The purpose of the analysis is to map the biomass production potentials and effects of conversion to cultivation of crops for green biorefining. The report provides concrete bids for hectares of agricultural land converted to grass for biorefining, tons of dry matter (DM) produced in biomass and the geographical location of the production of grass for biorefining for four selected coastal water catchments. Moreover, the effect in reduced nitrate emissions and greenhouse gas emissions measured as CO_2-equivalents (CO_2e) is calculated. Three arbitrary price levels for crop rotation grass for biorefining have been selected. Both the grassland area and the quantity of grass for biomass will naturally increase with rising grass prices. It is noteworthy that the expansion of grass used for biorefining is highest in coastal water catchment areas, where a lot of grass for roughage is already grown, which is otherwise kept unchanged. A switch to a larger proportion of grass cultivation results in a significant reduction in the climate impact from crop production due to a build-up of carbon in the soil. The greatest effect is achieved with the least possible N fertilization, i.e. by using grass-clover rather than pure grass.

Keywords: Coastal water catchments, Nitrate leaching, Greenhouse gases

Introduction

The purpose of this analysis is to map the production potentials and effects of a conversion to cultivation of crops for green biorefining. In green biorefining, protein is extracted from grass and can immediately be used as a protein source in feed for monogastric animals. In the slightly longer term, it is also intended that the protein product can be used for human consumption.

The production of green protein for feed can replace alternative protein sources in the feed ration for pigs and poultry, and in the long term it can potentially completely replace the large imports of soy that are currently used for feed. In the extraction of protein, there is also an output in the form of grass pulp, which can potentially be used for cattle feed or in biogas plants (Larsen *et al.*, 2019). In relation to the cascading utilization of biomass, it is preferable that the pulp is used as cattle feed, after which the cattle manure can be utilized in biogas plants. However, there is a balance between the degree of processing and the quality of the pulp for feed afterwards. If there is a high degree of processing, a lot of protein can be extracted from the grass, but then the pulp is less suitable as feed (Zoppi *et al.*, 2023). In this report, it is an important prerequisite that the grass pulp is not used as feed for cattle, as this would reduce the area requirement to produce roughage for cattle. This means that if the grass pulp was used for cattle feed, dairy farmers would be able to produce more grass for biorefining and receive pulp to cover feed needs, which would increase the grass potential for biorefining.

The focus of the analysis is primarily on conventionally managed areas and is carried out based on the assumption that the existing cattle population is maintained.

Grass is an interesting crop to grow as an alternative to annual crops, as there is potential for a lower nitrate leaching from grass cultivation compared to cereal crops (Jørgensen *et al.*, 2022). This is due, among other things, to the long growing season without fallow land after harvest. In addition to the reduced leaching, there is a build-up of organic matter in the topsoil during grass growth, which retains carbon in the soil and can thus reduce net emissions of greenhouse gases. In grass cultivation, there is also a lower pesticide consumption, which is attractive in relation to groundwater protection. The impact assessment of the global warming potential (GWP) reduction potential has been calculated with an economically optimal crop rotation as reference where selling biomass for biorefineries is not an option.

The economics of the biorefining plant and the costs of transporting the biomass are not included in this analysis. The results from this study are thus relevant to assess the expected price to offer farmers for grass for it to be an interesting crop. In addition, the results are relevant in relation to assessing which natural conditions (soil type, N-retention, etc.) determine where grass for biorefining can be produced at the lowest price.

Data and methodology

The quantitative calculations of the analysis are carried out using a *New Discharge-Based Area Regulation Model* (NDAR) developed by University of Aarhus, SEGES and University of Copenhagen, which to the greatest extent possible targets nitrate regulation in agriculture to areas with the greatest environmental impact compared to costs within coastal water basins (Eriksen et al., in preparation). In the model, coastal discharges are calculated for all fields in the catchment areas based on crop rotation, nitrogen use and the use of mitigating measures in the form of reduced fertilizer use, catch crops, intermediate catch crops, early sowing of winter cereals, crop rotation changes and precision agriculture.

The starting point for estimating the biomass potential is nitrogen regulation within the framework of the NDAR model. These are combined with financial incentives to grow more grass in the form of different prices for supplying grass to the biorefinery plant.

The regulatory principle expected in the future is that each farm is assigned a coastal discharge quota that must be respected. The nitrate quotas are derived from an overall discharge target to the coast from agriculture, which for most coastal waters is lower than current discharges. The analysis is made for the coastal water catchments Karrebæk Fiord, Knudedyb, Horsens Fiord and Thisted Fiord catchment area (see Appendix 1 for location). The discharge targets are differentiated for each of the four selected coastal water basins, but the same shadow price for nitrate discharge is used in all catchment areas. Thereby, the same three scenarios for the shadow price of coastal nitrate discharges apply to the four coastal water basins. Although the shadow price is used to define scenarios, the model results still indicate how much coastal discharges will be reduced for the four coastal river basins under different shadow prices and biomass prices.

The discharges to the coast are calculated with the greatest possible degree of detail, where the runoff/precipitation is estimated within the 10 x 10 km climate grid in which each field is located (Wang & Scharling, 2010). In addition, leaching from the root zone is determined using the officially used statistical model to determine leaching (NLSES5 model, (Børgesen et al., 2020)), and retention and thus discharges are determined based on the most detailed mapping of retention in the so-called ID15 areas.

NDAR calculation

The NDAR calculator is used as an umbrella term for the many calculations that take place in the process of calculating how much extra biomass is produced when a cost of nitrate discharges to the coast is introduced, while at the same time using four different prices for grass for biorefining purposes.

In the model, inputs are the mode of operation (organic/conventional, only conventional farms used), type of manure, use of mitigating measures, reduced fertilizer application, climate grid, clay content, soil type, C-horizon, and carbon content. Under the varying model inputs, an optimal crop rotation has been calculated among 25 different crop rotations. For each average farm, 12 scenarios with three different shadow prices and four scenarios for price of grass are estimated for coastal discharges. These 12 scenarios are used to estimate a functional relationship between coastal discharges and net results.

In the next part of the NDAR calculator, average farms are defined based on GIS-processed inputs. An average farm is defined according to farm structure in 2017 within each climate grid. Thus, for each climate grid (10 x 10 km), it is enumerated how large areas belong, for example, to cattle farms.

In the NDAR model, each farm is assigned a coastal discharge quota, which becomes limiting in the behavioral model. The discharge quota can be allocated among farms according to different principles and is here determined according to the shadow price. Thus, it is implicitly assumed that the farm will receive a quota which is consistent with the marginal cost of further adjustment which is equal to either DKK 0 per kg N[1], DKK 100 per kg N or DKK 200 per kg N.The optimization in the behavioral model takes place by selecting a linear combination of the 25 crop rotations, which ensures that the conditions for meeting the discharge quota are met. The conditions in the adapted behavioral model have been adjusted to harmonize with the purpose of this project.

Crop rotation changes

In the behavioral model, changes in crop rotation for farms are determined based on the price/discharge ratio for the relevant crops. However, this will most often be via a switch from cultivation of cereals and oilseed rape to grass-clover, as this increases the production of biomass for biorefining and at the same time contributes to meeting the requirements for reduced nitrate discharges.

Depending on requirements for continued roughage production, farm type and the specific catchment area, crop rotations are adjusted as a higher nitrate shading price is applied to coastal discharges and higher prices are offered for grass for biorefining, with both gradually leading to a higher production of grass for biorefining.

When growing grass-clover, the application of nitrogen fertilizer can be reduced, and by including some years of pure grass, it is expected that problems with clover fatigue can be avoided. In recent years, breeding has resulted in new grass varieties of, among other crops, tall fescue and festulolium with a higher yield potential and a greater persistence compared to perennial ryegrass varieties. It is relevant to assess whether a higher biomass yield can generally be assumed when growing new varieties instead of ryegrass, both in grass-clover and as pure grass.

[1] 1 DKK is approximately 0.13 Euro

In the period 2006-2007, experiments were carried out comparing perennial ryegrass and Festulolium hybrids of the tall fescue type (Hykor variety), either by cultivation in pure stand or in mixture with white clover or red clover (Pedersen, 2007). Based on this, it is considered that 20 percent additional yields can be assumed by including tall fescue.

Calculation of climate effects of crop rotation changes

The climate effect of changing from a cereal-dominated crop rotation to a more grass-dominated crop rotation has been elucidated according to the same principles as in Andersen & Adamsen (2023) and as described in (Hutchings et al., 2023a).

The climate effects for conventional cultivation have been calculated for the conversion of 1 hectare from standard cereal cultivation with a fertilization of 171 kg N per hectare per year in mineral fertilizers (Hutchings & Olesen, 2023) to either growing pure grass or clover grass.

For nitrous oxide emission, the following emission factors and conversion factors have been applied according to Hutchings & Olesen (2023):

- N_2O, direct emission (percentage of input N): 1.0 percent
- N_2O, indirect emission from nitrate leaching (percentage of leached N): 0.46 percent
- NH_3 evaporation, commercial fertilizer (percentage of N input in commercial fertilizer): 4.0 per cent
- NH_3 evaporation, manure (percentage of N input in manure): 9.1 percent
- Nitrogen input in plant residues (percentage of N applied with fertilizer): 41.0 percent.
- Conversion factor from N_2O-N to N_2O (kg N_2O per kg N): 1.571
- Global Warming Potential (GWP) factor for N_2O (kg CO_2e per kg N2O): 265

Thus, it is assumed that there will be a direct emission of nitrous oxide corresponding to 1 percent of the nitrogen added. In addition, an emission of nitrous oxide related to leached nitrate and NH_3 evaporation from fertilizers and from nitrogen in plant residues is assumed. For leached nitrate, it is assumed that 0.46 percent of the leached nitrogen is converted to nitrous oxide. For commercial fertilizers and animal manure, NH_3 evaporation of 4.0 per cent and 9.1 per cent of the nitrogen input is assumed, respectively, and that 1 per cent of this NH_3-N is converted into nitrous oxide. Similarly, it is assumed that 41 percent of the added nitrogen is embedded in plant residues and that 1 percent of this nitrogen is converted to nitrous oxide, according to Hutchings & Olesen (2023).

For the carbon sequestration in the soil by a switch from cereal cultivation to permanent grassland cultivation, an increased input of 540 kg C per hectare per year is assumed, corresponding to 1,980 kg CO_2e per hectare per year according to Hutchings et al. (2023a).

Results

In Table 1, the agricultural area for the four coastal river basins is shown by conventional and organic farming areas.

Table 1. Total agricultural area for the four selected coastal river basins by farm type for conventional land and organic area (ha)

	Organic farms	Cattle/ Dairy farms	Specialized plant production	Pig production and plant production	Small and non-spec. farms	Total
Karrebæk Fiord	-	-	30.461	20.565	17.255	68.300
Knudedyb	5.243	25.009	9.320	24.722	42.696	107.000
Horsens Fiord interior	-	733	613	16.863	12.918	31.100
Thisted	906	513	-	15.087	20.174	36.700

In Figure 1, the proportion of land cultivated with grass for biorefinery under different grass prices is shown. With a reference price of DKK 1,024 per ton of dry matter (current internal price for forage for cattle feed), no grass is produced for biorefining. When the price increases by DKK 120 per ton of dry matter to DKK 1,144 per ton of dry matter, the profitability of grass cultivation increases and thus also the proportion of the area on which grass is produced for biorefining. This proportion is highest in the Knudedyb catchment area with 5, 11 and 23 percent respectively of the agricultural area for the three scenarios with prices above the internal price for roughage.

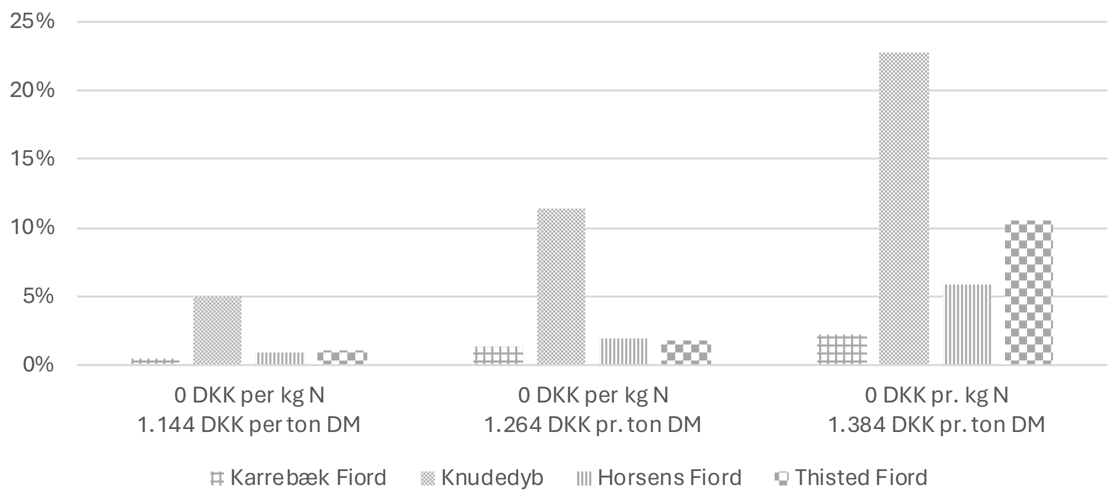

Figure 1. Share of agricultural area used for grass for biorefining under different prices for grass and with a nitrate shadow price of discharges to the coast of DKK 0 per kg N.

We also found that the nitrate shadow price of discharges was not driving the propensity to produce grass for biorefining in Denmark. Even though the discharges from grass-clover is lower than for cereal production, the share of agricultural area with grass for biorefinery was not that much higher for ambitious reductions in nitrate discharges, i.e. high shadow prices compared to low shadow prices for a given price for grass. For each farm type in Knudedyb catchment area is the amount of grass dry matter produced shown in Figure 2.

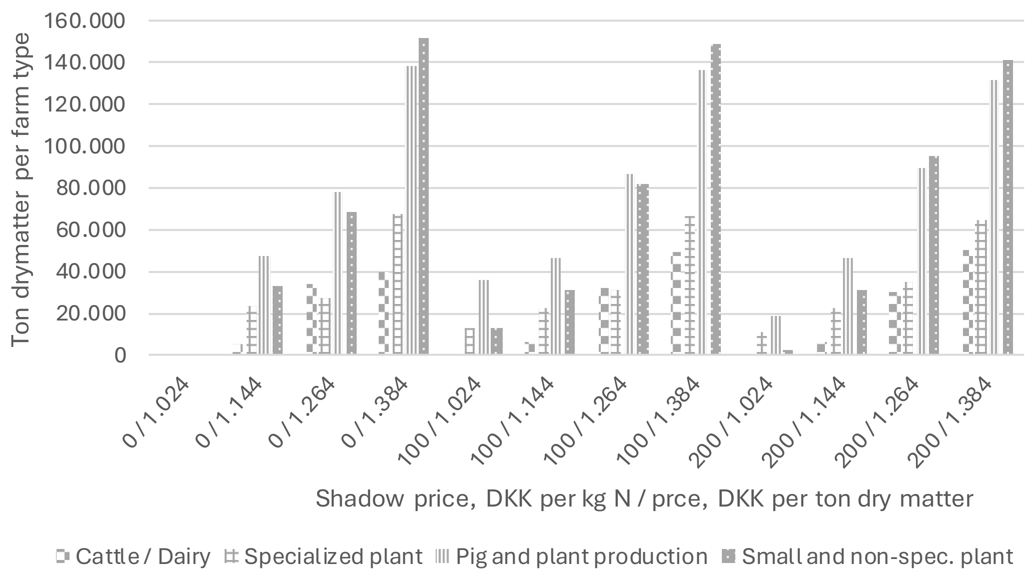

Figure 2. Amount of grass dry matter produced for biorefining in Knudedyb Catchment area under different prices for grass and with three nitrate shadow prices of discharges to the coast of DKK 0, 100, and 200 per kg N.

Climate effects of crop rotation changes

In Table 2, the reductions in greenhouse gas emissions from conversion from cereals to grass are shown for conventional cultivation and for a conversion to pure grass and grass-clover, respectively. For both combinations, there is a significant reduction in greenhouse gas emissions due to increased carbon storage when converting to grass production.

There is a slightly increased emission of CO_2e related to a higher energy consumption when growing grass than when growing cereals. The energy consumption of grass cultivation is to some extent expected to increase with an increasing yield, and thus the emission from energy consumption may be slightly higher with a larger nitrogen input. However, emissions linked to energy consumption are relatively minor compared to the effects of carbon storage and nitrous oxide discharges.

The discharge of nitrous oxide varies markedly between the three cropping systems in Table 2, and since both carbon storage and energy consumption are assumed identical for grass and grass-clover, the differences between these grass systems are solely due to the large variation in nitrogen fertilizer inputs.

As a sum of all greenhouse gas effects, there is a total reduction in greenhouse gas discharges for both combinations of cultivation and grass type, but the reduction varies from 604 kg CO_2e per hectare per year for conventional cultivation of pure grass to 1,250 kg CO_2e per hectare per year for cultivation of grass-clover. The greatest reduction is, therefore, obtained when growing grass-clover rather than pure grass.

Table 2. Greenhouse gas emission from standard cereal cultivation and reduction of greenhouse gas emission per hectare per year through a switch from standard cereal cultivation to either pure grass or grass-clover in conventional cultivation.

Greenhouse gas reductions/impacts	Greenhouse gas emission from standard cereal cultivation	Reduction in greenhouse gas emission	
		Grass	Grass-clover
	171 kg N/ha/year[1)]	394 kg N per hectare per year[1)]	287 kg N per hectare per year[1)]
CO_2 linked to LULUCF (kg CO_2e per hectare per year)	0	1.980	1.980
CH_4 (kg CO_2e per hectare per year)	0	0	0
N_2O (kg CO_2e per hectare per year)	1.147	-1.291	-645
CO_2 linked to energy consumption and liming (kg CO_2e per hectare per year)	455	-85	-85
Total emissions or reductions (kg CO_2e per hectare per year)	1.602	604	1.250

[1)]Fertilizer amounts are based on nitrogen standards. The reference is standard cereal cultivation with a fertilization of 171 kg N per hectare per year in the form of mineral fertilizer. For grass and grass-clover, the fertilizer amount corresponds to the nitrogen applied per year to these crops (average of two soil types, JB1 and JB6) in an eight-year crop rotation with three years of grass-clover, one year with barley, three years with pure grass and one year with barley.

Discussion

Effect on biomass production, environment, and climate

The results for selected coastal water catchments show that there is potential for producing grass for biorefining in areas of the country with good growing conditions for grass, if the price for the grass is in the region of DKK 1,250 per ton of biomass, the nitrate shadow price of the discharge to the coast is DKK 0 per kg N, and the other assumptions used in the investigation applies. In other parts of the country, a higher grass price may be needed to make grass production favorable. If crop prices for alternative crops rise, it will reduce the competitiveness of grasses in relation to these crops. The results also show that it is primarily the price of the grass that influences the potential for growing grass for biorefining.

A crucial assumption is that roughage production must remain unchanged. This means that the analysis will continue to use a relatively large part of the area for roughage production in those parts of the country where grass cultivation has the greatest comparative advantage against alternative crops. If the cattle population declines in those areas of the country, the land could be used for grass for biorefining.

The regulatory pressure in relation to nitrate does not affect grass potential as much as expected, which is illustrated by the increased shadow price on nitrate discharges only slightly increasing the potential conversion to grass for biorefining. One potential reason for the non-increasing competitiveness grass for biorefinery for increasing nitrate regulation could be caused by the competition from a set-a-side scheme for non-productive areas. When setting land aside is not costly then using this option as a nitrate leaching mitigation strategy is competitive compared to increasing grass production.

The regulatory pressure is modelled as the shadow price of nitrate discharges and set in a range that is assessed to be at a realistic level. With this approach, it is relatively easy to compare the potential of different coastal water basins with the same regulatory efforts. Conversely, it does not indicate which coastal water basins have high expected regulatory pressure and which water basins have a lower regulatory pressure in a future regulation.

Currently and in this analysis, the pulp fraction from biorefining of grass is used for biogas production. This is due, among other things, to the fact that the processing rate is too high for the pulp to be suitable for cattle feed. The high degree of processing and subsequent use in biogas plants currently provides the highest value of the grass. Thus, it does not help to reduce the need for roughage production on the farm. In the slightly longer term, the pulp may form part of the feed ration for dairy cows. Thus, dairy farmers will potentially be able to expand the area with grass, supply the majority for biorefining and receive the pulp for feeding afterwards. This will also increase the grass potential for biorefining.

A switch to grass cultivation leads to a significant reduction in the climate impact of the cultivation of the land, primarily due to carbon sequestration. The greatest effect is achieved by minimizing N fertilization, i.e. using grass-clover rather than pure grass, as well as by reducing the overall fertilizer level. These effects are not valued in the economic calculations. It will probably be possible to optimize the utilization of clover and alfalfa for biomass production for biorefining and thus further reduce N-fertilization and climate impact. However, one must be aware of the great need for potassium to be added to grass and legumes, which must still be applied. In the scenarios with a changed cattle population, there will be a change in manure production as well as a change in greenhouse gas emissions.

Model considerations

The NDAR model is still under development, and adjustments and changes will take place along the way. These changes will have an impact on the results presented. In addition, the specific implementation of future targeted and discharges-based land management will also have an impact on farmers' incentives. The sum of this means that there is considerable uncertainty attached to the results, but the model with the total discharge to the coast is still considered to be more relevant than calculating on some partial models that do not handle the nitrate retention from leaching from the root zone to the discharge to the coast.

Conclusion

The conclusion of this analysis is that farmers must be offered a price around 1,250 DKK per ton of dry matter for them to be expected to grow more grass. In addition, the results show that out of the four selected coastal water catchments, it is in the catchment area of Knudedyb, that grass will be produced at the lowest price. The assessment is that this is because 1) soil type plays a fairly large role in determining when grass cultivation is competitive with other crops and 2) a larger precipitation in this area, which supports the higher water use of grasslands. This is also reflected in the fact that there are many ruminants in areas with sandy soils with high precipitation such as Knudedyb, and therefore the livestock intensity with ruminants is a good proxy for where it is feasible to grow grass. However, a large part of the land is already allocated to roughage production in these areas, which is necessary to support livestock production.

The environmental benefits from conversion to grass on nitrate leaching do not immediately play a very large role in the economic potential to produce grass for biorefining. This may be related to the fact that the current set-aside subsidy can be used as a more economical alternative to reducing leaching than grass cultivation for biorefining. On the other hand, grass cultivation brings a significant climate benefit, which can be valued and which in the future can potentially help improve the profitability of the production and delivery of green biomass for biorefining.

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Appendix 1. Map of coastal basin catchments

The four chosen costal basins catchment areas in Denmark are presented in Figure A1.

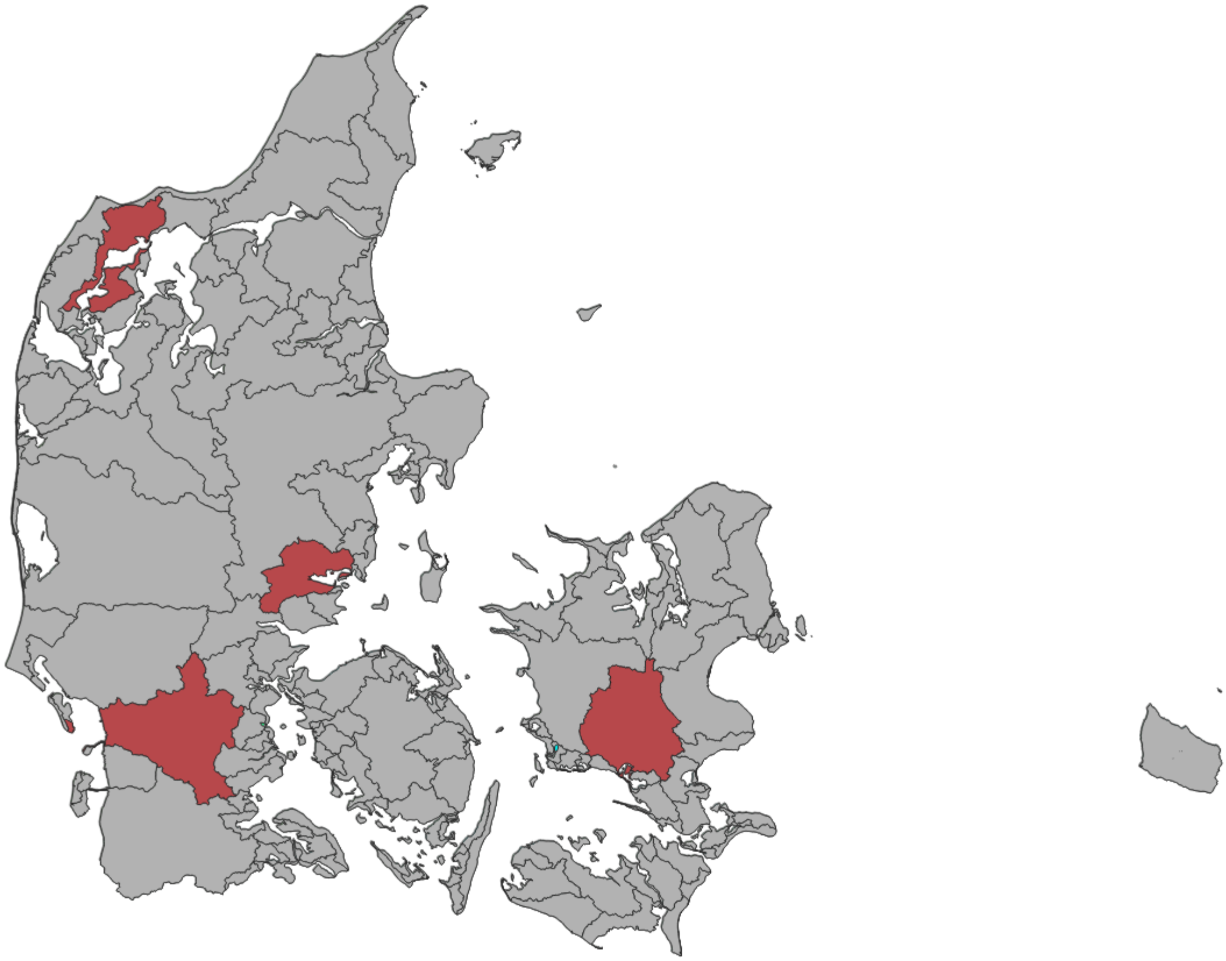

Figure A1. *The four chosen costal basins catchment areas, catchment for Karrebæk Fjord (Zealand), Knudedyb (South of Jutland), Horsens Fjord interior (East of Jutland) and Thisted (North of Jutland).*

IFMA24: Resilience through Innovation

BOOSTING COCOA FARMING INCOME: THE INTERACTION EFFECT OF ACCESS TO AGRICULTURAL EXTENSION SERVICES AND FARMER ASSOCIATION ON ADOPTION OF APPROVED PESTICIDES

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Academic Paper

Abstract

Innovation adoption is key to advancing agricultural productivity and improving farmers' economic welfare. However, farmers may exhibit reluctance towards embracing new innovations, necessitating efforts to overcome this resistance. This study aims to explore the interactive impacts of agricultural extension services and farmers organization on the adoption of approved pesticides and income generation from cocoa farming in Osun State, Nigeria. Probit and mediation analyses were used to analyze the data. The findings revealed a synergistic relationship between extension services and farmer associations in promoting the adoption of approved pesticides, increasing the likelihood of adoption by 23.9%. Moreover, mediation analysis indicated that the combined effect of extension services and farmer associations accounted for approximately 40.7% of cocoa *farming income, with pesticide adoption partially mediating the effect by 0.3%. Hence, to effectively facilitate innovation adoption, concerted efforts are needed to strengthen both agricultural extension services and farmer associations, capitalizing on their complementary effects.*

Keywords: Adoption, Extension, Farmer association, Income Interaction

Introduction

Agriculture in African nations has emerged as the principal catalyst for fostering economic progress, tackling food scarcity, and alleviating poverty. Serving as the lifeline for the majority, it supports human and livestock sustenance and supplies industries with essential raw materials (Oyenpemi, Tijani and Kehinde, 2023). In Nigeria, agriculture is particularly significant, engaging over 70% of the population and contributing 23.69% to the national GDP in 2022, reflecting its critical role in the country's economy (Statista, 2023; FAO, 2023). The cocoa crop subsector stands out for its notable export volumes, reinforcing Nigeria's agricultural prominence (NBS, 2020). Cocoa, often referred to as West Africa's "black gold," is foundational to the livelihoods of many Nigerian households. Its importance extends beyond chocolates and beverages to pharmaceuticals and cosmetics, highlighting its versatility and economic value. As Nigeria's leading agricultural export, cocoa plays a vital role in GDP contribution, foreign exchange earnings, job creation, and the supply of industrial raw materials (Ghosh, 2022; Kehinde and Ogundeji, 2022).

However, cocoa production has seen a decline, primarily due to the historical shift towards the oil and gas sectors in the 1980s and 1990s, which led to the neglect of agriculture (Adeyemo et al., 2020). This downturn is compounded by challenges such as policy issues, pests, labor shortages, financing difficulties, and unpredictable weather, all of which impede agricultural progress and farmers' welfare. Consequently, Nigeria, once a leading cocoa producer, now ranks fourth globally, trailing behind countries like Indonesia, Ghana, and Ivory Coast (FAO 2023). Despite having achieved a peak production of 485 MT in 2006, recent figures indicate a drop to about 290 MT in 2020/21, underscoring a significant production gap relative to global leaders (ICCO 2023).

This difference in productivity on individual cocoa farms has been traced to pest and disease infestation among other factors (Adeyemo et al.,2020). About 40% of the cocoa product was lost to the infestation of pests and diseases which impedes their quality (ICCO, 2023). Pesticides have been used combined with others management practices, including weeding, and pruning to reduce the infestation and occurrence of pests and diseases on the farms. Even after the harvesting, operations were carried out with care to get a high quality. However, improper use of some pesticides could lead to contamination of the cocoa beans, hence reduced its quality (Oyenpemi, Tijani and Kehinde, 2023). The use of some pesticides in cocoa farming has led to exceeding Maximum Residue Levels (MRLs) permitted in cocoa beans, posing health risks, and jeopardizing international market acceptance (Faloni, Tijani and Kehinde, 2022). The Nigerian government, through bodies like CRIN and NAFDAC, approved certain pesticides aligned with EU regulations to prevent bean rejection. However, farmers' noncompliance with approved pesticides stems from various factors including low literacy, inadequate training, poor labelling, improper application methods, and lack of awareness about health risks. The current scenario poses a risk to the standard and market value of Nigerian cocoa, which could result in trade limitations and financial setbacks (Mokwunye et al., 2012, 2014; Faloni, Tijani and Kehinde, 2022; Akande *et al.*, 2023; Kehinde, 2022).

Therefore, it is highly significant from a theoretical standpoint and holds practical importance to examine the key elements that drive farmers to accept approved pesticides. Agricultural extension could be a great factor in dissemination of approved pesticide. It is a significant determinant that helps farmers to increase agricultural output, leading to improved income, reduced poverty, and enhanced food security. Empirical research has demonstrated that agricultural extension is crucial in strengthening agronomic practices, promoting sustainable agriculture, improving food security, and facilitating the adoption of innovative technologies (Agula et al., 2018; Tarekegn and Ayele, 2020; Mabe, Mumuni and Sulemana, 2021; Somanje, Mohan and Saito, 2021).

The public extension system in Nigeria is currently inadequate and inefficient in its provision of services due to reduced government funding, which has been necessitated by the substantial expenses associated with maintaining the public system (Adebayo et al., 2015). The growth of private agricultural extension and advising services has been facilitated by changes in agricultural structures, government decentralization, and the development of emerging information and communication technologies. Over 70% of cocoa production extension services in Nigeria were provided by private entities due to the inefficiency of the public agricultural extension system following the elimination of commodities boards in the 1980s. (Adebayo et al., 2015). Private agricultural extension services serve as a substitute for the governmental service system. Nevertheless, the private sector has employed extension service delivery as a means of promoting its products or services, with a focus on providing valuable agricultural services (Davidson and Ahmad, 2002). Similarly, farmers organize themselves into collectives to enhance their productivity and revenue by facilitating access to credit, resources, expertise, and education. The behaviour of individual farmers is not entirely independent; social interactions play a significant impact in the spread and acceptance of technology (Xu et al., 2023). While external private investors typically supply extension services to producers from the outset, cooperatives or similar formally structured farmer groups gradually assume the responsibility of providing technical services to their members as they grow and develop. The outcome, meanwhile, has resemblance to extension functions in other private sector projects, but with less strength and thoroughness in providing technical services support. The extension services provided utilize a combination of group-based and individual face-to-face interactions with members, which are impacted by the specific commodities and technical matters (Bingen and Simpson, 2015).

Previous research has explored the individual effects of agricultural extension services and social institutions on farming practices (Danso-Abbeam, Ehiakpor and Aidoo, 2018; Takahashi, Muraoka, and Otsuka, 2019; Dhehibi *et al.*, 2022; Amrullah, Takeshita, and Tokuda, 2023), a comprehensive understanding of how their interaction influences technology adoption and economic outcomes remains lacking. Therefore, when analysing farmers' adoption of approved pesticides, it is necessary to focus not only on the important effect of agricultural extension but also on the influence of farmers' social organizations. Recognizing that farmers do not operate in isolation and the diffusion of technology is often accelerated within group settings, there is a clear need to investigate the combined influence of agricultural extension and farmer associations. Therefore, this study provided empirical answers to the following research questions: What is the combination effect of agricultural extension and farmers organization on the adoption of approved pesticides? How does this interaction affect their income? The study will provide valuable insights for policy makers regarding the formation and implementation of extension reform and transformation, specifically in terms of including the private sector and farmer organizations. This will foster synergy and establish a strong connection between them.

The study is structured as follows: Section 2 offers a comprehensive overview of the data collection process and the methodology employed for analysis. In section 3 we discuss the main findings, with an emphasis on the interaction effect of extension and farmers association on the adoption of approved pesticides and income. Finally, the conclusion and recommendations are presented in section 4.

Data and Methods

The survey was conducted from April to June 2021 in Osun State, Nigeria, targeting cocoa farmers across four local government areas (Ife East, Ayedaade, Ife North, and Ife South) recognized for their substantial cocoa production. Osun state is situated in the tropical rainforest belt with an average annual rainfall of 1570mm and temperature around 27°C. The state presents an optimal environment for cocoa, the principal export crop supporting 70% of households. From a random selection in five villages per local government area, a total of 200 cocoa farmers were administered questionnaire. The sample used for the analysis covered cocoa farmers from the age of 20 years to 70 years representing the active farming population, were surveyed. The questionnaire gathered data on socio-economic and household characteristics, production and management practices, and pesticide use. The study employed descriptive analysis, probit regression, and mediation analysis for data interpretation.

Probit Regression Model

The probit model was employed to examine the interaction effect of extension and farmer association on adoption of approved pesticides. The selection equation, indicating whether a farmer adopted approved pesticide, is expressed as follows:

$$P_j = \Pr\,(P_j / W_j^* > 0) = \beta_0 + \beta_1(Extension * Association) + \beta_2(Extension) + \beta_3(Association) + \beta_i X_{ij} + \varepsilon_j \quad (1)$$

Equation (1) is a probit model with P = 1 for adoption of approved pesticides and P = 0 for adoption of approved pesticides. Where W* represents the latent variable for the probability of adoption of approved pesticides. *The term "Extension × Association"* refers to the relationship between extension services and farmer associations. β_1 , β_2 , and β_3 measured the *interaction effect*, e*xtension* effect and *association* effect *on pesticide adoption.* β_i is the estimated coefficients of the independent variables. X_i denotes the set of control variables, and ε_j is the error terms.

In the empirical analysis, the coefficient of the interaction term determined whether there is substitution effect or complementary effect between extension and farmer association. Xu et al., (2023) explained that if the coefficient is positive, it means that there is a complementary effect while negative, denote a substitution effect. The adoption of approved pesticides is a binary categorical variable which was model using a probit model regression.

Mediation Analysis Model

This was done to test the mechanism of the role of extension and farmer association on the income of farmers and to calculate the effect transmitted through the adoption of approved pesticides among cocoa farmers in Nigeria. Mediation analysis can identify the relationship between the total effect, the direct effect, and the indirect effect in nonlinear probabilistic models; with Probit or Logit makes it appropriate to be used for our analysis (Hicks and Tingley, 2011). The amount of effect of the interaction of extension and farmer association (treatment variable) that is transmitted by the approved pesticides (mediating variable) represents the indirect effects or causal mediation effects for each unit i the average causal mediation effect (ACME) δ(t) is defined in equation (2):

$$\delta_i\ (t) = Y_i\ \{t, M_i(1)\} - Y_i\ \{t, M_i(0)\} \tag{2}$$

for each treatment status, i.e., the interaction t = 0,1. The direct effects of the treatment, the average direct effect (ADE) is defined in equation (3):

$$\zeta_i\ (t) = E[Y_i\ \{1, M_i(t)\} - Y_i\ \{0, M_i(t)\}] \tag{3}$$

The mediation effect is fitted using two regressions as shown in equation (4),

$$\begin{aligned} M_i &= \alpha + \beta_1 T_i + \partial_i X_i + \varepsilon_i \\ Y_i &= \varphi + \beta_2 T_i + \phi_i X_i + \varepsilon_i \end{aligned} \tag{4}$$

M = adoption of approved pesticides, and Y = Log of income from cocoa farming.

T = interaction term of extension services and farmer associations.

β_1 and β2 measured the interaction effect for model 1 and model 2, respectively. δ_i and ϕ_i are the estimated coefficients of the independent variables for model 1 and model 2, respectively. X_i denotes the set of control variables, and ε_i is the error term.

Result and Discussion

Socioeconomic and household characteristics of the farmers

Descriptive analysis was used to describe all the variables used in the probit regression. The dependent variable is the adoption of approved pesticides. The previous study Oyenpemi, Tijani and Kehinde (2023) explained the various types of pesticides used by the cocoa farmers which distinguished banned pesticides from approved pesticides. Farmers who adopted only the approved pesticides were assigned a value of 1, and others who do not use approved pesticide or at least used banned pesticides were assigned a value of 0. In the sample about 88.70% of farmers used approved pesticides as shown in Table 1. The mean age (measured in years) of cocoa farmers is 50.027 ± 11.435 years. 95.7 percent of cocoa farmers were males. It shows that cocoa cultivation is a male-dominated farming business. Education variable (measured in years spent in school). for the farmers that went to school spent an average year of 9.323 ±4.441 years. The average household size (measured in number of people) is 7.091 ± 3.361. Farmers that have accessed financial aid inform of credit were about 32.8%. The experience in cocoa farming on average was 22.000 ± 12.836. The income and expenditure of the cocoa farmers were about ₦656526, and ₦302685, respectively.

Table 1: Socioeconomic and household characteristics of the farmers

Variable	Mean	Std. Dev.	Min	Max
Approved pesticides	0.887	0.317	1	0
Age	50.027	11.435	24	70
*Sex(male)	0.957	0.203	0	1
Education	9.323	4.441	0	16
Household size	7.091	3.361	2	25
*Access to credit (Yes)	0.328	0.471	0	1
Farm size (ha)	3.298	2.874	0	20
Cocoa experience	22.000	12.836	2	60
Income (₦)	656526.344	578857.815	15000	3280000
Expenditure (₦)	302684.946	491624.830	14000	2880000

Note: * represent the categorical variable

Institution characteristics of cocoa farmers

Figure 1 revealed that about 18% and 66% of the farmers have access to extension and farmers association respectively. About 15% of farmers have access to both, representing the interaction variable. Agricultural extension services play a crucial role in providing rural farmers with the knowledge and information necessary to increase productivity and sustainability. Extension visits are particularly important for keeping farmers updated on new agricultural technologies, such as the use of approved pesticides. Farmers' associations such as cooperatives, farmer-based organizations, and farmer groups, are increasingly factor in supporting the sustainable development of the agricultural sector and improving the living standards of rural households (Ma, Marini, and Rahut, 2023). These associations provide a platform for farmers to collaborate, share information, and access various benefits. Farmer associations grants farmers access to knowledge on modern farming production and management (Onubuogu et. al., 2014).

This study focuses on examining the joint effect of both extension services and farmer associations on the adoption of approved pesticides, because farmers often encounter barriers in accessing and adopting agricultural technologies due to information asymmetry and lack of necessary knowledge and skills (Ma, Marini, and Rahut, 2023). It is assumed that these institutions will facilitate the rapid dissemination of new agricultural technologies.

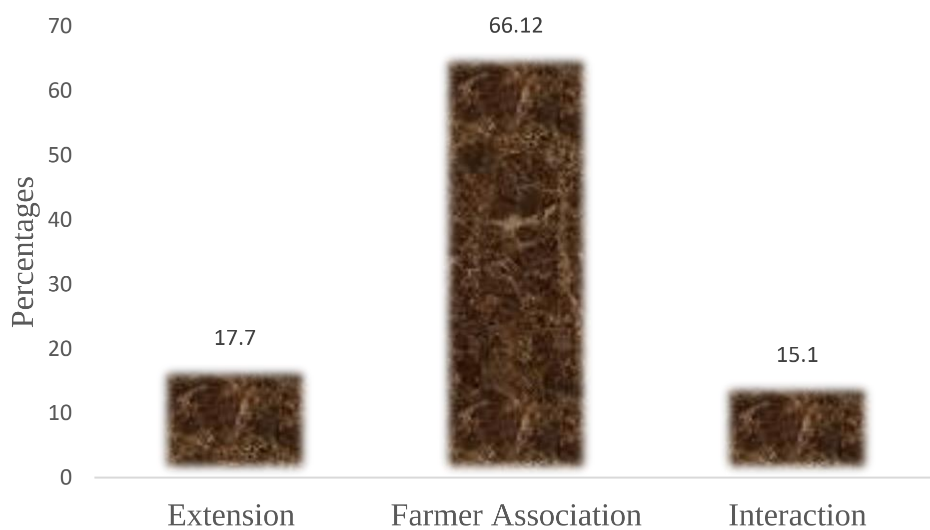

Figure 1: Access to Extension and Farmer Associations

Interaction effect on the adoption of approved pesticides

Table 2 presents the estimates of the marginal effect of the interaction of extension and farmer association and other control variables on the adoption of approved pesticides. The chi squared statistic for the probit regression model was significant at 5%, suggesting that the model is of good of good fit. The interaction effect had a positive significant effect on the adoption of approved pesticides with a marginal effect of 0.239, implies that the probability of adoption of approved pesticides increased by 23.9% on average for farmers who had contact with extension and belong to farmer association. This implies that the effective coordination between farmer associations and extension services enhances the likelihood of adopting approved pesticides. This synergy is attributed to extension services increasing awareness about the implications and benefits of approved pesticides, as well as providing training and support for their proper usage.

Table 2: Interaction Effect on the Adoption of Approved Pesticides

Approved pesticide	Coefficient	Marginal effect	P-value
Interaction	**1.490**	**0.239**	**0.076**
	(0.840)*	**(0.133)**	
Farmer association	-0.175	-0.028	0.490
	(0.253)	(0.041)	
Extension	-1.414	-0.227	0.058
	(0.747)*	(0.118)	
Education	0.059	0.009	0.093
	(0.035)*	(0.006)	
Log of Expenditure	0.477	0.076	0.011
	(0.188)**	(0.029)	
Cocoa experience	-0.025	-0.004	0.062
	(0.013)*	(0.002)	
Age	0.022	0.004	0.188
	(0.017)	(0.003)	
Sex	-0.527	-0.085	0.489
	(0.761)	(0.122)	
Household size	-0.016	-0.003	0.694
	(0.040)	(0.006)	

Credit	-0.342	-0.055	0.246
	(0.295)	(0.047)	
Farm size (ha)	0.017	0.003	0.796
	(0.066)	(0.011)	
Log of income(₦)	0.141	0.023	0.249
	(0.122)	(0.020)	
Constant	-6.390		0.025
	(2.848)**		
χ^2	22.47**		

Note: Standard error is in the parenthesis

Drawing from Schulz's theory of human capital, which underscores the importance of education and knowledge acquisition in boosting productivity (Sweetland, 1996)., it's evident extension services and farmer associations contribute significantly to human capital development in agriculture by offering training programs, and technical support (Xu et al., 2023). This collaboration facilitates the exchange of information, knowledge dissemination, and the adoption of innovative practices in pesticide usage.

The result of the separate effects of agricultural extension and farmer association revealed that farmer association does not have a significant effect on the adoption of pesticides, while extension services had a significant negative effect on the probability of adopting approved pesticides with the marginal effect of -0.227 indicating that the probability of farmers who had contact with extension using approved pesticides decreased by 22.7% on average. This outcome is surprising because the extension should increase the enactment of the approved chemicals. However, the negative marginal effect may suggest a range of obstacles or difficulties linked to extension services in Nigeria, which could impede the adoption of the approved pesticides. These factors may comprise insufficient inadequate outreach, limited involvement of farmers, or inadequate funding for education and training linked to pesticides and ineffective communication strategies. The negative marginal effect emphasizes the significance of cooperation between extension services and other entities, including farmer associations, agricultural input providers, and regulatory bodies. Through collaboration, these organizations may create more thorough and efficient plans to encourage the use of approved pesticides, overcome obstacles, and offer full support to farmers.

Among the control variables, farmers' expenditure had a significant positive effect with a marginal effect of 0.076 on farmers' adoption of approved pesticide, indicating that for each additional year of experience, the likelihood of adopting approved pesticides increased by 0.076 units. Farmers who allocate more resources towards agricultural expenditures, including the purchase of approved pesticides, demonstrate a willingness to invest in inputs that can potentially enhance their productivity and income.

Education had a significant positive effect with a marginal effect of 0.009 on farmers' probability to adopt approved pesticides, implying that for each additional year spent in education, the likelihood of adopting approved pesticides increased by 0.009 units. This finding aligns with the conclusions drawn by Oyenpemi, Tijani and Kehinde, (2023). Tijani and Sofoluwe (2012) affirmed that farmers with higher educational attainment are more adept at interpreting news, bulletins, and pesticide labels, rendering them better equipped to embrace innovation.
Experience had a significant negative effect with a marginal effect of 0.004, suggesting that with each additional year of experience, the likelihood of adopting approved pesticides decreased by 0.004 units. Farmers with extensive experience in farming may adhere to established practices and routines, leading to reluctance in embracing new technologies such as approved pesticides.

Interaction effect on the income from cocoa farming

Table 3 showed the result of the mediation analysis, the Average Causal Mediation impact (ACME) was 0.043 suggesting that, on average, the adoption of approved pesticides leads to a 4.3% increase in cocoa farming income, considering the interaction impact. The Average Direct Effect (ADE) was 0.364 implying that on average, the interaction effect leads to 36.4% in cocoa farming income. Lastly, the Total Effect was the addition of direct and mediation effects, estimated to be 40.7%. Although approved pesticide adoption only accounts for a small fraction (5.7%) of the overall effect, it still plays a significant role in increasing income in cocoa production. These findings suggest that a combination of collaboration between extension services and farmer associations, along with the adoption of approved pesticides, shows potential for increasing income in cocoa farming.

Table 3: Mediation Analysis of the Interaction Effect on Income

Effect	Average Effect
ACME	0.043
ADE	0.364
Total Effect	0.407
% of Total Effect mediated	0.057

Conclusion

Encouraging the adoption of approved pesticides within the sustainable farming practices is key to overcoming resistance to innovation among cocoa farmers. This study concluded that the collaborative efforts of agricultural extension services and farmer associations play a vital role in establishing sustainable farming management practices, thereby enhancing adoption of innovation and income levels for farmers.

Policy Implications

Building on the research findings, we suggest that an establish robust linkages between extension services and farmer associations. This partnership is essential for promoting the diffusion of innovation among farmers, allowing them to efficiently implement new technology and reducing the search costs associated with accessing farming management information.

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IFMA 2024: Agricultural Policy

USING A FARM MODEL TO SUPPORT AGRICULTURAL POLICY, AN EXAMPLE OF DAIRY FARMS

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Academic paper

Abstract

In this contribution, we provide an example of using farm model to analyse the dairy farming sector. It is a case study for supporting agricultural policy decision-making. We focus only on those farms that mainly operate on permanent grassland. Our aim was to analyse in detail the economic indicators achieved by these diverse group of farms and the significance of CAP measures. It turns out that these farms, in general, achieve slightly poorer results (7.9€/h), comparing with dairy farms on mainly arable land, depending primarily on the size of the herd and the extent of cultivated land. Budgetary payments serve as a significant income source for dairy farms. It's mainly due to these payments, that we observe a decline in economic results for these farms after the CAP reform. Considering the range of measures available in CSP for dairy farms, the situation is expected to deteriorate (6% of GM) on most of these farms, especially if farms decide to participate in one-year Eco-schemes. The results confirm that the farm model approach used is suitable for such analyses in supporting agricultural policy, even at the subgroup level.

Keywords: Dairy farming, farm model, CAP, agricultural policy, impact assessment

Introduction

The dairy sector is an important sector in agriculture both in the EU and also in Slovenia. It represents a diverse group of farms that vary in terms of the number of dairy cows, the extent of cultivated land, location, as well as in farming technology and management practices. In this analysis, our main interest was in understanding how a particular group of dairy farms, which predominantly produce fodder on permanent grasslands, operates. We aimed to determine the proportion of production resources they utilize and assess their significance in terms of both social and economic sustainability. Additionally, we wanted to investigate the impact of the reform of CAP measures brought by the CAP Strategic Plan (CSP). This document prepared by each EU Member State, cover all agricultural policy measures for the programming period 2023-2027. The interventions in CSPs are therefore customized solutions tailored to the conditions and needs of each Member State. They address resource allocation and priorities concerning agricultural structure, environmental considerations, economic factors, and social challenges (European Commission, 2023). To analyse the impact of CSP interventions on chosen group of dairy farms we employed a modelling approach and in such a manner also give feedback to agricultural policy.

The use of various methods to support political decision-makers has a long history, however due to changed paradigm also modelling concepts and challenges changed significantly in recent decade. In 2003, EU Commission established the instrument of ex-ante impact assessment (IA) in order to promote better regulation of CAP interventions. Such an analysis enables also to measure intended as well as unintended impacts of policy and adds also to collective understanding of politics (Reidsma et al. 2018). Policy frameworks also move increasingly away from a ‘one-size-fits-all’ approach of policy design towards more flexible systems, giving greater freedom to shape, implement, and target policy measure to specific regions, farm management practices and farm types (Britz et al., 2021).

Recently there has been an increasing emphasis on models that allow simulation at the level of farms or at the level of selected aggregate (Langrell et al., 2013). It is a type of micro-simulation models, commonly referred to as bioeconomic farm models (BEFM) (Janssen and van Ittersum, 2007). These models provide a deeper understanding of decision-making and management within farms. Moreover, they offer policymakers valuable insights into the operations of specific types of farms, empowering them to make more informed decisions. Notably, result-oriented and data-driven agricultural policies are increasingly emphasized, leading to a growing demand for micro-simulation tools. These tools facilitate the analysis of policy impacts at the level of individual farms (Ciaian et al., 2013).

Given the variability in policy impacts across different types of farms, the use of models offering more reliable estimates is crucial. It's important to note that conducting analyses at the individual farm level is practically infeasible due to both logistical constraints and the complexity of factors involved. Instead, it is more practical to categorize farms into groups using techniques that enable the identification of groups sharing common characteristics (Robles et al., 2005). Farms vary not only in their primary focus but also in terms of specialization level, size, intensity, resource impact, constraints, objectives, and decision-making processes. Consequently, they differ in their economic, environmental, and social impacts under various scenarios and policies (Reidsma et al., 2018). In this manner, typical farms (TAH) can be defined as representatives for different number of farms.

Below we present an example of analysis, using a farm model, focusing on those farms whose key economic activity is milk production, predominantly carried out on permanent grassland. In the first part, we briefly introduce the SiTFarm tool used for analysis. This is followed by presentation of typical dairy farms. Furthermore, we present key economic results achieved by such farms based on model estimates. Additionally, we discuss the importance of CAP measures and what CSP brings for the period 2023-2027. The contribution concludes with key findings.

Material and methods

SiTFarm tool

For the purpose of this study SITFarm tool (Slovenian Typical Farm Model Tool) has been applied (Žgajnar et al., 2022). It is an example of a farm model based on mathematical programming and allows for diverse analyses at the level of the farm's production plan. It is based on a modular structure, which combines three different modelling approaches. First are the static models of typical agricultural holdings (TAHs), which are different farming systems (production models) that could be found in practice. The production plan mirrors the expected situation on a certain type of dairy farm, which is thus representative of a larger number of actual farms. TAHs were defined as part of another study (Žgajnar et al., 2022). The second approach are budget calculations (model calculations – MC) as the main source of economic and technological data at the level of production activities. These are static production models of production activities, which are otherwise part of an independent system prepared by the Agricultural Institute of Slovenia (AIS, 2023). They include different models of all the main agricultural production activities ranging from fodder production, cash crops, vegetable production down to livestock models. MC enable real-time adjustment of individual budget calculations in terms of production technology, intensity (yield), and price-cost relations to the conditions on the analysed typical farm. And the third approach is a farm model (FM) that merges both previous modelling approaches and enables autonomous calibration of farm production plans according to technological axioms and each farms production constraints and endowments.

A comprehensive analysis of decision-making at the farm level, which is covered by the present approach, it is primarily important to be able to simulate the baseline situation (BL). This is important especially in terms of the structure of the production plan (which activities are included), and in further steps also from the viewpoint of the achieved economic results and various economic indicators at farm and also sector level.

The SiTFarm applied is based on the principles of mathematical programming with limited optimization. This allows the use of different techniques in solving the production plan, which is the basic level of problem solving. In the given model version, deterministic linear programming is used. The developed matrix of production possibilities is an example of production planning in which we focus on finding the optimum solution maximizing Gross Margin (GM).

However, it should be stressed that in the case of our analysis we are not interested in finding the optimal solution per each TAH, but in a production plan that could be found in practice, that deviates from optimal allocation of production resources due to many different reasons. Our main aim was to reconstruct the production plan. For this purpose, we used a "partial optimization process", which is an upgrade of LP, with a complex system of equations. These make it possible to search for the values of those variables we do not know for certain and which we want to calculate in such a way that the production plan on the agricultural holding will be completed and also technologically consistent. The key purpose is not to optimize production, but try to present the current situation on the farm or to reconstruct the current situation.

The problem of reconstructing the production plan is based on the fact that we define all key production activities or at least the lower and upper limits. The values of unknown variables (x_j) are calculated based on the optimisation potential of LP such that the solution is technologically appropriate (balances of nutrients and purchased fodder, balances of animals, balances of mineral fertilizers etc.). Partial optimization refers to the condition that a certain part of the activities is fixed (x_f) and should be included in the optimal solution to a given extent (b_f), regardless of whether it is an optimal allocation of production resources or not.

$$maxGM = \sum_{j=1}^{n} c_j x_j + \sum_{f=1}^{n} c_f x_f \qquad \ldots(1)$$

So that

$$\sum_{j=1;f=1}^{n;r} a_{ij} x_j + a_{if} x_f \leq b_i \qquad \text{for all } i = 1 \text{ do } m \qquad \ldots(2)$$

$$x_f = b_f \qquad \text{for all } f = 1 \text{ to } r \qquad \ldots(3)$$

$$x_j \geq 0 \qquad \text{for all } j \qquad \ldots(4)$$

All production activities (x_f), the scope of which are known (e.g. number of dairy cows, number of beef cattle, number of heifers), are fixed with additional constraints (b_f). These activities are defined in the calibration phase of TAH and do not change during further scenario analyses. The basic idea is that these are the activities that define the type of agricultural holding.

Typical dairy farms that mainly farm on permanent grassland

As part of the analysis, we focus on dairy farms that have the majority of their cultivated land as permanent grassland. We have selected those TAHs whose share of permanent grasslands ranges between 60% and 100% of the total cultivated area. Most of these farms are located in Less Favoured Areas (LFA). As evident from the Table 1, this is a diverse group of farms. From the perspective of TAH, half of the farms belong to the group of small herds (<10 dairy cows), while the other half are TAHs with more than 12 dairy cows, ranging up to 180 dairy cows in a herd. In total, these farms represent over 60% of farms in Slovenia, where milk production is the primary economic activity. This is expected given the prevailing permanent grasslands and natural conditions. In the analysed group of farms, smaller farms (<10 dairy cows) are more numerous, accounting for over 74% of the total number of these farms, while larger farms (>12 dairy cows) represent only about a quarter (Table 1). Expectedly, there are also differences in the extent of cultivated areas. The first three TAHs are within the range of the average Slovenian farm size, while the rest cultivate larger areas. Generally, intensity of livestock farming per unit area of land increases with farm size. However, this trend is inversely proportional to the share of permanent grasslands in the total cultivated area.

Within the analysed group we encounter all size classes of dairy farms, so it's expected that the cattle breed structure is also very diverse. As indicated by the assumptions of TAHs, there are representations of Simmental, Brown Swiss, Holstein in combination with Simmental, and also Holstein-Friesian breeds. Milk yield per average lactation on these farms is low, averaging just over 6,400 litres of milk. Additionally, only 25% of the top-performing farms achieve a milk yield higher than 7,100 litres per average lactation. Most farms are also engaged in bull fattening as a supplementary activity. These are own domestic calves from dairy cows. However, from an economic viewpoint it is less important production activity on these farm types and occurs at a low intensity level (daily weight gain is in most cases below 1,000 g/day). Breeding of heifers also takes place on all farms, either to meet the needs of herd renewal or to sell surplus animals on the market. On farms where the number of bred heifers is insufficient, a certain portion of breeding animals is also purchased. This affects both the revenue and variable cost sides per each TAH.

Table 1: Typical dairy farms that have more than 60% of permanent grassland in UAA

TAHs code	Representative for No of farms	FTE	UAA		Livestock			
			Total	% of grassland	LLU	Dairy	Beef	Heifers
	(No)	(1800h)	(ha)	(%)	(No)	(No)	(No)	(No)
TAH1-0001_SI_4000	350	0.37	3.2	84	$1.7^{T,1}$	1	1	0.2
TAH2-0003_SI_4500	660	0.72	5.6	83	$4.8^{T,1}$	3	2	1
TAH3-0005_SI_5000	450	0.83	8.7	85	$7.4^{T,2}$	5	3	1
TAH4-0006_BR_6000	440	1.03	12.2	75	$8.7^{T,1}$	6	3	1.5
TAH6-0009_HF_8000	400	0.93	7.4	62	$10.8^{T,1}$	9		3
TAH7-0010_SI_6500	300	1.22	12.4	60	$14.8^{T,1}$	10	5	3
TAH8-0010_BR_7000	300	1.25	12.5	76	$14.2^{T,1}$	10	4	3
TAH10-0012_BR_7500	240	1.38	14.9	74	$16.8^{T,1}$	12	5	3
TAH12-0015_SI_6500	200	1.49	16.0	69	$21.6^{T,2}$	15	6	5
TAH15-0018_BR_7000	190	1.60	18.5	100	$24^{T,2}$	18	5	5
TAH17-0025_BR_6500	160	1.79	21.3	86	$33.4^{T,2}$	25	8	6
TAH23-0035_BR_7000	100	1.86	29.3	83	$47^{F,2}$	35	10	10
TAH24-0035_HS_7000	100	1.74	24.9	72	$47^{F,3}$	35	8	12
TAH32-0180_HF_7500	18	7.37	186.0	73	$219^{F,3}$	180		65

Legend: SI – Simmental, BR - Brown, HF – Holstein Friesian, HS – Mixed Holstein Simmental, T – tied-in housing system, F - Free stall housing system, Machinery and equipment capacity: 1 – poor, 2- semi, 3 - modern and powerful;

In Table 1, we illustrate also the required effective workforce on each TAH. This is, of course, largely dependent on the livestock population but also partly on milk production, housing system and feed preparation. The latter is significantly influenced by the machinery equipment, its capacity and efficiency. It is categorized into three classes: good (3), average (2), or poor (1). This relates to the power of tractors (measured in kilowatts) and the capacity of machinery (measured in hours per hectare, cubic meters per hour, cubic meters per transport, meters per cut, etc.). On 75% of TAHs, the workforce requirement is thus less than 1.75 FTE of effective labour. The exception is the TAH 32, where it concerns breeding on a larger scale.

CAP scenario analysis

In this study we present the results based on the three-year average prices, covering the period 2020 to 2022. Additionally, we analysed the impact of changes in CAP measures. We took into account

7

measures that were in place during the period 2014-2022 (baseline), as well as changes introduced by the CAP strategic plan (CSP) for the period 2023-2027. We considered all key interventions for which dairy farms may be eligible. The key change lies particularly in the abolition of payment entitlements, which were relatively high on dairy farms, and the introduction of a single payment in the form of income support for sustainability. Farms that meet the necessary criteria are also eligible to receive production coupled payments for dairy cows and beef cattle. Additionally, we also considered the new one year ECO scheme measures that dairy farms may be eligible for. Changes also occur on the side of LFA payments.

Results and discussion

In this section, we present the main results for a group of TAHs engaged in milk production, with the majority of their cultivated land being permanent grasslands. This group represents dairy farms prevailing in Slovenia, which, on average, achieve poorer economic results compared to comparable farms where arable land predominates.

As already evident from the description of TAHs (Table 1), the structure of farms is very diverse. Consequently, it is expected that they also differ in key economic indicators. Smaller farms, in particular, tend to achieve poorer economic results. GM per working hour and achieved GM per hectare roughly follow the trend of farm size. Generally, larger farms (both in terms of hectares and number of dairy cows) achieve better results. Interestingly, this is also reflected in the proportion of budgetary payments (BP) relative to GM. For TAHs achieving lower GM per hectare, the importance of budgetary payments is greater, thus, they are also more sensitive to changes and institutional risk and vice versa.

Table 2: Key economic results according to dairy TAH

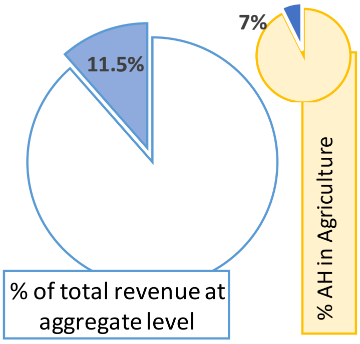
TAHs code	TR	BP	GM	BP/GM	GM/ha	GM/h	GM/h
CAP	Baseline 14-22						CSP 23-27
	(EUR)	(EUR)	(EUR)	(%)	(EUR)	(EUR)	(EUR)
TAH1-0001_SI_4000	4,699	1,155	1,365	84.6	427	2.1	2.2
TAH2-0003_SI_4500	11,237	2,180	2,872	75.9	517	2.2	2.3
TAH3-0005_SI_5000	17,923	2,301	3,797	60.6	438	2.5	2.5
TAH4-0006_BR_6000	26,366	5,952	6,633	89.7	544	3.6	3.5
TAH6-0009_HF_8000	34,969	4,864	12,158	40.0	1,637	7.2	6.8
TAH7-0010_SI_6500	44,264	7,347	15,789	46.5	1,277	7.2	7.0
TAH8-0010_BR_7000	42,835	7,116	15,364	46.3	1,229	6.8	6.7
TAH10-0012_BR_7500	53,746	8,382	18,318	45.8	1,227	7.4	7.0
TAH12-0015_SI_6500	60,189	9,530	22,732	41.9	1,417	8.5	8.0
TAH15-0018_BR_7000	72,445	11,603	31,463	36.9	1,705	11.0	10.4
TAH17-0025_BR_6500	97,310	14,181	46,610	30.4	2,188	14.4	13.7
TAH23-0035_BR_7000	140,154	19,219	60,201	31.9	2,058	18.0	17.0
TAH24-0035_HS_7000	135,282	18,595	58,833	31.6	2,359	18.8	17.6
TAH32-0180_HF_7500	709,543	116,477	297,525	39.1	1,599	22.4	21.6

Legend: TR – total revenue, BP – budgetary payments, FTE- Full-Time Equivalent

On average, analysed farms achieve 14,305€ of GM per FTE, equating to an average of 7.9 €/h. The best-performing farms approach or even exceed 20 €/h. However, both Table 2 and Table 3 show that with the CAP changes and the set of measures for the period 2023-2027, the situation deteriorates. This is mainly due to the abolition of payment entitlements, which, despite being generally lower on these farms compared to those primarily managing arable land, still have an impact. The deterioration is particularly noticeable on larger farms. Of course, there is a significantly greater effect on income, which we did not measure in this analysis, but due to the need for equipment, there are a lot of fixed costs on these farms, which means that income could deteriorate by 15 up to 20%. Although budgetary payments from first pillar, especially on larger farms, decrease by over 23%, this will affect the gross margin by around 6%. Part of this is due to the fact that the amount of LFA payments will slightly increase on most of these farms (on average by about 7%). The situation is somewhat different for very small farms that rear a few dairy cows (<5 cows). On these farms, the situation may slightly improve (up to about 7% in terms of GM).

However, these are small amounts that will not significantly impact further structural changes. Regarding the changes shown in Table 3, it should be noted that we show the average, minimum and maximum values separately for each indicator.

Table 3: Summary of selected indicators for the dairy sector, cultivating more than 60% of permanent grassland



	Gross margin	Gross margin per FTE	Gross margin per working hour	Gross margin per working hour	Gross margin	Revenues	Budgetary payments	Less Favoured Areas
	(EUR)	(EUR)	(EUR/h)	(EUR/h)	Relative change after CSP			
	Baseline (2014-2022)			2023-2027				
Minimum	1,365	3,713	2.1	2.2	0.936	0.968	0.767	0.941
Average	15,570	14,305	7.9	7.6	0.956	0.983	0.890	1.084
Maximum	297,525	40,360	22.4	21.6	1.072	1.021	1.085	1.213

Farms that primarily manage permanent grasslands represent about 7% of all farms and, based on model estimates, contribute 11.5% of total agricultural revenue (Table 3). They utilize 19% of permanent grasslands and 6% of arable land (Figure 1). From the point of view of the use of plant protection phytopharmaceuticals (PPP), these farms are fairly unproblematic. In the assessment of the total costs of PPPs in agriculture, only 2% is spent on these farms. This is, of course, also a consequence of the fact that these farms mainly manage permanent grassland.

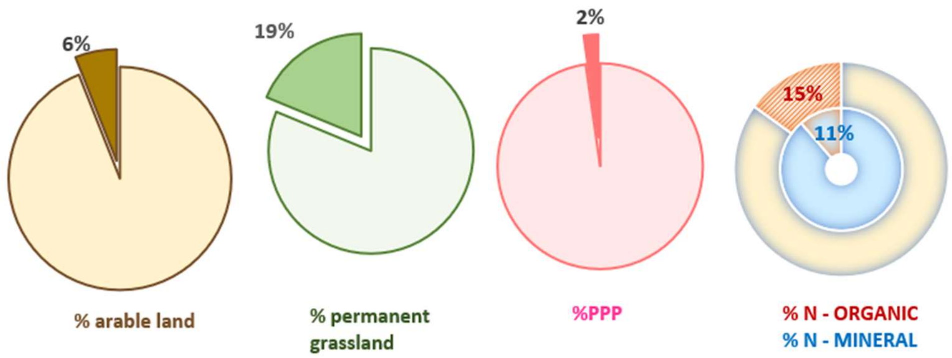


Figure 1: Consumption of selected production resources on dairy farms cultivating more than 60% of permanent grassland *(PPP - Plant protection products; FTE – full time equivalent; N - nitrogen consumption)*

Conclusion

In this contribution, we focused on economic indicators from selected dairy farms and examined the differences between small and large dairy herds. Additionally, we analysed the implications of the CSP for the period 2023-2027. These farms represent more than 60% of all dairy farms in Slovenia, making them undoubtedly significant in terms of social and environmental sustainability. Within this group, there are numerous small herds (<10 dairy cows) that are not economically sustainable in the long run, accounting for almost three-quarters of the analysed group. The results reveal that the average hourly GM on these farms is low, around 4.5 €/h, with the median even below 4 €/h. The situation is considerably better on larger farms, especially those with more than 25 dairy cows. Model results show that the significance of budgetary payments ranges from 30% to over 80% of the gross margin. Thus, the abolition of payment entitlements considerable worsens the situation, but the impact is less pronounced on very small herds.

The SiTFarm tool allows for simulating various scenarios of political measures, such as different subsidies for dairy, price changes, regulatory changes, etc. Based on these simulations, it is possible to assess how individual measures affects milk production, farmers' GM, and other relevant indicators. The farm model approach used enables us to analyse the situation on individual TAH, and by extrapolating the results, we can make assessments at the group level within the sector.

Therefore, we can conclude that the farm model can be applied for monitoring development trends in Slovenian dairy sector. This also makes it possible to support a CSP and further simulations of different CAP scenarios and possible changes in CSP interventions.

Acknowledgements

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THE CAPITAL MARKET AND ECONOMIC GROWTH IN NIGERIA

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Abstract

The capital market offers access to a variety of financial instruments which are very essential for government and private businesses in need of long-term funds. The objective of this study is to determine the effect of capital market on economic growth in Nigeria being an alternative source of finance for investment. The data used for the study were obtained from the Central Bank of Nigeria Statistical Bulletin and World Development Indicators, spanning 1985-2021 and, analyzed using Auto-regressive distributive lag (ARDL) on Eviews. Value of transactions, all share index, government stocks, corporate bonds, equities and inflation rate; were the independent variables, while economic growth proxied by gross domestic product was the dependent variable. The results obtained showed that equities and all share index had positive and significant effects on economic growth in Nigeria. We therefore, recommend that the Securities and Exchange Commission should come up with measures that will boost investors' confidence in the Nigerian capital market and make it a veritable alternative source of finance for businesses including agriculture.

Keywords: Auto-regressive Distributed Lag (ARDL), Capital Market, Economic Growth, Nigeria.

1. INTRODUCTION

Financial markets in general deal in financial assets and liabilities of various maturities and consist of institutions, instruments, rules and regulations which guide the mobilization of funds from surplus units of the economy to the deficit units (CBN, 2013). However, financial markets can be divided into money and capital markets in view of their *modus operandi*. This paper focuses on the capital market by virtue of the fact that businesses and governments can raise long-term funds from the savings of other economic agents by selling stocks and bonds in the capital market. Because of its capacity to mobilize savings and investment, the capital market is a highly specialized and organized financial market that plays a crucial role in driving economic growth. For self-sustaining economic growth, which is consistent with external adjustment and rapid economic expansion, the capital market must be the source of long-term financing (Iyola, 2004). Thus, the economy's level of growth and development depends heavily on the capital market.

According to available literature, industrialized nations had looked into both capital market and money market channels that influence economic growth and development (Demirguc-Kunt and Levine Roos, 1996). However, this is not the case in developing economies, where the money market was prioritized with little regard for the capital market.

With the financial sector's deregulation and the privatization process in Nigeria during the implementation of the Structural Adjustment Programme (SAP) in 1986 through to the early 1990s, activities in the Nigerian stock market increased dramatically Soyode (1990), Alile (1996). Investors and businesses became more aware of the stock market's importance. Equity financing has developed into one of the capital market's most affordable and adaptable sources of funding and continues to be a crucial component of the economy's sustainable growth.

Thus, the main objective of this paper is to evaluate the performance of the Nigerian capital market. In specific terms, to find out the extent to which equities and stocks affect economic growth in Nigeria.

This is premised on the empirical fact that the capital market plays a critical role in mobilizing savings, providing finance for investment, and promoting economic growth and development. The variables of interest, such as value of transactions, all share index, government stock, corporate bonds and equities are essential in understanding the impact of the capital market on the Nigerian economy.

This study utilizes a time series design which span a 36-year period between 1985 and 2021, due to data limitation. In order to explore the relationship between capital market and economic growth, economic growth was proxied by Gross Domestic Product (GDP), while the capital market variables considered were, Value of Transactions (VLT), All Share Index (ASI), Government Stocks (GS), Corporate Bonds (CB), Equities (EQ) and Inflation Rate (INF) as a control variable.

The rest of the paper is structured as follows. This brief introduction constitutes section one and it is immediately followed by section two which is devoted to literature review. Section two contains a review of the Nigerian Capital Market as a background to the paper as well as a review of some theoretical and empirical literature. The methodology and estimation methods are covered in section three. The results and discussion of their interpretations are presented in section four. The summary of findings, conclusions, and recommendations resulting from the empirical findings is provided in the fifth and last section of the paper.

2 LITERATURE REVIEW

2.1 The Nigerian Capital Market

In Nigeria, the capital market first came into existence with the establishment of the Lagos Stock Exchange in 1961. The Exchange was incorporated under the company's ordinance as an association limited by guarantee. The Lagos Stock Exchange was given initial financial backing by the Central Bank of Nigeria in the form of annual subventions. Following the recommendations of the Government Financial System Review Committee of 1976, the Lagos Stock Exchange was re-named and reconstituted into the Nigerian Stock Exchange in 1977. Additional trading floors were also opened in the same year in Port Harcourt and Kaduna (to serve the Eastern and Northern parts of the country).

The Nigerian Stock Exchange (NSE) is the center point of the Nigerian capital market, while the Security and Exchange Commission (SEC) serves as the apex regulatory body. The NSE provides a mechanism for mobilizing public and private savings, and makes such funds available for productive purposes. The Exchange also provides a means for trading in existing securities.

The functions of the Nigerian capital market include:

(1) Provision of an additional channel for harmonizing and mobilizing domestic savings for productive investment;

(2) Foster the growth of the domestic financial services sector and the various forms of institutional savings such as life insurance and pension funds;

(3) Improves the efficiency of capital;

(4) Facilitates the transfer of enterprises from the public sector to the private sector; and

(5) Provides access to finance for small companies (CBN, 2013).

The Nigerian capital market consists of the following institutions: Securities and Exchange Commission (SEC)- the apex regulator; the Nigerian Stock Exchange (NSE); the Abuja Commodity Exchange (ACE); the Stock broking firms; the issuing houses as well as the registrars.

There are two main segments of the market. These are primary and secondary markets. The major instruments used to raise fund at the Nigerian capital market include: equities (ordinary shares and preference shares); government bonds (Federal, States and Local governments); and industrial loans/debenture stocks and bonds. Consequently, the capital market products/instruments can be divided into two broad categories namely; equities and debts. Debt instruments are interest -bearing obligations with fixed or floating interest rates. The equities are the instruments that confer ownership rights on the investors.

2.1.1 Equities Market

The market for equities in the Nigerian Stock Exchange consists of the first-tier and the second-tier securities market. One important feature of the equities market is that subscriptions must be fully paid up before allotments are given to an individual investor. Another feature of the equities market is part ownership by the subscribers immediately after allotment of the shares. Thus, holders of the instrument are entitled to attend the Annual General Meetings and can vote to elect the management. The return on equities is by way of dividend or price appreciation or scrip's issues. Unlike a debt instrument, repayment of the principal occurs only if the instrument is traded through the secondary market.

2.1.2 First tier securities market

The First Tier Securities Market deals with issues of quoted companies. The essential difference between the two tiers lies in their listing requirements. The listing requirements for the first-tier market are:

(1) The company must be registered as a public limited liability company under the provisions of the Companies and Allied Matters Act (1990) as amended;

(2) At least 25 percent of the nominal value of share capital must be offered to the public;

(3) The date of the last audited accounts must not be more than nine (9) months:

(4) The company must submit to the Exchange its financial statements and business records for the past five years;

(5) The annual quoted fee payable by the companies in this market is based on a percentage of its total market capitalization;

(6) After listing, the company must submit quarterly, half-yearly and annual accounts to the Exchange;

(7) At the time of listing, the number of shareholders in the company must not be less than 300; and

(8) The securities must be fully paid at the time of allocation.

A benefit that accrues to members of the first-tier markets is that the amount of money that the firm can raise in the market is unlimited. This however depends on the borrowing capacity of the company.

2.1.3 Second tier securities market

The Second Tier Securities Market (SSM) on the other hand was introduced on 30^{th} April 1985, primarily to attend to the needs of small and medium size enterprises, which cannot meet the strict listing requirements of the first-tier market. In effect, it provides an avenue for smaller companies to access public issues for expansion. The listing requirements in this market include:

(1) That at least 10 percent of the nominal share capital must be offered to the public;

(2) At the point of listing the number of shareholders must not be less than 100;

(3) The quotation fee for companies in this market is a flat rate of N30,000 per annum;

(4) The amount that can be raised may not exceed N100 million;

(5) Financial statements and business records of the company for the past three years must be submitted to the Exchange; and

(6) After listing, the company must submit half yearly and annual accounts to the Exchange.

Under the SSM, an individual cannot have more than 75 percent of total shares directly or indirectly. Besides these, all other requirements such as registration, date of last audited accounts as well as securities being fully paid up at the time of allocation are the same for the two markets.

2.1.4 Operators of the capital market

The operators in the capital market include Brokers/Dealers, Issuing houses, Registrars, Underwriters, Trustees and Portfolio/Fund Managers, which provide various services for the investors and borrowers in the capital market.

2.1.5 Regulators of the capital market

The regulatory bodies of the Nigerian stock market consist of the Securities and Exchange Commission, the Nigerian Stock Exchange, Central Bank of Nigeria and Federal Ministry of Finance. On the basis of their experiences, different countries evolve different statutes for stock market operations. In Nigeria, there are several statutes that have provisions for guiding the operations of the stock market. The statutes are:

(1) The Lagos Stock Exchange Act, 1961;

(2) Trustee Investment Act, 1962;

(3) Companies and Allied Matters Act (CAMA), 1990;

(4) Banks and Other Financial Institutions Act, 1991;

(5) Nigerian Investment Promotion Act, 1995;

(6) Foreign Exchange (Miscellaneous provisions) Act, 1995;

(7) Securities and Exchange Commission Act, 1999;

(8) Investment and Securities Act, 1999.

2.1.6 Securities and Exchange Commission

The apex regulatory body in the capital market is the Securities and Exchange Commission (SEC). It is empowered by the Securities and Exchange Commission Act, 1999 amongst others to:

(i) Register and approve all securities for subscription or sale to the public, while ensuring that full disclosure is given in the prospectuses and other issue documents in the case of a public offer;

(ii) Ensure fair, orderly and equitable dealings in securities;

(iii) Register commodity and stock exchanges, investment advisers and all market operators with a view to maintaining an enviable standard of conduct and professionalism in the stock market;

(iv) Review, approve and regulate mergers and acquisitions;

(v) Perform market oversight functions through surveillance, Monitoring and on/off site inspection with a view to assuring fair play and equitable dealings on the Exchange; and

(vi) Promote investors' education and all categories of intermediaries in the securities market.

Thus, the SEC regulates the issue of securities and conduct of operators/players in the market, as well as sales practices. In addition, to its administrative and regulatory roles, the SEC is also vested with the power to suspend or revoke the registration of any person/body involved in price manipulations, unjust or inequitable practices, after an opportunity for hearing has been given. The Commission may annul such a transaction and further prescribe appropriate measures to rectify such irregularities. The SEC is also expected to relate with some international securities market organizations, stock exchanges, the International Finance Corporation, etc. It became a member of the International Organization of Securities Commission (IOSCO) in 1995. The Commission has also sustained its membership with the Emerging Market Committee (EMC) and the Africa and Middle East Regional Committee (AMERC), among others. The membership provides a platform for SEC to showcase the Commission to the external world, thereby, inducing foreign investment.

2.2 Theoretical Review

2.2.1 Efficient Market Hypothesis (EMH)

The efficient markets hypothesis (EMH), also recognized as the Random Walk Theory, is the idea that current stock prices accurately reflect the information that is currently available about the firm's value and that it is impossible to make excess profits (earnings that are greater than the whole market) using this knowledge. It addresses one of the most important and fascinating topics in finance: the causes and mechanisms of price movements on security markets. Both financial managers and investors must consider the significant ramifications. The phrase "efficient market" was first used in a 1965 study by E.F. Fama, who claimed that on average, competition causes the full effects of new information on intrinsic values to be reflected "instantaneously" in actual prices.

Many investors look for inexpensive stocks whose values are predicted to rise in the future, particularly those whose values will rise faster than those of other securities. The belief that investment managers can choose assets that will outperform the market is shared by many investors. To help them make better investment decisions, they employ a number of forecasting and valuation tools. It goes without saying that every advantage a trader has can result in large earnings. According to the EMH, none of these strategies are successful (the benefit does not outweigh the transaction and research expenses incurred), and as a result, nobody can consistently outperform the market.

According to the efficient markets hypothesis (EMH), it is extremely difficult and improbable to make money by correctly predicting price changes. The emergence of new information is the primary driver of price movements. A market is deemed "efficient" if prices respond to new information rapidly and, on average, impartially. Because of this, the current prices of securities always include all information that is currently available. As a result, there is no justification for thinking that prices are either too high or too cheap. Before an investor has a chance to trade on and profit from fresh knowledge, security prices change (Clarke, Jandik, and Mandelke, 2001).

The fierce competition among investors to make money off of any new knowledge is the main driver of an efficient market. It is extremely important to be able to spot overpriced and underpriced stocks since it would enable investors to purchase some stocks below their "true" value and sell other stocks for more than they were really worth. As a result, a lot of people invest a lot of time and money in looking for "mis-priced" stocks. Naturally, the likelihood of being able to profit from overvalued and undervalued assets decreases as more analysts engage in competition with one another in this regard (Clarke, Jandik, and Mandelke, 2001).

The opportunity to locate and profit from such mispriced assets diminishes over time. In equilibrium, there will only be a few analysts who can profit from the mispriced securities frequently discovered by accident. The information analysis reward would probably not outweigh the transaction costs for the vast majority of investors.

The EMH's most important conclusion can be summed up in the following phrase: Trust market prices! Prices of securities in effective markets represent all information that is currently known to investors at any one time. Investors cannot be duped; therefore, all investments in efficient markets are properly priced, meaning that, on average, investors get what they paid for. Even if all assets are priced fairly, that does not guarantee that they will perform equally or that they would all have the same chance of appreciating in value.

According to capital markets theory, a security's projected return essentially depends on its risk. The security's price reflects the present value of its anticipated future cash flows, which takes into account a number of variables like volatility, liquidity, and bankruptcy risk. However, while prices are rationally based, changes in prices are expected to be random and unpredictable, because new information, by its very nature, is unpredictable. Therefore, stock prices are said to follow a random walk (Clarke, Jandik and Mandelke, 2001).

2.2.2 Solow's Growth Model

It is well known that Solow's 1956 growth model, which can be found in the article "A Contribution to the Theory of Economic Growth," served as the foundation for the theory of growth. The article includes a differential equation-based mathematical model to illustrate how more capital stock results in higher per capita production. Solow's thesis is that society saves a certain fixed percentage of its incomes. Both the population and the work pool are expanding steadily it is possible to regulate capital intensity (or capital per employee). In this model, a steady-state growth path is reached over time and in the absence of technical advancement when output, capital, and labor all expand at the same rate. As a result, output per worker and capital per worker are constant, and the economy is getting closer to a situation where capital, labor, and total output are growing at the same rates. It is impossible for the percentage of saved incomes to permanently raise growth rates. In fact, without technological advancement, the pace of growth will remain constant (regardless of the share of savings) and will only depend on a rise in the labor force (Schiliro 2017).

Solow's growth-theoretical model had a significant influence on economic analysis. The model has influenced how we view macroeconomics as a whole and economic growth specifically.

2.3 Empirical Review

There have been the growing concerns and controversies on the role of the Stock market on economic growth and development. This section contains excerpts from previous research works on this subject matter.

Esian and Ebipre (2020) looked at how Nigeria's capital market affected economic growth between 1980 and 2016. Data were gathered from CBN statistical bulletin. Real Gross Domestic Product (RGDP) served as the dependent variable and a proxy for economic growth, while Market Capitalization (MCAP), Volume of Shares Traded (VST), Government Expenditure on Health (GCEH), and Government Capital Expenditure on Education (GCEE) served as the independent variables and proxies for the performance of the capital markets. The results showed that Market Capitalization (MCAP) had a positive and significant impact on the economy in the short run but had an adverse effect on the economy over the long run. Volume of Shares Traded (VST) had a positive and significant impact on the economy in the short run but had an adverse effect over the long run. While government capital expenditure on education had a negative and statistically significant impact on economic growth both in the short- and long-terms in Nigeria, government capital expenditure on health (GCEH) had a positive and statistically significant effect on economic growth in the long-run but not in the short-run. The conclusion was drawn that Nigeria's capital market has the ability to contribute to economic growth with a low ECM (-1) of 20% speed of convergence to equilibrium.

Angaye and Frank (2020) studied the impact of Nigeria's capital market expansion on economic growth between 2008 and 2018. Market capitalization rate, interest rate, and inflation rate were used as proxies for stock market development, while GDP was used to measure economic growth. The study used the multiple regression analysis test to determine whether there is a strong correlation between Nigeria's stock market development and national economic expansion. According to the empirical findings, the Nigerian stock market is favorably correlated with economic growth, but its impact is minimal.

The impact of Nigeria's capital market was looked at by Rilwanu and Daniel (2020) to determine the contribution made by the capital market to the growth of Nigeria's economy and to identify the challenges the Nigerian capital market is currently experiencing that are preventing further economic expansion. The majority of the data used in the study came from the CBN and World Bank Group, and it was evaluated using correlation analysis. The findings of the study show that the capital market is a key factor in the expansion of the Nigerian economy and that the Nigerian public views it as a significant outlet for savings and investment.

Binuyo Oluwatimilehin, Edy-Ewoh and Binuyo (2019) looked at how the growth of the capital market affected the Nigerian economy from 1987 to 2018. Time series data were employed in the study and the ordinary least squares method was used for analysis. The findings indicated that while value of transactions had a negligible and minor impact on GDP, market capitalization has a favorable impact on GDP.

Secondary data was used by Acha and Akpan (2019) to investigate the causal relationship between stock market performance and economic development in Nigeria from 1987 to 2014. Gross domestic product (GDP) serves as a proxy for economic growth, and market capitalization, total new issuance, volume of transactions, and listed equities serve as indicators of capital market performance. Using the Vector Autoregressive (VAR) model as the foundation, the Granger causality test was used to investigate the causal link. The results imply that the relationship between capital market performance measures and economic growth runs unilaterally. The analysis demonstrates that between 1987 and 2014, the Nigerian economy was positively and considerably impacted by the capital market performance.

Ugbogbo and Aisien (2019) Used time series data from Nigeria for the years 1981 to 2016 to look at the effects of capital market development on economic growth. The empirical finding showed that the expansion of Nigeria's capital market has a considerable and favorable impact on economic growth over the long and short terms. Interest rate, money supply, and investment level were additional significant factors in the empirical finding. In order to ensure a dependable, effective, and stable stock market in Nigeria.

Kuna, Hassan Ibrahim (2019) study goal was to empirically examine the relationship between Nigeria's capital market performance and its socioeconomic progress. The gross domestic product (GDP) served as a proxy for socioeconomic development. Stock market capitalization (SMC), stock market index (SMI), trade share (TS), and capital market saving ratio (CMRS) are among the capital market variables taken into account. The study's findings demonstrate that the capital market has a favorable and considerable influence on the economic growth of the nation.

Nwamuo (2018) studied the effect of Nigeria's capital market on economic growth for the years 1981 to 2016. Annual time series data on the study's variables were gathered from the Securities and Exchange Commission statistical bulletin and the Central Bank of Nigeria's statistical bulletin. The variables were stationary, even though they were at different levels, according to the results of a unit root test using the Augmented Dickey-Fuller test procedure. The model's variables were co-integrated, which means there exist a long-run relationship. According to the short run regression results, total listed equities and the volume of transactions had a negative impact on Nigeria's economic growth, whereas market capitalization and the number of deals had a favorable impact. According to the results of the long run dynamic analysis, the number of deals had a negative and non-significant impact on Nigeria's economic growth; whereas total listed equities had a positive and significant impact.

Briggs (2015) examined effect of the capital market on the Nigerian economy between 1981 and 2011. Gross Domestic Product (GDP) was used as a proxy for economic growth, and market capitalization (MCAP), total new issues (TNI), value of transactions (VLT), and total listed equities and government stocks (LEGS) were all taken into account as capital market variables. The outcome demonstrated that the capital market unmistakably has favorable relative impact on economic growth.

Yadirichukwu and Chigbu (2014) examined the effect of Nigeria's capital market on economic growth. The study used secondary data spanning the years 1985–2012. The research revealed that new issues (TONIS) and value of transaction (VALTRAN) showed a statistically significant positive association with economic growth, whereas Market capitalization (MKTCAP) and Total listing (TOLIST) showed a negative relationship.

Eze and Nwankwo (2013) studied the effect of capital market reform on the expansion of the Nigerian economy. The study's time frame was from 1990 to 2011.The outcome of the analysis demonstrates that capital market reform has a considerable impact on Nigeria's rate of economic growth.

3. METHODOLOGY

3.1 Scope, Data and Variables

In this study, the 36-year period between 1985 and 2021 was used to evaluate the relationship between the capital market and economic growth in Nigeria. The Central Bank of Nigeria's (CBN) Statistical Bulletin and World Development Indicators were the primary sources of the data utilized for the analysis.

The variables of interest were; value of transactions, all share index, government stocks, corporate bonds, equities and inflation rate; which were the independent variables, while economic growth proxied by gross domestic product was the dependent variable. Below is the full description of the variables used for the study.

3.1.1 Value of Transaction

The value of a transaction refers to the total amount involved in buying or selling financial instruments such as equities, debt securities, or other financial products. There are various factors that can influence the value of a transaction, including the type of financial instrument, the number of shares or securities being traded, and the current market price of the instrument.

3.1.2 All Share Index

The All-Share Index (ASI) is a type of stock index that represents the performance of a broad market segment, including stocks from various sectors and sizes. It is a capitalization-weighted index, meaning that the weights of the constituent stocks are determined by their market capitalization. The ASI is often used as a benchmark for the overall performance of a stock market, and it helps investors to gauge market movements and compare the performance of their portfolios. Example is the All-Share Index in Nigeria, which tracks the performance of the Nigerian stock market and is composed of stocks from various sectors, including banking, insurance, consumer goods, oil/gas, and more.

3.1.3 Government Stocks

Government stocks, also known as government bonds or sovereign bonds, refers to debt securities issued by a national government to raise funds to finance its operations and projects. It is a form of borrowing where the government acts as the borrower and investors, such as individuals, institutions, and other governments, act as lenders by purchasing these bonds.

Government stocks are typically considered low-risk investments because they are backed by the creditworthiness and taxing power of the issuing government. They are often regarded as safer investments compared to other types of bonds due to the lower probability of default.

These bonds have predetermined terms, including the interest rate (yield), maturity date, and face value. Governments pay periodic interest payments, typically semi-annually or annually, to bondholders based on the agreed-upon interest rate. At maturity, the face value of the bond is repaid to the bondholders.

3.1.4 Corporate Bonds

A corporate bond is a debt obligation that an investor buys as a way to lend money to a business. It's usually considered a less risky investment than a stock. Companies issue corporate bonds to raise money that they use to reinvest in operations, buy other companies, or even pay off older, more expensive loans. A corporate bond is like an IOU (I Owe You) that a company gives you in return for money you lend the business. It's a contract to pay you back at a certain rate of interest at a certain period.

3.1.5 Equities

Equity refers to the ownership interest or residual claim that shareholders have in a company's assets after deducting liabilities. It represents the ownership stake in a company and represents the value that would be returned to shareholders if all the company's debts were paid off and its assets were liquidated.

3.1.6 Inflation Rate

Inflation is defined as a general increase in the price of goods and services in the economy, or a general decrease in the value of money. It refers to the decline of purchasing power of a given currency, meaning over time, the currency holds less value. Inflation can be measured using various indexes, such as the Consumer Price Index and Wholesale Price Index. For this study inflation is use as a control variable as investors and participants in the capital market often closely monitor inflation indicators and assess their potential impact on various asset classes to make informed investment decisions.

3.1.7 Economic Growth

Economic growth is typically expressed as an increase in real gross domestic product, or real GDP, expressed as a percentage. Economic growth, according to Balcerowicz (2012), is a process of quantitative, qualitative, and structural changes that have a positive impact on the economy and the standard of living of the population and have a propensity to rise steadily over time. Economic growth, according to Fasanya, Onakoya, and Agboluaje (2013), is the process of enlarging national economies and macroeconomic indicators, such as the GDP per capita, in an ascendant but not necessarily linear direction. This has favorable effects on the economic and social sectors. Economic growth, according to Friedman, is a process of innovation that results in the fundamental alteration of the social system. Schumpeter (1912) contrasts this by defining it as a discontinuous and spontaneous change in the stationary state that permanently modifies and replaces the preceding equilibrium state.

Economic growth, however, is defined for the purposes of this study as an increase in the actual value of goods and services generated in the nation over time.

3.2. Model Specification

The model which specifies that economic growth [proxied by Gross Domestic Product (GDP)] is influenced by the capital market indices (value of transactions, all share index, government stocks, corporate bonds and equities as well as inflation rate) is formulated as follows,

GDPGR = f (VLT, ASI, GS, CB EQ, INF) --- (I)

Where:

GDPGR = Gross Domestic Product Growth rate
VLT=Value of Transactions
ASI=All Share Index
GS= Government Stocks
CB= Corporate Bonds
EQ= Equities
INF=Inflation (Consumer price index)

$GDPGR = \propto_0 + \propto_1 LVLT_t + \propto_2 LASI_t + \propto_3 LGS_t + \propto_4 LCB_t + \propto_5 LEQ_t \propto_6 INF + U_t$--------- (II)

Equation II shows the Statistical model of the equation

Where:

$\propto_{1, 2, 3, 4,5,6}$ =coefficient of the independent variables

t = time

U_t=error term

$LGDP_t - LGDP_t(-1) = \propto_0 + \propto_1 LVLT_t + \propto_2 LASI_t + \propto_3 LGS_t + \propto_4 LCB_t + \propto_5 LEQ_t \propto_6 INF + U_t$-(III)

Equation 3 can be written as:

$LGDPGR_t = \propto_0 + \propto_1 \ VLT_t + \propto_2 \ ASI_t + \propto_3 \ GS_t + \propto_4 \ CB_t + \propto_5 \ EQ_t \propto_6 INF + U_t$-------------- (IV)

Equation 4 shows the logarithmic model of the equation.

Where:

LGDPGR = Log of Gross Domestic Product Growth Rate

$LGDP_t - LGDP_t(-1)$= LGDPGR = Change in economic growth

The ARDL short run model is specified as:

$LGDPGR_t = \propto_{01} + \sum_{i=1}^{p} a_{1i}\Delta VLT_{t-i} + \sum_{i=1}^{q} a_{2i}\Delta ASI_{t-i} + \sum_{i=1}^{q1} a_{3i}\Delta GS_{t-i} + \sum_{i=1}^{q2} a_{4i}\Delta CB_{t-i} + \sum_{i=1}^{q3} a_{5i}\Delta EQ_{t-i} + \sum_{i=1}^{q4} a_{6i}\Delta INF_{t-i} + u_t$-- (V)

Where;

$\propto_0$ = intercept

Δ= difference operator

p,q,qi,q2,q3,q4,= lag length

$\propto_1, \propto_2, \propto_3, \propto_4, \propto_5, \propto_6$,= coefficient of the independent variables

The *apriori* expectations are α1, α2, α3, α4 α5> 0 and α6<0 meaning we expect a positive relationship between the dependent variable and the independent variables except for inflation

3.3. Estimation Technique and Procedures.

The Auto-regressive distributive lag (ARDL) econometric method was used in view of the preliminary stationarity test that was conducted. Some of the variables were integrated at order 0, stationary at levels, while others were integrated at order 1, stationary at first difference. The unit root tests were conducted using enhanced Dickey-Fuller and Phillips Perron-tests. Also, the VAR model was also estimated to get the optimal lag for the study following the Units root test. Additionally, bounds test was conducted where it was discovered that there is no long run relationship. The Error Correction Model was also established in order to understand the short-run relationships between the variables.

3.4 Post Estimation Tests.

To assess the stability of the short run dynamic model, the following tests were performed using the residual diagnostic test: The Ramsey Reset test for linearity, the Serial Correlation test (LM test), the Heteroscedasticity test, the JarqueBera test for normality, and the Cusum test for stability.

4. EMPIRICAL ANALYSIS

4.1 Descriptive Statistics

From Table 4.1 the observation for all the variables is 37 with a mean value of 39894.15, 472.0084, 17500.44, 2890.492, 190.5516, 4981.973 and 19.12162 for RGDP, VLT, ASI, GS, CB, EQ and INF respectively which is the average value of the distribution of the series. The median values are 33004.80, 120.4026, 15559.90, 25.20000, 5.800000, 1325.700 and 12.54000 which is the middle value for each of the variables. The Table then lists each variables maximum values as 72393.67, 2350.876, 50424.70, 19026.10, 1400.430, 22296.84 and 72.84000 and minimum values as 16997.52, 0.225400, 117.2833, 2.100000, 0.000000, 2.700000 and 5.390000 for RGDP, VLT, ASI, GS, CB, EQ and INF respectively.

Table 4.1 Descriptive Statistics

	RGDP	VLT	ASI	GS	CB	EQ	INF
Mean	39894.15	472.0084	17500.44	2890.492	190.5516	4981.973	19.12162
Median	33004.80	120.4026	15559.90	25.20000	5.800000	1325.700	12.54000
Maximum	72393.67	2350.876	50424.70	19026.10	1400.430	22296.84	72.84000
Minimum	16997.52	0.225400	117.2833	2.100000	0.000000	2.700000	5.390000
Std. Dev.	20195.37	588.0348	15467.88	4830.090	392.6335	6227.638	17.43978
Skewness	0.435313	1.204470	0.421620	1.993800	2.353634	1.163348	1.775772
Kurtosis	1.561574	4.030235	1.979928	6.338104	7.343232	3.542731	4.846922
Jarque-Bera	4.358382	10.58258	2.700381	41.69266	63.24229	8.799939	24.70457
Probability	0.113133	0.005035	0.259191	0.000000	0.000000	0.012278	0.000004
Sum	1476084.	17464.31	647516.3	106948.2	7050.410	184333.0	707.5000

Sum Sq. Dev.	1.47E+10	12448258	8.61E+09	8.40E+08	5549798.	1.40E+09	10949.25
Observations	37	37	37	37	37	37	37

Source: Author's Compilation (2023)

The standard deviation numbers, which represent the dispersion of the observation around the mean, are 20195.37, 588.0348, 15467.88, 4830.090, 392.6335, 6227.638 and 17.43978. All observations according to the Skewness metric in the table that quantify the asymmetry of the distribution of the series are positively skewed which implies that their distributions have long right tail and are normally distributed around their mean. RGDP and ASI have kurtosis's that are less than three which suggests that their distributions are platykurtic or flat in comparison to the mean. VLT, GS, CB, EQ and INF are leptokurtic, or significantly peaked as their values are all higher than 3.

Additionally, the statistics for Jarque-Bera were shown on the table for RGDP, VLT, ASI, GS, CB, EQ and INF which implies that the series is normally distributed. These variables probabilities, RGDP and ASI are all greater than 5% (0.05). This shows that the normal distribution's null hypothesis cannot be rejected. However, because the VLT, GS, CB, EQ and INF probability values are less than 0.05, the null hypothesis is rejected, indicating that the series is not normally distributed.

4.2 Unit Root Test

As indicated in Table 4.2 the stationary characteristics of the data were examined using the Augmented Dickey-Fuller (ADF) and Phillips-Perron Test for unit root. Under the ADF test, all variables aside from LGDPGR and ASI are stationary at first difference (integrated at order 1). At levels integrated at order 0 the LGDPGR and ASI are observed to be stationary. All variables are stationary at first difference (integrated at order 1) under the Philips-Perron test, with the exception of LGDPGR, LASI and INF, which is stationary at levels (integrated at order 0). The mixed order of integration shows that the estimating procedure uses the Autoregressive Distributed Lag (ARDL) model.

Table 4.2 Unit Root Test

VARIRBLES	AUGMENTED DICKEY-FULLER (ADF)	PHILLIPS-PERRON (PP)

	T-statistics	P-Value	Remark	T-statistics	P-Value	Remark
LGDPGR	-3.937292*	0.0046	I (0)	-3.850941*	0.0057	I (0)
LVLT	-5.123735*	0.0002	I (1)	-5.134178*	0.0002	I (1)
LASI	-2.750621***	0.0756	I (0)	-3.011166**	0.0433	I (0)
LGS	-3.422497*	0.0001	I (1)	-4.058280*	0.0033	I (1)
LCB	-5.326768*	0.0001	I (1)	-7.518823*	0.0000	I (1)
LEQ	-4.971483*	0.0003	I (1)	-4.933911*	0.0003	I (1)
INF	-4.537745*	0.0012	I (1)	-2.770284**	0.0726	I (0)

Note: *, **, and *** denote that the variable is significant at 1%, 5% and 10%.

Source: Author's computation. (2023)

4.3 Optimal Var Test

Table 4.3 Optimal Lag Length for Endogenous Variable

Lag	LogL	LR	FPE	AIC	SC	HQ
0	61.53277	NA	0.001494	-3.668653	-3.623304	-3.653394
1	64.29037	5.180946	0.001343	-3.775174	-3.684477	-3.744657
2	67.07405	5.061238*	0.001206*	-3.883276*	-3.747230*	-3.837501*
3	67.86705	1.393753	0.001222	-3.870730	-3.689335	-3.809696

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Source: Author's Compilation (2023)

From table 4.3, the Akaike Information Criteria were used to determine the best lag length. According to this criterion, lag 2 is the most optimum lag length for the dependent variable.

Table 4.4 Optimal Lag Length for Exogenous Variable

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-288.4558	NA	7.170824	18.99715	19.27469	19.08762
1	-138.8658	231.6232	0.004937	11.66876	13.61158*	12.30207
2	-87.35343	59.82082*	0.002409*	10.66796	14.27606	11.84411*
3	-44.83492	32.91755	0.003803	10.24741*	15.52079	11.96640

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

Source: Author's Compilation (2023)

On the basis of the Akaike Information Criteria, an appropriate lag length was chosen. According to this criterion, lag 3 is the most optimum lag length for the independent variable**.**

4.4 Estimation Analysis

4.4.1 Bounds Test

The outcome of the bounds test is displayed in Table 4.5. At the 5% level of significance, the number of parameters under observation is 6, the upper limit critical value is 3.28, and the lower bound critical value is 2.27. Indicating that the null hypothesis of no co-integration is accepted. The F-statistic, which is 1.516382 is less than the upper and lower bound critical values. This test proves that the series under observation have no long-term relationship. The ARDL Error Correction model is used to estimate the short run relationship.

Table 4.5 bounds test table

F-Bounds Test — Null Hypothesis: No levels relationship

Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	1.516382	10%	1.99	2.94
K	6	5%	2.27	3.28
		2.5%	2.55	3.61
		1%	2.88	3.99

Source: Author's Compilation (2023)

4.4.2 ARDL Error Correction Model.

The Error Correction Model (ECM) result is shown in Table 4.6. The stability of the coefficient is positive and significant indicating that the model has reached a point where it can no longer improve its performance, with a probability value of 0.0014 and coefficient of 0.059526. Additionally, the coefficient's significant value is demonstrated by a high t-statistics of 4.769249.

The R-squared value of 0.877030 indicates that the independent variables in the model explained 87.7 percent of the variation in the dependent variable, which is quite high.

TABLE 4.6. Estimated Coefficient of Short Run and Error Correction Model

ECM Regression
Case 2: Restricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LGDPGR(-1))	-0.746942	0.119557	-6.247577	0.0002
D(LVLT)	0.004957	0.011300	0.438710	0.6725
D(LVLT(-1))	-0.005283	0.011847	-0.445912	0.6675
D(LVLT(-2))	-0.000261	0.011946	-0.021858	0.9831
D(LASI)	0.030391	0.043988	0.690895	0.5092
D(LASI(-1))	0.095899	0.041124	2.331938	0.0480
D(LASI(-2))	-0.023581	0.029574	-0.797361	0.4483
D(LGS)	-0.041023	0.011774	-3.484307	0.0083
D(LGS(-1))	0.000551	0.010394	0.053014	0.9590
D(LGS(-2))	-0.032587	0.011581	-2.813734	0.0227
D(LCB)	-0.022247	0.006987	-3.184136	0.0129
D(LEQ)	0.056950	0.029889	1.905362	0.0932
D(LEQ(-1))	-0.061950	0.035208	-1.759545	0.1165
D(LEQ(-2))	0.045914	0.031957	1.436768	0.1887
D(INF)	-0.001097	0.000409	-2.681952	0.0278
D(INF(-1))	0.000754	0.000357	2.113144	0.0675
D(INF(-2))	-7.96E-05	0.000434	-0.183288	0.8591
CointEq(-1)*	0.059526	0.012481	4.769249	0.0014

R-squared	0.877030	Mean dependent var	-0.001132
Adjusted R-squared	0.737665	S.D. dependent var	0.042158
S.E. of regression	0.021593	Akaike info criterion	-4.530475
Sum squared resid	0.006994	Schwarz criterion	-3.714198
Log likelihood	92.75283	Hannan-Quinn criter.	-4.255822
Durbin-Watson stat	1.909274		

Source: Author's Compilation (2023)

With a coefficient value of 0.095899, t-statistic of 2.331938 and probability value of 0.0480 the first lag value of all share index (ASI) have a positive and significant effect on economic growth in Nigeria. Suggesting that every one-unit increase in the first lag of All Share Index results in a 0.095899 percentage increases in economic growth. Similarly, with a coefficient value of 0.056950, t-statistic of 1.905362 and probability value of 0.0932, equities (EQ) have a positive and significant impact on economic growth in Nigeria. This implies that a one-unit increase in equities will increase economic growth by 0.056950 percent. Value of transactions (VLT), with a coefficient value of 0.004957, t-statistic value of 0.438710 and probability value of 0.6725 indicated a positive but insignificant effect on economic growth in Nigeria. These results are in line with apriori expectations as their coefficients are positive.

However, with a coefficient value of -0.041023, t-statistic value of -3.484307 and probability value of 0.0083, Government Stocks (GS) has a negative and significant effect on economic growth in Nigeria in the period under consideration. The implication is that one-unit increase in Government stock leads to a 0.041023 percentage decline in the rate of economic growth in Nigeria. Similarly, Corporate Bonds (CB), with a coefficient value of -0.022247, t-statistic value of -3.184136 and probability value of 0.0129, has a negative and significant effect on economic growth in Nigeria. That is a one-unit increase in Corporate Bonds will bring about a 0.022247 percent decrease in economic growth in Nigeria. These results are contrary to apriori expectations.

As expected, the coefficient value for inflation rate (INF) at -0.001097, t-statistic value of -2.681952 and probability value of 0.0278 indicates that a one percentage increase in inflation rate will lead to a 0.001097 percentage decrease in economic growth.

5. SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary of Findings

This paper examined the role of capital market in the development of the Nigerian economy between 1985 and 2021, using the Auto Regressive Distributed Lag estimation technique (ARDL). The capital market variables included in the model were; value of transaction, all share index, government stocks, corporate bonds, equities and inflation rate in view of its

macroeconomic significance. The Central Bank of Nigeria Statistical Bulletin and World Development Indicators were the sources of the data. The ARDL technique was adopted after a stationarity test was conducted using the Augmented Dickey Fuller Units Roots test and Phillips-Perron Units Roots test, and stationarity was found at both levels and first difference. In order to get the best optimal lag for the model, the VAR lag order was estimated after which a bounds test was conducted. The findings of the study are as follows:
(1) The first lag of the all share index (ASI), actual values of equities and (EQ) and value of transactions (VLT) were the capital market variables that impacted economic growth positively. Government stocks (GS) and corporate bonds (CB) on the other hand impacted economic growth negatively. As expected inflation rate (INF) impacted economic growth negatively.

5.2 Conclusion

The study reveals that the capital market impacts economic growth in Nigeria positively and significantly via the all share index (ASI) and equities (EQ). This is in line with the results obtained by Esian and Ebipre (2020), Rilwanu and Daniel (2020), Binuyo, Edy-Ewoh and Binuyo (2019) Acha and Akpan (2019) and Nwamuo (2018). However, in this study, economic growth is impacted negatively and significantly by Government stocks (GS) and Corporate bonds (CB). This could be as a result of the fact that government stocks (GS) and corporate bonds (CB) are still traded at a very low levels in the Nigerian capital market.

5.3 Recommendations

The following recommendations are based on the outcome of the study:

i. Since equities contribute positively and significantly to economic growth, government is therefore advised to put up measures to step up investors’ confidence and activities in the market and more foreign investors should be encouraged to participate for improvement in the capital market.

ii. Similarly, since the all share index is positive and significant, there should be increase in the total member listed companies to ensure stable macroeconomic environment in order to encourage foreign multinational companies (MNCs) or their subsidiaries to be listed on the Nigerian stock exchange, relax the listing requirements to the first tier market and ensure tax rationalization in the capital market to encourage quotation and public interest in shareholdings.

iii. To boost the value of transactions in the Nigerian capital market, there is need for availability of more investment instruments such as derivatives, convertibles, future, and swaps options in the market.

iv. Governments and regulatory bodies can enforce stricter disclosure requirements for corporate bond issuers. This includes mandating companies to provide comprehensive and accurate information about their financial health, operations, and risk factors associated with their bonds. This could make them more attractive to investors who want to take informed decision.

v. To improve the performance of government bonds, governments should take steps to enhance the liquidity of the secondary market for government bonds. This can involve promoting market-making activities, facilitating the entry of market makers, and encouraging the participation of intermediaries. Measures to increase secondary market liquidity make it easier for investors to buy and sell government bonds, thereby improving market efficiency.

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DEGLOBALIZATION OF THE AGRICULTURE?

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Abstract
The term "globalization" usually refers to the increasing economic integration and dependence between countries created through trade, foreign investment, immigration and emigration, cooperation, alliances, etc. across borders. Specific driving forces behind the globalization of agriculture and the agri-food industry can be identified and are important in an assessment of whether globalization is still increasing, decreasing, weakening or changing.

However, great uncertainty is recognized about the continued development of globalization, which is of great importance not least for agriculture and the entire agricultural sector. The purpose of the article is thus to assess the historical and present globalization trends in the agricultural sector, and to identify possible new future trends.

Regarding the entire global economy, the past decade has been characterized by constant globalization (slowbalization or deglobalization), and we are now well below the long-term trend. When it comes to the agricultural and food industry, in the same period there has been an increasing globalization, but a weakening after 2020. Parallel to this, the trend shows increasing foreign direct investments, which are now the biggest source of globalization.

It is found that although the long-term trend indicates a continued increase in globalization, a number of specific political conditions and factors can send globalization back in the short or long term.

Keywords

Globalization, deglobalization, reglobalization, agriculture, driver, trend

Introduction

Over several decades, globalization has been increasing and has thus contributed to increased economic growth and welfare throughout the world at once. A number of identified factors affect globalization – both historically and in the future:

Globalization requires stable geopolitical conditions: Globalization is limited if, for example, there is a high risk of seizure of foreign assets and investments, or if a general lack of trust and credibility in the political and business conditions is widespread in the foreign markets where sales, investment and production could be relevant.

Globalization also follows economic cycles: During positive business cycles, economic growth and high profitability, companies' foreign investments increase.

The climate crisis also plays a role in globalization: International trade and transport over long distances increase greenhouse gas emissions. Less long-distance international trade may therefore be one of the solutions to the climate crisis.

With geopolitical instability, weakened economic cycles in many countries and unresolved climate crisis, several drivers may weaken or change globalization in the near future.

Area description and definitions

The analyzes in this article have a global approach and relate to agriculture in an international perspective. Agriculture and farmers, who today depend on international trade and international investment, will obviously be most affected and have the most interest in the content of the article. However, agricultural markets are largely exposed to international competition, so the consequences of a possible deglobalization could be far-reaching and affect farmers in large parts of the world.

"Agriculture" includes associated industries upstream and downstream, including also the processing and supplying companies.

"Globalization" usually describes the ever-increasing economic integration between countries created through trade, foreign investment, immigration and emigration, cooperation, alliances, etc. across borders. However, globalization is far from a unique concept, and globalization is defined differently in many places.

There are also more and more varieties and new dimensions of the concept of globalization:

- Globalization refers to the increasing integration of economies around the world, particularly through the exchange of goods, services, labor, knowledge and capital across borders. Also broader cultural, political and environmental dimensions of globalization can be included.
- Deglobalization is the opposite of globalization, i.e. a development towards less integration and interdependence between countries. This development is often driven by a focus on national interests and the protection of domestic companies against foreign competition.
- Near-globalization implies that trade, investments, cooperation etc. increasingly takes place with countries within the same geographical or political area. Near-shoring is a similar concept, where you previously moved parts of production to distant countries and now move production back to more nearby countries. In the same category we find the terms "friend-shoring" (moving foreign activities closer to "friendly countries"), "de-risking" (risk reduction in foreign activities).
- Slowbalization describes a development where globalization only increases slowly or even stagnates for periods. The development may be due to external shocks such as the financial crisis, Covid-19 or war, or it may be due to more structural and long-term conditions such as geopolitical instability.
- Regionalization means that international trade increasingly takes place within regions – often in regional trade agreements or trade blocs.
- Reglobalization as a concept has been introduced by several sources over recent years. For example, the WTO has used it as an alternative to deglobalization. Without being particularly well defined, reglobalization implies an “Interdependence without overdependence. Deeper, more diversified, and deconcentrated international markets” (WTO, 2022). For example, more and less concentrated markets will increase security of supply and reduce vulnerability.
- The terms internationalization and globalization are often used interchangeably and as synonyms. However, globalization is usually considered something different and

more than internationalization. Internationalization often focuses on a company's exports and international establishment, while globalization further involves global economic integration.

Results

Drivers behind globalization

Globalization does not occur by itself, but is the result of a number of underlying driving forces ("drivers"). If these driving forces are weakened or changed, then globalization can also be reduced or change. An identification of the driving forces behind globalization can thus help to uncover whether the driving forces and thus also globalization are weakened, decreasing or undergoing change.

In what follows, the focus is on the driving forces behind the globalization of agriculture and the food industry. The starting point is that the globalization of agriculture and the agri-food industry is created and driven by specific and unique conditions and factors.

Among the identified driving forces, trade liberalization in the form of multilateral WTO agreements on the reduction of agricultural protection in particular has been a significant driving force and factor. Subsequently, the conclusion of a large number of regional trade agreements has also strengthened globalization.

Geopolitical stability was particularly prominent in the 1990s and until Russia's invasions of neighboring countries and until trade and political conflicts between China and the West. Until this period, the geopolitical risks were relatively modest, which encourage foreign investment in particular. Subsequently, increasing geopolitical instability has reduced investments in, among others, Russia and China, and re-shoring (moved production returns to the home country) and thus deglobalization is now more widespread when it comes to these countries.

Investment funds and pension funds have become more important players in the international capital markets. They show an interest in diversifying their investments so that they include more countries, more sectors and more risk classes. Investments in foreign agriculture and agricultural land can meet these needs, and several concrete examples emphasize this.

Faster and cheaper transport solutions have been – and still are – an important driving force for both international trade and international investment in the agricultural and food sectors. Effective global value chains have contributed to the fact that part of Europe's production of vegetables and flowers has moved to Africa and Asia, see e.g. Hansen (2013).

Benefits and exploitation of comparative advantages is a significant driving force. The restructuring of the European sugar industry is an example of this: in this example, sugar beet production and sugar production have moved away from countries with relatively poor comparative advantages and conditions.

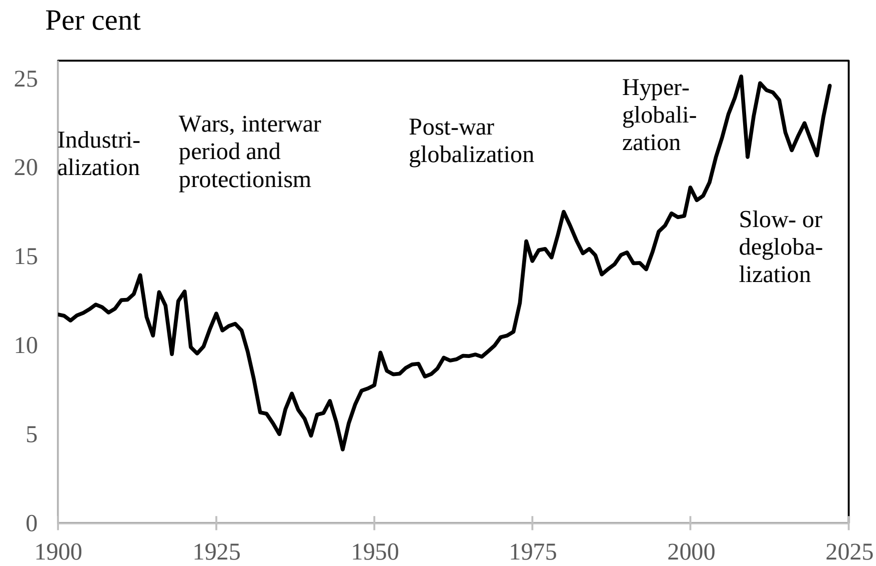
Developments in the globalization of agriculture and industry – empirically illustrated

As shown in the previous sections, a number of possible factors can explain increasing globalization in agriculture and in the food industry. On a qualitative basis, it is fair to assume that globalization is increasing, but that i.a. geopolitical conditions are likely to be a barrier in future development.

Firstly, the globalization trend is calculated in a long historical perspective and for all sectors in total. Considered over a very long time horizon, the extent and significance of globalization has varied considerably. During economic recession, world wars, and global crises, globalization, measured as the importance of international trade, declines. After the Second World War, both production, economic activity and international trade increased. The end of the Cold War, increasing trade liberalization and the fall of the Berlin Wall and subsequent more market economy in the 1990s gave further impetus to globalization.

In this millennium, the financial crisis, the pandemic, wars and growing protectionism have again put a damper on globalization. The various phases in the extent and significance of globalization are outlined in figure 1.

Figure 1. Total merchandise trade as a percentage of GDP, 1900-2022

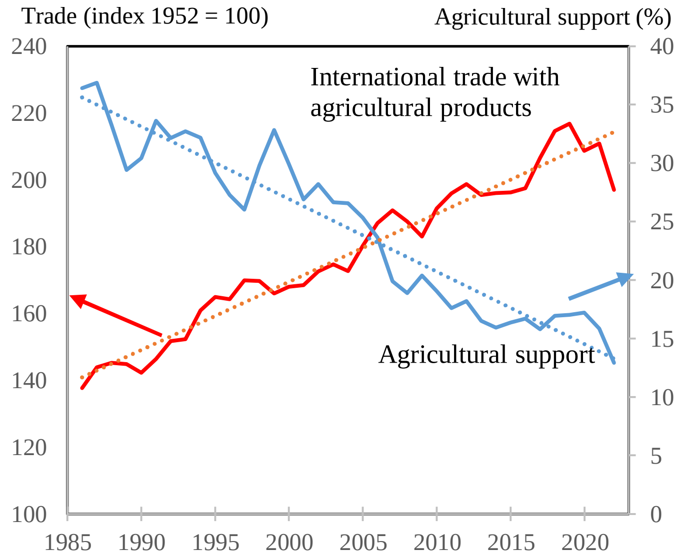


Source: Own presentation based on FAO (2024), World Bank (2024); Fouquin and Hugot (2016) and Keller and Marold (2023)

The figure indicates that whether globalization including increased international trade and cooperation will continue in the future is not a foregone conclusion. Deglobalization, slowbalization or reduced globalization occurred after the financial crisis, and the geopolitical situation, the extent of protectionist interventions, etc., may further reduce globalization in the coming years.

When zooming in on agriculture and food, a slightly different picture emerges. Based on empirical data and considering the historical development over a slightly longer period, no immediate signs of a decreasing globalization in agriculture and in the related food industry are obvious: International trade in agriculture and food is increasing, and agricultural support – and especially trade-distorting agricultural support – is falling and is now at the lowest level since 1986. As shown earlier, international trade and international trade protection in the agricultural and food industries are two important elements of globalization, and trade protection is a significant driving force. Figure 2 thus shows the development respectively in agricultural support in the OECD and in the international specialization with agricultural products in the period 1986-2022.

Figure 2. Agricultural support and international trade in agricultural products, 1986-2022



Source: Own presentation based on WTO (2023) and OECD (2024)

The figure reveals two trends:

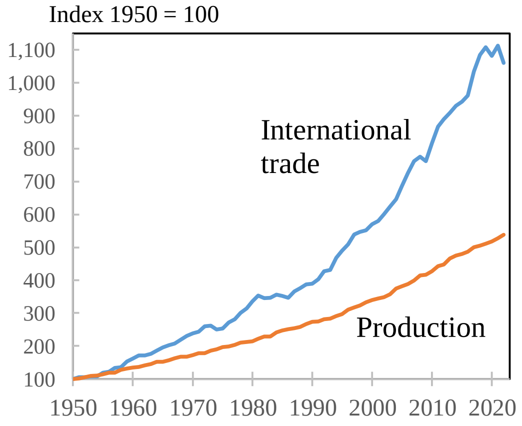
International trade in agricultural goods (measured as a percentage of total agricultural production) is increasing from year to year. The long-term trend is relatively clear, although a decline occurred in some years. For example, international trade decreased in 2020, which was largely due to the Covid19 pandemic and the resulting disruption to the global transportation of goods. The food crisis and the war in Ukraine have further restricted international trade. Ukraine is among the world's largest exporters of wheat, corn and sunflower oil, so a weakening of their export opportunities will also negatively affect world trade. However, the long-term development indicates that the share of the world's agricultural production that is traded on an international market will increase.

During the past decades agricultural support in the Western world has had a downward trend. In 2022, it averaged approx. 13 per cent of revenue in agriculture. This is more than a halving since the mid-1980s and the lowest level in the same period. The significant decline in 2021 and 2022 is largely due to the food crisis and the high world market prices, so this is also probably only a temporary decline. Normally, low agricultural support and trade liberalization will mean that the conditions for international trade are strengthened and favorable and that globalization and international specialization can be expected to increase.

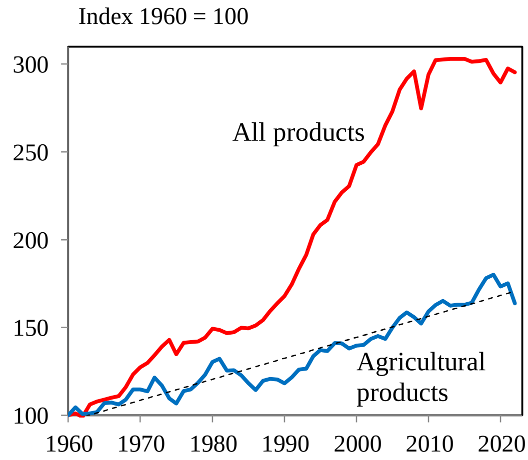
The international specialization is illustrated as international trade in relation to the world's total production. It is noteworthy that the world's total production of agricultural and food products increases steadily year after year – without significant changes as a result of business cycles, pandemics, weather conditions, etc. International trade in agricultural goods increases significantly more, but also has greater fluctuations from year to year, cf. figure 3A.

Figure 3. Trends in international trade, production and specialization

A: International trade and total production (agricultural products, 1950-2022)



B: International specialization (international trade/global production), all products and agricultural products,



Source: Own presentation based on WTO (2023)

Figure 3A shows that in the period, international trade in agricultural products has increased more than total world production. Figure 3B also shows that international specialization is growing faster for all products than for agricultural products: When it comes to agricultural products, both the long- and short-term development is different from the development for all products taken together: international specialization and globalization is growing more slowly, and the stagnation in the past decade is less or almost non-existent, cf. Figure 3B.

The immediate conclusion is that international specialization in the agricultural and food sector appears to have a moderately increasing trend, where only temporary phenomena such as covid19 and the food crisis have limited international specialization. For all products taken together, international specialization has been constant or even slightly declining over the past decade. This latest development is probably the aftermath of the financial crisis in 2007-09 as well as consequences of relatively low economic growth and geopolitical instability during the period.

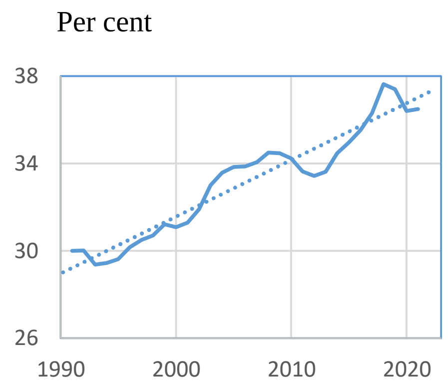
Below is a summary of the main results from figure 3:

	All products	Agricultural products
Short run (2011-2022)	Constant globalization (slowbalization or deglobalization) Far below long run trend	Increasing globalization, but weakened after 2020
Long run	Strongly increasing globalization	Moderately increasing globalization

The figures are so far based on index numbers, which can be used to show a development over time. This is of course important when the purpose is to present a possible globalization or deglobalization trend. Nominal values for export and production figures, respectively, can be difficult to obtain and, not least, to compare. This is due, among other things, to the fact that the products produced and exported are not identical: in agriculture, for example, milk, pigs and sugar beet are produced, while the associated exports may be cheese, bacon and sugar.

With these reservations, Figure 4 shows the value of international trade in agricultural products as a percentage of the value of total agricultural production for the years 1992-2021.

Figure 4. Value of international trade in agricultural products as a percentage of value of total agricultural production



Notes:
International trade: “Agricultural products. Export value”
Total production: “Value of Agricultural Production. Gross production value”

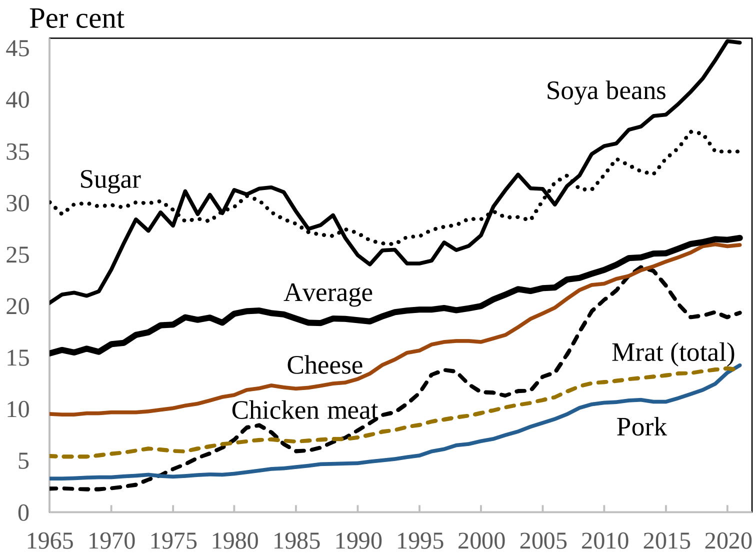
3 year moving average

Source: Own presentation based on FAO (2024)

The figure shows a clear trend towards increasing international trade (exports) compared to total production. Variations over time in the figure can be more or less random as a result of world market price fluctuations, good or bad harvests, stock changes, etc. – and without being a direct indication of a decreasing or increasing globalization trend.

The impact of price developments on international trade and on globalization can be reduced by comparing the quantities of agricultural products that are respectively exported and produced worldwide. Examining the individual products separately can be advantageous and beneficial, as the export shares can be very different from product to product, cf. figure 5.

Figure 5. International trade (export) as a percentage of the world's total production for selected agricultural products, 1965-2021



Notes: Average = Weighted average of 14 major agricultural commodities
3 year moving average

Source: Own presentation based on FAO (2024)

The figure only shows a selection of agricultural products that are traded internationally. Some products such as tropical fruits and coffee have very large international trade, while fresh products such as milk and vegetables are predominantly traded locally.

The figure shows and confirms fairly clear trends: An increasing share of the production of essential agricultural products is traded internationally.

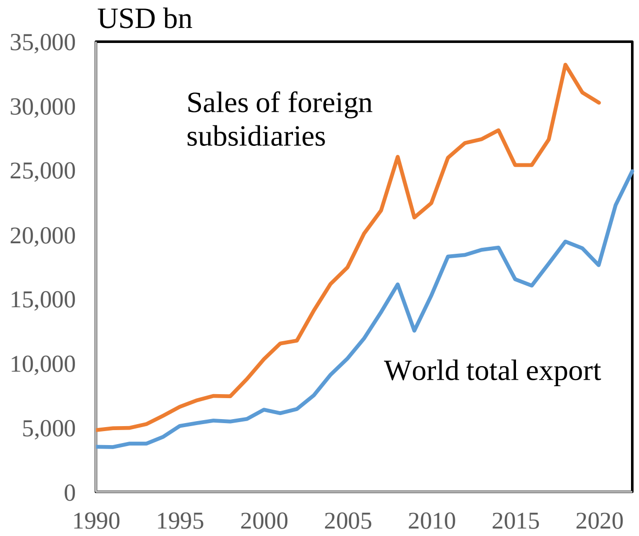
Changing globalization: From international trade to international investment

The concept of globalization includes more than just international trade. Foreign direct investment is also part of globalization. Foreign direct investment means that companies establish themselves abroad and produce and sell abroad. Often foreign production is based on foreign raw materials.

Companies' choice between either exporting from the home country or direct investment, production and sales abroad depends on a number of different factors. The product, the company and the markets can be decisive for which penetration strategy is most advantageous in the individual cases, cf. for example Hansen (2013). Direct foreign investment can, for example, be attractive if import barriers make exporting difficult, if access to resources (raw materials, labor, technology, etc.) in a foreign market is good, if the political risk in a foreign market is small, or if production is close to a large market is attractive.

The general process is: small companies are primarily home market-oriented and become internationalized through exports – initially especially export to the closest markets. When companies grow, they will typically establish themselves abroad, as well as invest and produce abroad. In recent decades, the capital markets have also been liberalized, and access to investments abroad has become much easier. In combination with increasingly larger companies, increased geopolitical stability and less risk from foreign direct investments, the result has been more globalization through production abroad and sales from foreign subsidiaries. As can be seen from Figure 6, the world's total sales of foreign subsidiaries are now significantly greater than the world's total exports.

Figure 6. Sales of foreign subsidiaries and world total export



Note: Sales of foreign affiliates: Data for 1990, 2005-07, 2018-2020
Source: Own presentation based on FAO (2024) and UNCTAD (2022, 2023)

The agricultural sector has broadly followed the same development: Farmers have increasingly established themselves abroad and the agri and food industry has made significant investments in foreign production. However, the trend has reversed in the very last few years. Several companies have all closed or sharply reduced their investments in Russia and China. A national and global trend towards re-shoring is likely to change the current development.

Discussion: Risk of deglobalization

Although the long-term trend indicates continued increasing globalization, political and economic factors can in the short or long term reverse globalization (Hansen, 2024).

- The geopolitical development, war in Europe and struggle between superpowers increase the uncertainty and risk in international trade and especially in foreign direct investments.
- The food crisis, expensive food and sometimes food shortages have led politicians and others to argue for higher national self-sufficiency and more local food supply.
- The climate crisis may make international trade over long distances less attractive. It will also limit globalization.
- Higher energy prices, which are likely to remain for a longer period, will also favor local sales and restrict international trade.
- Neo-protection, of which there are certain indications, may also restrict international trade and thus also globalization, especially on the agricultural markets.

A significant deglobalization will in many ways result in an extensive change for both the economy, for the business world and for citizens. However, such a scenario will only be likely in a very serious crisis or war situation. There is a certain inertia and momentum in both the liberalization of agricultural subsidies and in increased world trade: both liberalization and increasing international trade contribute to greater economic welfare, and no country will have any rational economic incentive to change the trend. The climate crisis may be one of the few reasons that can rationally limit globalization.

Deglobalization as a tool in climate policy is, however, a double-edged sword: on the one hand, shorter international trade distances can reduce the transport cost and thus also the climate impact. On the other hand, a trend towards less international trade and more national self-sufficiency can lead to an inefficient use of resources and thus an increased use of resources, which can damage the climate even more. The connection between international trade and globalization on the one hand and the climate crisis and climate policy on the other is thus complex.

Conclusion

As for the entire global economy, the last decade has shown a constant globalization (slowbalization or deglobalization) and we are now (2024) well below the long-term trend.

When it comes to the agricultural and food industry, globalization has been increasing in the same period, but has weakened after 2020. Parallel to this, a trend towards increasing investments abroad appears, which is now the biggest source of globalization. Although the long-term trend indicates continued increasing globalization, political conditions can reverse globalization in the short or long term.

A number of new questions or problems are raised: Deglobalization can probably both solve and intensify the climate problems. A paradox is that increasing international trade contributes to greater economic welfare, and no country will have any rational economic incentive to change the trend. Still, political conditions can reduce international trade and create a deglobalization.

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LESSONS FROM ENTERING A REGIONAL TRADE AREA - LONG-TERM EXPERIENCE BY DANISH AGRICULTURE

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Abstract

Regional trade areas now cover more than half of international trade, and the impact on agriculture and agricultural trade is significant. Based on this, this article is a case study of a country that has entered a regional trading area, and where agriculture played an important role in the pre-entry discussions. Denmark became a member of the EU in 1973, and the aim is to identify, analyze and discuss experience from these more than 50 years.

Since 1973, Danish agriculture has gone through a very extensive development, and EU membership has played a role. Agricultural support and exports, agricultural markets, the environment, productivity and use of resources have all been affected by the membership.

Furthermore, since 1973, the EU and the common agricultural policy has changed, which has changed the role of EU for Danish agriculture.

However, the most important developments in Danish agriculture after joining the EU have probably been consequences of conditions other than the EU: Technological development, exploitation of economies of scale, globalization, liberalization and the general developments in markets and demand have been more important drivers than EU membership itself.

Keywords

EU, Agricultural policy, Market, Export, Resources, Productivity

Introduction

The majority of world trade now occurs between pairs of countries that have established a regional trade agreement (OECD, n.d.). The number of regional trade agreements has increased rapidly, and the impact on agriculture and agricultural trade is significant. A regional trade agreement may be a free trade area, a common market, a customs union, etc. The degree of integration can be very different, but what they have in common is that internal trade between the countries takes place on relatively liberal terms.

The role of agriculture in such regional trade areas can vary greatly depending on the degree of integration and trade, the competitiveness of agriculture, and developments within and outside the regional trade area.

In this article, a case is analyzed where a country has entered a regional trade area, and where agriculture played an important role in the discussions prior to entry. Denmark became a member of the EU in 1973 (which is marked in the figures), and thus more than 50 years of experience exists and can be assessed and discussed. During this period, Danish agriculture has gone through a very extensive development. EU membership has played a role, but conditions in Denmark, in the EU and in the rest of the world have been very important factors for the development of Danish agriculture. Taking into account the specific conditions in this case, the experience can be used elsewhere where regional trade areas are considered, analyzed or developed.

Area description and definitions

This article is based on a case study where Denmark's entry into the EU in 1973 is analyzed. The foundation for the article and for the analyzes is i.a.

- that agriculture did play a significant role in the political decision on joining the EU.
- that the EU as an institution has changed a lot, becoming significantly larger both in number of member states and in degree of integration.
- that the external environment, including the agricultural external environment, has changed significantly since 1973. This applies to international trade, geopolitics, structural development, agricultural policy goals, etc.
- that the development of Danish agriculture has been influenced by many factors, and that entry into the EU is only one of many factors that has determined the development of agriculture.
- that the Danish experiences to a certain extent can be scaled up and generalized and utilized by other countries, even though agriculture can be very different around the world. The Danish experiences can therefore only be used if they are related to the specific countries, their agriculture, their specific regional area, etc.

The analyzes are carried out on a statistical and empirical basis. The intention is to be able to present results which are not only of theoretical or academic interest, but which may also be of interest to other stakeholders, including farmers, advisers and politicians.

In this article, the term "regional trade area" includes several levels of regional cooperation: From a free trade area to an economic and political union:

In a free trade area, in principle, goods have free movement across borders. With respect to third countries, the countries in a free trade area can maintain their individual trade barriers.

In a customs union, economic integration is greater because a common external tariff vis-à-vis third countries is maintained. The goods also have free movement within the customs union.

In a common market there is full movement of both goods, capital and labour. The free movement of labor in particular can be problematic or at least challenging.

If the goal is perfect competition with equal economic conditions in all member states, a coordination of economic conditions must take place, and in this way an economic union can emerge.

An economic and monetary union goes a step further and introduces a common currency or a fixed exchange rate policy, possibly with more or less fixed exchange rates.

In a political union, integration has increased further compared to the economic and monetary union. The member states of a political union leave sovereignty to the community when it comes to, for example, foreign policy in a broad sense.

A complete analysis of all relevant competitive conditions and factors as well as of all potential consequences of joining a regional trade area will be very comprehensive. The article therefore limits itself to assessing selected consequences, which are either most affected by EU membership, or have great significance for the development of agriculture. The focus is therefore on topics such as:

- Agricultural policy and support
- Agricultural export
- Market conditions
- Environment and nature
- Productivity and use of resources

Calculating the exact implications is inherently impossible. No one knows the alternative to the policies and interventions: what would the world have looked like without the EU's agricultural policy, and what would the "counterfactual" situation have looked like?

In this article, the name "EU" is used consistently, regardless of the period. Formally, the name or abbreviation "EU" was first used from the implementation of the Maastricht Treaty in 1993.

Results

Consequences of forms of integration – theoretical aspects

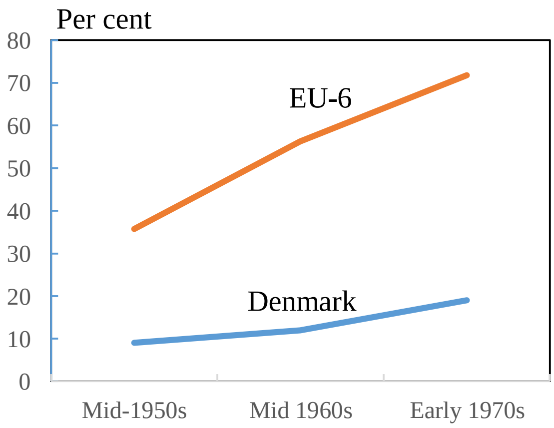
The step from no trade agreements to limited free trade agreements and to participation in a highly binding political union can have major consequences – both for the participating countries and their economies and for other countries. This form of economic integration thus affects the economies of both the participating countries and third countries in several ways. Prices change, and thus the competitive situation on the entire market is affected. Resource allocation, welfare economics, international trade and financial transfers between different sectors of society are some of the conditions that are affected to a certain extent.

In general, strong and competitive industries will benefit from entering into closer economic and commercial cooperation without protection, while weaker industries may experience disadvantages from being exposed to more international competition. Countries with a low level of support will also benefit from free access to other countries that have high support and weak competitiveness.

Agricultural policy and support

Agricultural policy and support were among the most important points of discussion – and arguments – in the negotiations on Danish participation in the EU. Danish agriculture looked forward to higher agricultural support and better market access. A few empirical studies also suggest that Danish agriculture experienced a significant increase in support via EU membership. Figures 1 and 2 show support levels for agriculture in Denmark and in the former EU-6.

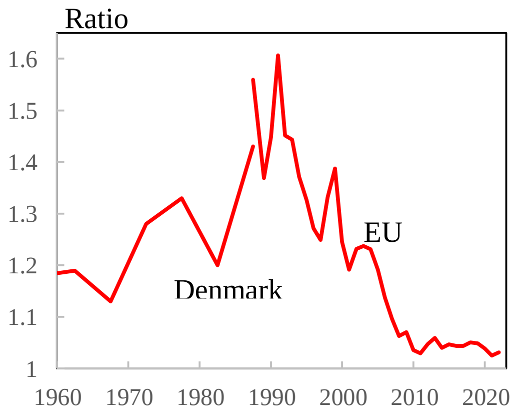
Figure 1. Agricultural support (per cent) in Denmark and the EU-6 before 1973



Note: EU-6 is unweighted average of West Germany, France, Italy and Benelux

Source: Hansen (1987) based on UNCTAD (1980), Guldbrandsen and Lindbeck (1975) and own calculations.

Figure 2. Trade protection (NPC) in agriculture in Denmark and the EU



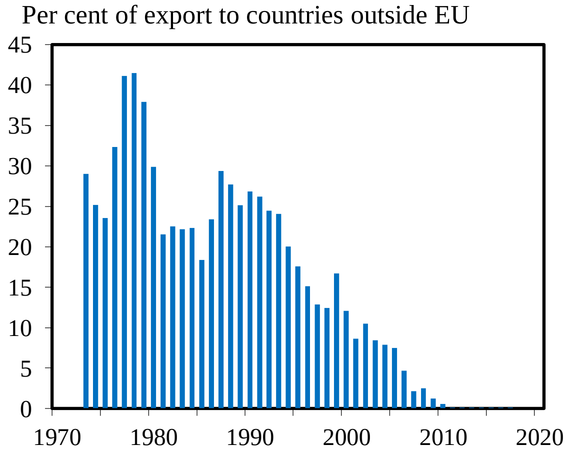
Note: EU: Nominal protection coefficient (NPC) cf. OECD's calculations for the period 1989-2022. Annual data. Denmark: Ratio between domestic prices and world market prices (weighted average where, for example, 1,2 is 20 per cent higher prices on the domestic market). Moving 5 year average

Source: Own calculations and Hansen (1987) and OECD (2024)

Denmark and Danish agriculture thus entered a quite different agricultural policy regime upon entry into the EU. Agricultural support became significant, and agricultural policy was a very important part of EU cooperation. The Common Agricultural Policy (CAP) was the most important policy area in the EU, and it dominated both internally in the EU and in other countries' perception of the EU (Cunha, A. and Swinbank, A. (2011).

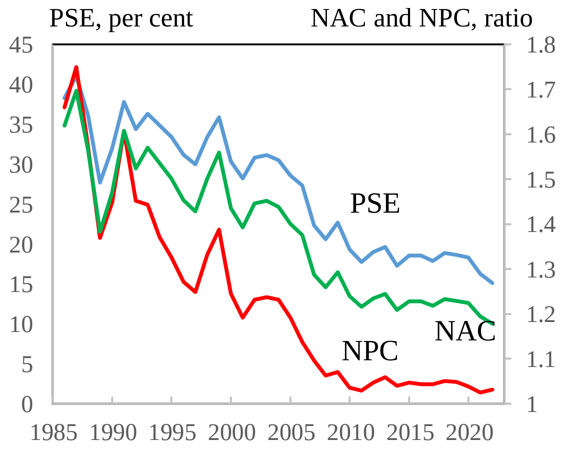
After a few years in the EU CAP was changed, and the abolition of export support was a direct and very visible consequence of the changes. Danish agriculture was very dependent on exports to countries outside the EU (third countries) and thus also very dependent on export support. In the 1970s, export subsidies accounted for up to 40 percent of Danish agricultural exports to third countries, and in the following decades export subsidies were reduced and completely phased out. This development was a clear result of the liberalization and restructuring of the CAP from the mid-1980s, cf. figures 3 and 4.

Figure 3. Export subsidies to Danish agriculture



Source: Own calculations based on Statistics Denmark (2024) and L&F (several issues a)

Figure 4. Level of agricultural support in the EU, 1986-2022



Note: PSE: Producer Support Estimate
NAC: Producer Nominal Assistance Coefficient
NPC: Producer Nominal Protection Coefficient

Source: Own presentation based on OECD (2024)

A number of factors explain the declining export support, including:

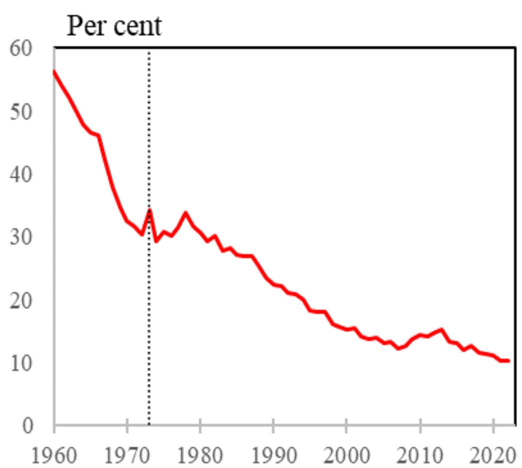
- To a certain extent, export subsidies were replaced by hectare support and livestock payments, as the support changes from market support to direct payments. Thus, compensation is given for the reduced export support.
- When the internal prices in the EU were reduced, the gap between the EU and world market prices was also reduced, and thus the need for export support was reduced. Rising world market prices, as in the 1990s and during food crises, reduced the need for export support. Increasing world market prices were also often a result of the lower internal prices and most of all a result of the restrictions on export support and "price dumping" on the world market.

- The distribution of sales in the individual markets changed, as exports partly moved from competitive and export subsidy-dependent markets to the EU market, where export subsidies were not necessary.

Agricultural export

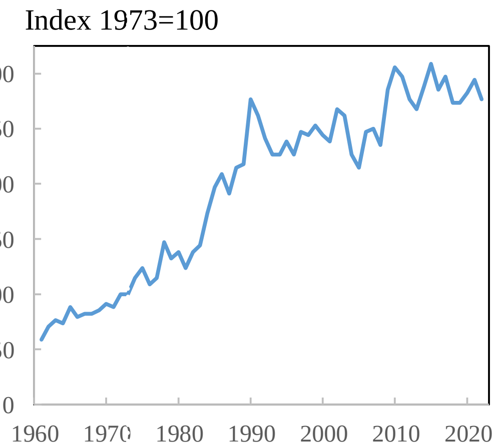
Since the end of the 1800s, exports have made up a significant proportion of the total Danish sales of agricultural goods – especially when it comes to dairy and meat products. Clearly, agriculture and agricultural exports have a decreasing importance for a country's economy in step with the country's economic development and industrialization – even though agricultural exports show an increasing trend. These developments can be found in Denmark during several decades, cf. figure 5 and 6.

Figure 5. Agriculture's share of total exports in Denmark



Source: Own calculations based on Statistics Denmark (2024, several issues)

Figure 6. Development in Danish agricultural export, volumes, 1961-2022



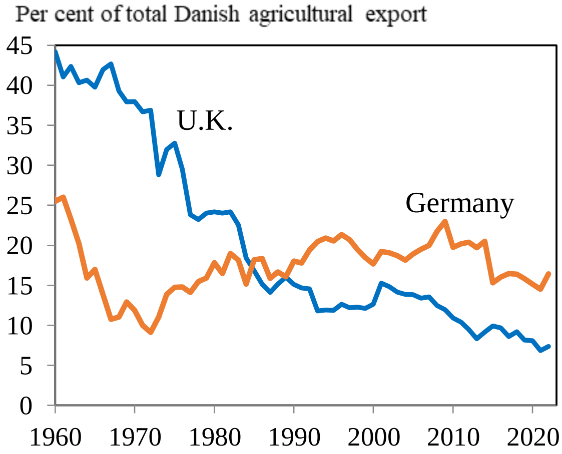
Source: Own calculations based on FAO (2024)

Figure 5 shows a significant change after 1972. The increase around 2008 is partly due to the financial crisis, which caused a slowdown in the non-agricultural sector in particular, and partly to the food crisis, which led to significant price increases for agricultural products on the international markets.

The composition of the Danish agricultural export markets has changed considerably since the beginning of the 1970s. Access to both the British market and the EU market for agricultural products were important arguments in the discussions prior to the referendum in 1972, so it is to be expected that the importance of the export markets may have changed subsequently.

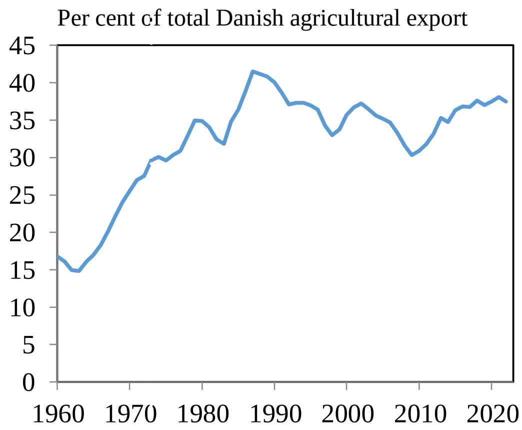
In 1972 – the year before Denmark joined the EU – 37 percent of Danish agricultural exports went to the UK and 9 percent to Germany (West Germany), cf. Figure 7.

Figure 7. Danish agricultural export to U.K. and Germany



Source: Own calculations based on Statistics Denmark (2024) and L&F (several issues a)

Figure 8. Danish agricultural export to non-European countries



Source: Own calculations based on Statistics Denmark (2024) and L&F (several issues a)

Given that agricultural exports to the UK played such a large role in the debate on Danish membership of the EU in 1972, it is remarkable that these exports continued to decline after Denmark's entry – together with the UK – into the EU.

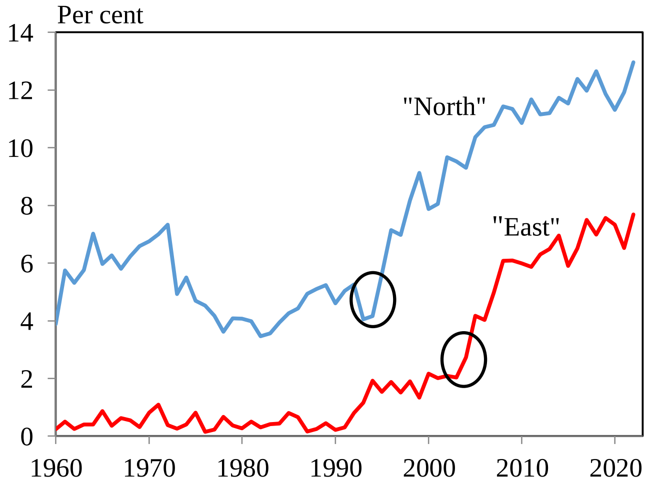
In a normal internationalization process, a market diversification away from few close markets to more and more distant markets occurs. Danish agricultural exports also followed this development before and in the years after Denmark's entry into the EU. Despite the immediate advantage of gaining free access to a larger EU market, exports to countries outside Europe increased relatively more, cf. Figure 8.

Denmark has generally increased agricultural exports to the new member states of the EU. When the EU was expanded to include Sweden, Finland and Austria in 2004, agricultural exports to these countries rose from 4 percent to almost 10 percent of total Danish agricultural exports. In 2022, the share had risen to 13 percent.

When the EU was expanded to include the 10 Eastern and Central European countries in 2004, Danish agricultural exports to these countries rose from 3 percent to just under 7 percent and in 2022 8 percent of total Danish agricultural exports. This is remarkable as these countries had a relatively significant agricultural sector prior to their entry into the EU.

The Danish agricultural exports to new member states before and after their entry into the EU are shown in Figure 9.

Figure 9. Danish agricultural exports to new member states: Before and after accession. Share of total Danish agricultural exports



Note: Expansion towards "North": Sweden, Finland and Austria in 1995

Expansion towards the "East": 10 Eastern and Central European countries in 2004

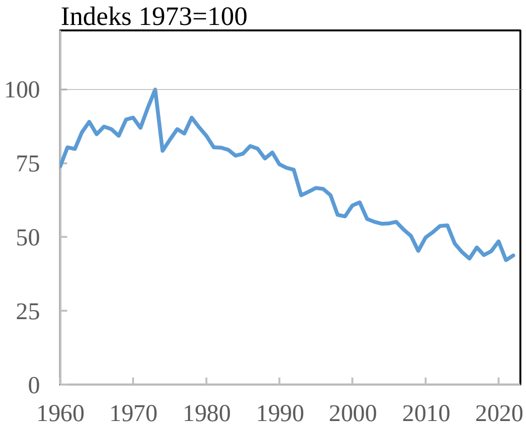
Source: Own calculations based on Statistics Denmark (2024) and L&F (several issues a)

The conclusion is that Danish membership of the EU has apparently had a positive effect for Danish agriculture when the EU has subsequently been enlarged.

Market conditions

Market conditions were – and still are – essential in the EU's agricultural policy. An important foundation in the creation of the EU was to influence and strengthen the market conditions for agricultural products: Farmers' prices for agricultural products had to be raised and stabilized in order to, among other things, increase security of supply and to secure farmers' incomes. You can always discuss whether the market interventions used were effective and optimal, and whether you have chosen the right instruments to achieve the overall goals – and whether goals have been met at all. The facts are, however, that the markets have been affected and that especially the prices, input and output prices, have been affected, which is also evident from figures 10 and 11.

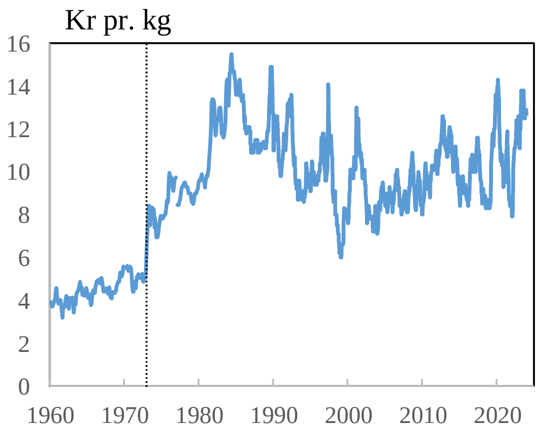
Figure 10. Danish agricultural terms of trade, 1960-2022



Note: Terms of trade are the relationship between agricultural sales prices and input prices (output-input prices

Sources: Own calculations based on Statistics Denmark (2024, several issues)

Figure 11. Farmers' prices for pork in Denmark



Note: 1960-1985: Monthly prices. After 1985: Weekly prices

Source: Own production based on Statistics Denmark (2024, several issues) and L&F (several issues b)

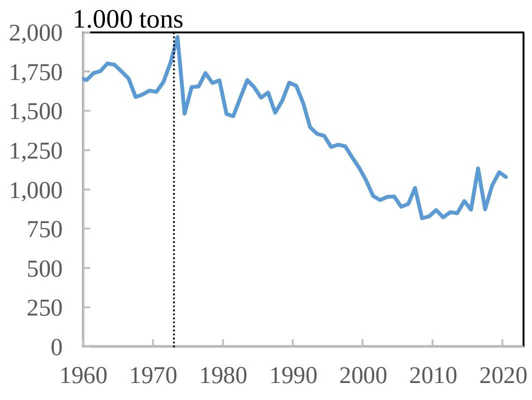
Figure 10 shows that the terms of trade for Danish agriculture increased significantly upon entry into the EU, but in the following 50 years the terms of trade have more than halved. The same development is seen in other countries in and outside the EU, cf. for example Hansen (2013, 2024). Similarly, figure 11 shows a significant increase in the price of pork after 1972, but from the mid-1980s there has been a price reduction even in nominal prices.

Environment and nature

During EU membership, Danish agricultural production has increased by just over 50 per cent on an agricultural area that has fallen by just over 10 per cent. Agriculture and agricultural production have become far more intensive and industrialized. All other things being equal, this increases the risk of negative impacts on the environment and on nature. Being an EU member has both directly and indirectly been a factor in agriculture's impact on nature and the environment: for many years, agricultural support was linked to production, which provided incentives for more intensive production, including more use of fertilizers and pesticides, utilization of marginal agricultural land, etc. Subsequently, support has been decoupled, intensive agricultural production has become less economically attractive, and later extensification policies etc. have been implemented to the benefit of both nature and the environment.

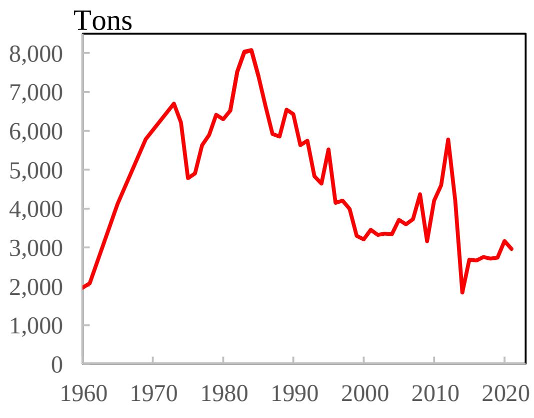
A few key figures thus show that agriculture's impact on the environment and nature has been changing since the beginning of the 1970s, cf. figures 12 and 13.

Figure 12. Total supply of mineral fertilizers in Denmark, 1959/60-2021/22



Source: Own presentation based on Landbrugsstyrelsen (2023)

Figure 13. Total pesticides sale (active ingredients) in Denmark, 1960-2021



Source: Own presentation based on Statistics Denmark (2024, several issues) and Kyed, K. (2002)

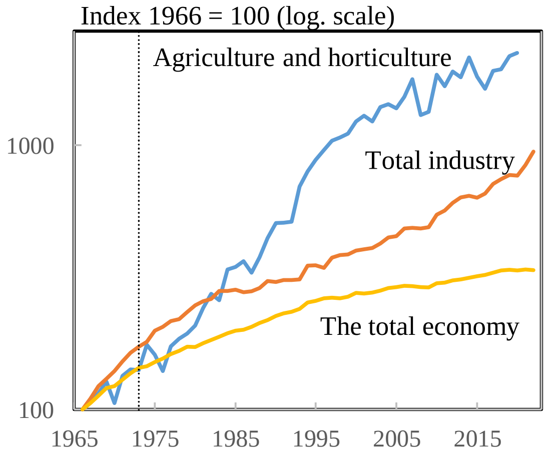
The figure shows a significant reduction in the use of commercial fertilizers and pesticides starting in the early 1970s and 1980s respectively. The reduction in the use of both fertilizer and pesticide is primarily a result of national environmental legislation. The EU's role has been both negative and positive: From coupled support to decoupled support and extensification has reduced the use of both fertilizers and pesticides.

Productivity and use of resources

Agriculture is generally characterized by strong productivity growth. Agriculture can produce an increasing amount of agricultural products without using correspondingly more labour, capital or other input factors.

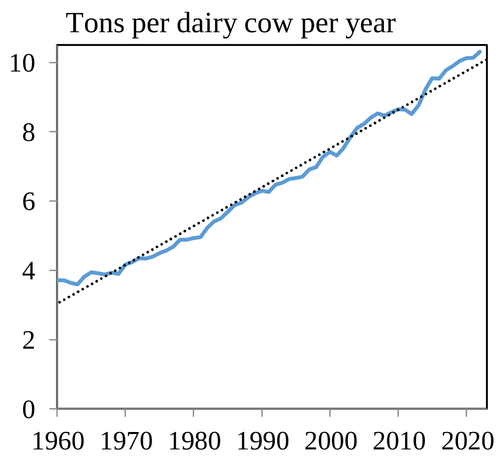
As Figure 14 shows, growth in labor productivity (output per labor input) in agriculture and horticulture has been very strong compared to other industries, although there has been some stagnation in the past decade.

Figure 14. Development in labor productivity in agriculture and horticulture and in other industries in Denmark, 1966-2022



Source: Own presentation based on Statistics Denmark (2024)

Figure 15. Development in productivity in Danish milk production, 1960-2022



Source: Own presentation based on Statistics Denmark (2024, several issues)

The increasing labor productivity in agriculture is due to several factors, including among others:

- Machines and technology – and thus capital – replace labour.
- Utilization of economies of scale in agriculture
- Plant breeding, improved livestock genetics etc. leads to increasing production per unit.
- Support coupled to production (direct impact of EU membership)
- Advisory service, training, improved management etc. lead to economic optimization.

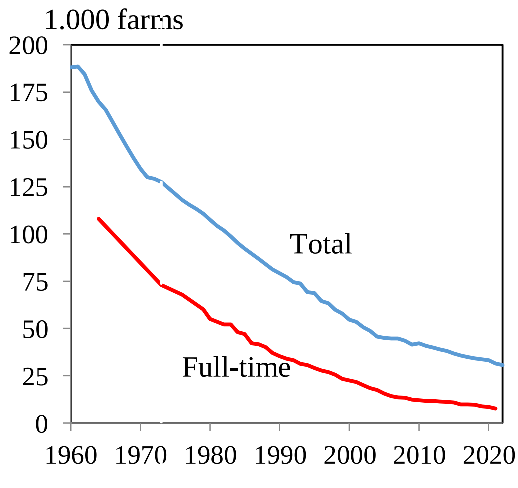
The productivity in milk production (figure 15) has followed a very straight line over several decades. In this case, a number of factors can be identified, such as improved breeding and feeding, disease control, advisory service, R&D, economies of scale and management.

Structure of farms

The structural development of agriculture is probably one of the most obvious signs of changes in agriculture in the last half century. This is how it is in agriculture in most countries and not least in Denmark. The structural development of agriculture is driven by a number of persistent factors, including technology and economies of scale. The structure of agriculture is therefore affected in the long term, and the short-term changes and impacts are very limited. It also means that changed market conditions, agricultural policy adjustments etc. do not change the structural development in the short term.

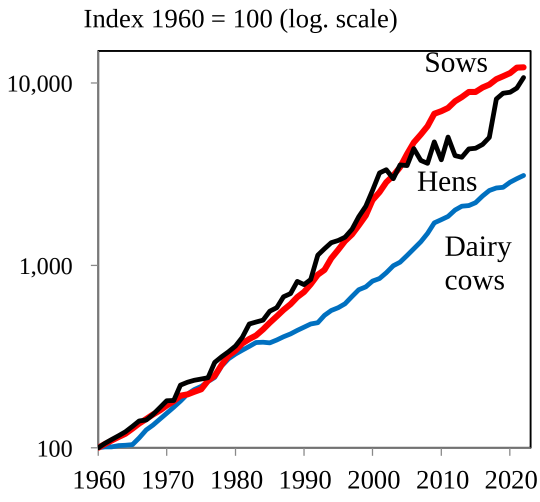
In this context, Figures 16 and 17 illustrate that the structural development is relatively stable and follows long-term – and global – trends.

Figure 16. Number of farms in Denmark, 1960-2022



Sources: Own production based on Statistics Denmark (2024; several issues)

Figure 17. Herd sizes in Denmark, 1960-2022



Sources: Own production based on Statistics Denmark (2024; several issues)

Figure 17 shows an exception: Dairy herd size stagnated temporarily from the mid-1980s until around 2010, which can be explained by the concurrent milk quotas, which limited structural development. It shows an impact of the EU's agricultural policy on the structural development of Danish agriculture.

Discussion and conclusion:

Denmark's entry into the EU changed decisively, but in the short term, the competitiveness of Danish agriculture: Agricultural support increased, exports were supported, sales prices rose, and production and exports increased. However, both the EU and the surrounding environment changed, so the changes were not permanent.

In a shorter period, it is possible to support an agricultural industry, but in an increasingly developed, globalized and liberalized world, financial subsidies are not an effective tool in the slightly longer term. In the longer term, market-based competitiveness will be a necessary and decisive prerequisite for agricultural development. A regional trade agreement can create a larger free internal market, which can strengthen competitiveness to the benefit of economically sustainable agriculture. However, a coordinated policy to strengthen R&D, knowledge dissemination, structural development and innovation will be very important elements in an agricultural policy that can improve the long-term competitiveness of agriculture.

In a global perspective, the decisive question is of course whether a regional trading area totally increases or reduces protectionism. Danish agriculture received increased support upon entry into the EU, and thus total agricultural support increased – but also the short-term competitiveness of Danish agriculture increased.

Without knowing a counterfactual scenario – Denmark outside the EU – an important conclusion is: The most important developments in Danish agriculture after joining the EU have probably been consequences of conditions other than the EU: Technological development, exploitation of economies of scale, globalization, liberalization and the general developments in markets and consumption have been more important drivers than EU membership itself.

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FACTORS INFLUENCING BEEF FARMERS' INTENTION TO ADOPT SEMI-CONFINEMENT SYSTEMS IN *MATO GROSSO DO SUL* STATE, BRAZIL

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"This work is original, as part of the PhD candidacy of the first author, and has been carried out by all the authors, who also wrote, read and agreed with the content."

Abstract

Beef farming is relevant to Brazil's and Mato Grosso do Sul's (MS) economy, and to global food security, but needs to tackle environmental impacts. MS farmers' intention to adopt semi-confinement as a strategy to produce beef more efficiently and with less environmental impact was analyzed following the guidelines of the Theory of Planned Behavior. Results indicated a strong intention to use the semi-confinement system, a positive attitude, an encouraging social pressure and a high level of perceived control over this decision. Farmers perceived a supportive state government, but supposedly an unveiled disapproval by the Federal government, which is inconsistent with current public policies in place (i.e., the ABC+ plan) that promotes the sustainable intensification of beef farming, including the semi-confinement practice. Better communication with farmers and meso-institutions working as facilitators are, therefore, encouraged to accelerate the uptake of the technology.

Keywords Beef production, semi-intensive beef farming, sustainable intensification, Theory of Planned Behavior.

1. Introduction

The Brazilian beef sector is relevant for the country's economy, and in particular to *Mato Grosso do Sul* state, and for contributing to global food security. Environmental impacts, particularly associated with methane enteric emissions and its global warming potential, have been a liability for beef farming. Several strategies have been proposed to reduce greenhouse gas (GHG) emissions (Arango et al., 2020), including sustainable intensification practices. Cardoso et al. (2016), for instance, demonstrated that a shift from degraded pasture to confinement plus nitrogen fertilization of pastures reduces the required area from 320 to 45 m^2/kg carcass and total emissions from 58.3 to 29.4 kg CO_2eq/kg carcass. In this study, we explore farmers' intention to adopt semi-confinement system following the guidelines of the Theory of Planned Behavior. This practice consists of high grain-feeding cattle for a short period, while they still graze, which allows for adequate fat finishing and reduced age at slaughter, consequently, reducing emissions intensity (kg CO_2eq/kg live weight).

2. Methods

We employed a two-step approach to conduct our research, guided by Sok et al.'s (2020) methodology for developing a comprehensive study based on the Theory of Planned Behavior (TPB). The first step comprised a qualitative pilot survey, conducted with a small sample of beef farmers in *Mato Grosso do Sul* (MS), with the results feeding into the second step, i.e. quantitative phase, which was implemented with a larger sample of farmers. Below, the theoretical model of TPB is shown (Figure 1).

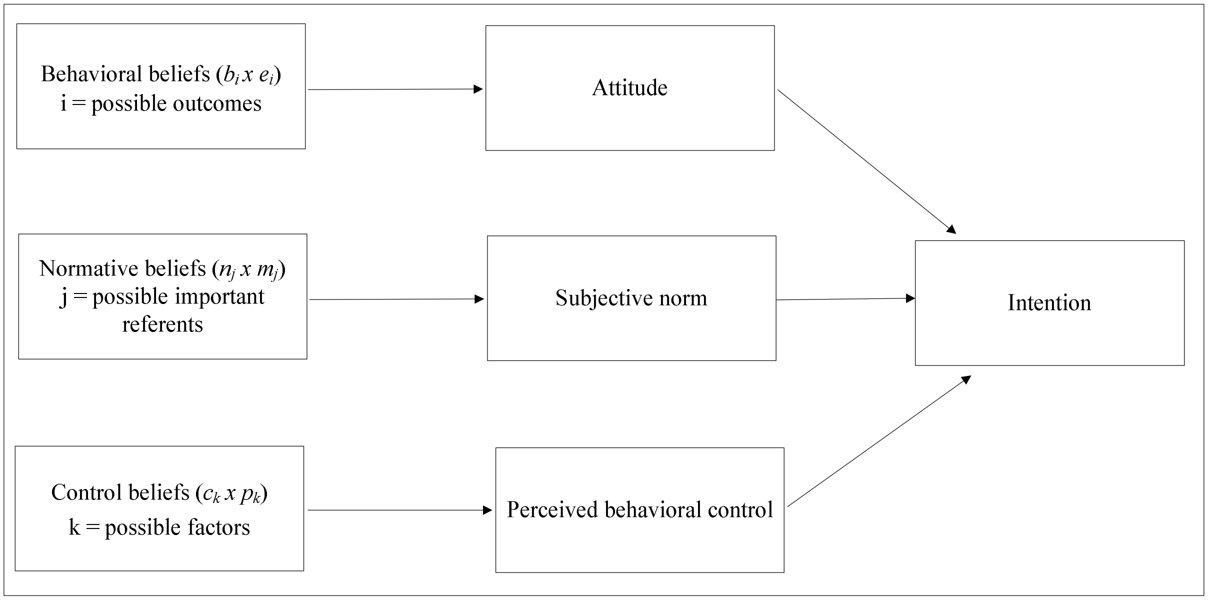

Figure 1 – TPB framework (adapted from Ajzen, 1991).

2.1 Qualitative stage

In March 2023, 15 beef cattle farmers were interviewed face-to-face during the qualitative stage of the research, using a standardized interview protocol, based on the guidelines suggested by Fishbein and Ajzen (2010) to minimize interviewer bias. The qualitative questionnaire had two main sections. The first section collected information on farm size and farmers' demographic characteristics. The second section included open-ended questions to elicit salient behavioral, normative, and control beliefs. Possible advantages and disadvantages of adopting the semi-confinement system in finishing beef cattle were identified, as well as individuals or groups who would approve or disapprove the use of it, and the factors that would facilitate or act as barriers to its implementation. Through content analysis, we identified twenty-five key beliefs (see Tables 3, 4 and 5), which were used in the second stage of this research.

2. 2 Quantitative stage

In the second stage, a survey was conducted with 209 beef cattle farmers from the state of *Mato Grosso do Sul* (MS), Brazil. We used a convenience sampling method, interviewing farmers at various livestock events, after an informed consent was secured (all farmers voluntarily agreed to participate in the survey). Farmers from the four mesoregions of MS State (Pantanal region, Central-North, East and Southwest) were interviewed.

The structured questionnaire had three main sections: (1) information on the farm size and farmers' demographics (e.g., age, gender, and education attainment); (2) a series of statements to measure intention (INT), attitude (ATT), subjective norms (SN), perceived behavioral control (PBC), status quo bias (SQB) and loss aversion bias (LAB); and, (3) the farmers' behavioral, normative and control beliefs about using the semi-confinement for finishing cattle. Variables in section two and three (i.e. statements and beliefs, respectively) were measured using a seven-point scale anchored in the extreme points, with one being the most negative answer and seven the most positive one.

The statements used in section two were developed based on reasoned action theories guidelines (Fishbein and Ajzen, 2010), and are presented in the Box A1 (Appendix A), while questions in section three derived directly from the qualitative pilot survey. Two questions were prepared for each perceived advantages and disadvantages, referents, and facilitators or barriers of using the semi-confinement system for finishing beef cattle, identified at the qualitative stage (See Tables 3, 4 and 5).

Descriptive statistics were conducted to characterize the sample and the variables used to measure intention, attitude, subjective norms, perceived behavioral control, status quo bias, loss aversion, and beliefs.

3. Results

Table 1 shows the demographic characteristics of the sample. The average farmer was a well-educated (35% with university degree or higher, plus 44% with high school) 52-year male (only 8% women). The average farm size was 750 hectares, with 220 animals finished annually. Just over 60% of participants reported using the semi-confinement system in the last year.

Table 1. Demographic characteristics of the sample.

Variable	Cases	n	%
Used semi-confinement last year	Didn't use	77	36.8
	Used	132	63.2
Days of semi-confinement	0	77	36.8
	60	35	16.7
	70	16	7.7
	75	27	12.9
	80	15	7.2
	85	2	1.0
	90	25	12.0
	100	12	5.7
Gender	Female	17	8.1
	Male	192	91.9
Age group	18-25 years old	1	0.5
	26-35 years old	10	4.8
	36-45 years old	63	30.1
	46-55 years old	57	27.3
	56-65 years old	52	24.9
	66 years or older	26	12.4
Educational level	Incomplete high school or less	32	15.3
	High school graduate	92	44.0
	Incomplete college/university	11	5.3
	College/university graduate	68	32.5
	Postgraduate	6	2.9
Mesoregions of MS	Pantanal	36	17.2
	Central-North	35	16.7
	East	47	22.5
	Southwest	91	43.5
Breed of beef cattle	Nellore	206	98.6
	Red Angus	3	1.4

Considering the variables that make up the TPB model, the results indicate an overall strong tendency towards the intention to use the semi-confinement system (INT), a positive attitude (ATT), encouragement of subjective norms (SNI and SND), and a high level of perceived control (PBC) over the use of the semi-confinement system (Table 2). At least 60% of participants scored four or higher for the statements representing the constructs.

Table 2. Percentage of participants with scores 1 to 7 (most negative to most positive) for each variable.

Variables*	**1**	**2**	**3**	**4**	**5**	**6**	**7**
ATT_1	8.1	4.3	2.4	1.4	10.5	14.4	58.9
ATT_2	7.7	4.8	3.8	1.9	13.9	34.0	34.0
ATT_3	3.8	5.3	3.8	0.5	13.9	27.3	45.5
ATT_4	14.8	12.4	10.5	2.9	16.3	11.5	31.6
SNI_1	3.3	3.8	2.9	0.5	7.7	26.3	55.5
SNI_2	5.7	5.3	6.2	4.8	36.4	30.6	11.0
SNI_3	1.0	5.3	2.4	0.5	10.5	20.1	60.3
SND_1	2.9	1.4	4.8	1.0	15.3	53.1	21.5
PBC_1	2.4	1.0	1.9	1.0	2.4	9.6	81.8
PBC_2	23.9	6.7	1.4	0.5	26.3	17.2	23.9
PBC_3	4.3	0.5	1.4	1.9	1.4	30.1	60.3
PBC_4	2.9	1.4	1.4	1.0	10.0	34.9	48.3
INT_1	11.0	5.7	1.0	1.0	14.4	13.9	53.1
INT_2	9.6	2.9	1.9	1.4	29.7	17.2	37.3
INT_3	9.6	4.3	6.2	3.3	21.5	15.3	39.7
SBQ_1	38.8	1.9	2.4	-	1.4	1.4	54.1
SBQ_2	30.1	6.2	5.3	1.0	2.4	1.9	53.1
LAB_1	33.5	11.0	16.3	1.0	7.2	10.5	20.6
LAB_2	16.3	11.5	9.1	0.5	2.9	4.3	55.5

*Variable: INT=intention; ATT=attitude; SNI= Injunctive subjective norm; SND= Descriptive subjective norm; PBC= perceived behavioral control; SQB=status quo bias; LAB=loss aversion bias.

The results in Table 2 also revealed that farmers' decision-making regarding the use of the semi-confinement system may be influenced by the status quo bias, as nearly 60% of participants scored four or higher for the two statements used to measure this cognitive bias. However, the loss aversion bias seems to influence producers' decision-making slightly less and more inconsistently, as the percentage of participants scoring four or higher for this cognitive bias was just over 50% and scores were more dispersed amongst the options.

Regarding behavioral beliefs (Table 3), the vast majority of participants (over 90% of the sample) believed that when using the semi-confinement system for at least 60 days for finishing beef cattle, it is likely and important that the following occur: a decrease in time required to finish cattle, an increase in pasture stocking rate, improvement in cattle carcass quality, reduction in pasture recovery time, an increase in production system complexity, and an increase in production cost. Additionally, more than 80% of the sample believed it is likely that the semi-confinement system will promote greater control over the outcome of cattle finishing, and more than 90% of participants consider this important to occur. However, only about 60% of participants believed that using the semi-confinement system is likely to result in a reduction in greenhouse gas (GHG) emissions from cattle. Yet, more than 70% of the sample considers this important to occur.

Table 3. Percentage of participants with scores 1 to 7 (most negative to most positive) for each variable of behavioral beliefs.

If you use the semi-confinement system for at least 60 days in the finishing phase of beef cattle, how likely are the situations below:							
	1	**2**	**3**	**4**	**5**	**6**	**7**
There will be a reduction in the time required to finish cattle.	2.4	-	-	-	-	-	97.6
There will be an increase in the pasture stocking rate.	1.0	1.0	1.0	-	-	-	97.1
The quality of the cattle carcass will improve.	1.0	0.5	-	1.4	-	-	97.1
There will be greater control over the outcome of cattle finishing.	1.0	1.0	-	0.5	2.9	8.1	86.6

The time for pasture recovery will decrease.	1.0	1.0	0.5	-	2.9	3.3	91.4
The complexity of the production system will increase.	1.4	-	-	-	-	-	98.6
The production cost will increase.	0.5	-	-	-	-	-	99.5
It will reduce the greenhouse gas emissions by the cattle.	19.1	2.9	2.9	6.7	5.3	2.9	60.3
How much do you care about:							
	1	**2**	**3**	**4**	**5**	**6**	**7**
Reducing the time required to finish cattle	1.0	-	-	-	1.4	1.9	95.7
Increasing the pasture stocking rate	0.5	-	-	-	-	-	99.5
Improving the quality of the cattle carcass	-	-	-	-	1.0	1.0	98.1
Having greater control over the cattle finishing	-	-	-	0.5	0.5	1.9	97.1
Reducing the time for pasture recovery	1.0	0.5	-	-	1.4	2.9	94.3
Increasing the complexity of the cattle production system	-	0.5	-	-	-	-	99.5
Increasing the production cost of the cattle	-	-	0.5	-	-	-	99.5
Reducing the greenhouse gas emissions by the cattle	6.2	1.9	5.3	1.4	8.1	2.4	74.6

Considering key people and institutions regarded by the farmers when making decisions (normative beliefs), the results indicate that a majority of participants (over 70%) believe that institutions providing technical assistance, cooperatives and associations, their ***families***, meatpacking plants, the international market, and their ***neighbors*** would approve their use of the semi-confinement system. Furthermore, the participants expressed concern about the opinion of these groups regarding their farm management decisions. However, a slightly smaller percentage of the sample, above 50%, reported believing that livestock brokers/buyers, research institutions, employees, the state government, and other ranchers would approve their use of the semi-confinement system. Similarly, the participants also indicated caring about the opinion of these groups regarding their farm management decisions. In contrast, regarding the group of environmentalists, over 20% of the sample expressed disbelief that this group would approve the use of the semi-confinement system, while over 20% believed they would. Similarly, over 20% of participants doubted the approval of the media (newspapers, social networks) regarding their use of the semi-confinement system, but over 30% believed they would approve. However, the majority of these participants indicated they do not consider the opinion of this group significant (over 50% of responses between scores 1 and 2) in guiding their farm management decisions. Regarding the Federal government, the majority of farmers (over 60%) believe it is unlikely to approve the use of semi-confinement for finishing cattle and they disregard (over 70%) whether the Federal government approves it or not.

Table 4. Percentage of participants with scores 1 to 7 (most negative to most positive) for each variable of normative beliefs.

How much would each of the groups below approve of you using, still this year, the semi-confinement system for at least 60 days for finishing beef cattle:

	1	**2**	**3**	**4**	**5**	**6**	**7**
Cattle brokers/buyers	11.5	4.3	4.3	3.3	9.6	7.7	59.3
Research Institutions	9.1	-	1.4	2.9	15.3	19.1	52.2
Technical assistance	1.4	0.5	-	1.4	0.5	-	96.2
Cooperatives or associations	2.9	0.5	-	1.0	9.1	11.0	75.6
Your family	0.5	-	-	-	-	1.0	98.6
The slaughterhouses	1.0	0.5	-	-	8.6	7.2	82.8
The international market	1.9	0.5	-	0.5	9.1	9.1	78.9
The farms' employees	2.4	1.0	2.9	2.9	9.6	20.1	61.2
Environmentalists	24.4	3.3	10.0	8.1	28.7	12.9	12.4
The media (newspapers, social networks)	21.5	4.3	9.1	10	32.1	13.9	9.1
The current State government	4.3	1.4	1.9	1.0	8.6	24.9	57.9

The current Federal government	61.7	2.4	3.8	1.9	14.8	5.7	9.6
Neighbors	2.4	1.0	0.5	1.0	3.3	4.3	87.6
Other cattle ranchers	3.3	1.0	0.5	1.0	9.1	27.3	57.9
How much do you care about the opinions of the groups below on what to do on your farm?							
	1	**2**	**3**	**4**	**5**	**6**	**7**
Cattle brokers/buyers	29.7	2.9	5.3	3.3	10.5	5.7	42.6
Research Institutions	12.0	3.8	3.3	1.9	12.9	14.4	51.7
Technical assistance	1.4	-	-	0.5	3.8	1.9	92.3
Cooperatives or associations	1.4	0.5	0.5	-	8.6	17.2	71.8
Your family	-	-	-	0.5	0.5	-	99.0
The slaughterhouses	1.0	0.5	-	0.5	4.8	10.5	82.8
The international market	2.4	0.5	-	1.4	7.7	11.0	77.0
The employees of the property	1.9	0.5	0.5	-	4.3	12.0	80.9
Environmentalists	49.3	1.9	6.7	9.1	17.2	9.1	6.7
The media (newspapers, social networks)	45.9	4.8	6.2	9.1	19.6	6.7	7.7
The current State government	5.3	0.5	0.5	1.9	10.5	23.4	57.9
The current Federal government	68.9	3.8	1.9	2.9	10.5	7.2	4.8
Neighbors	4.3	-	0.5	0.5	3.8	2.4	88.5
Other cattle ranchers	5.3	-	0.5	1.0	6.2	23.4	63.6

Finally, the results from Table 5 demonstrate that the vast majority of participants (over 70% of responses between scores 6 and 7) believe that when using the semi-confinement system: there will be an increase in the price per *arroba* of cattle in the following semester after use, there will be qualified labor and sufficient information to use the system. Additionally, a similar percentage of participants believes that tax incentives, access to credit, a network of specialized technical assistance, feed ingredients, and nearby marketing channels would facilitate the use of the semi-confinement system. Similarly, participants reported caring about having all these aforementioned items when using the semi-confinement system.

Table 5. Percentage of participants with scores 1 to 7 (most negative to most positive) for each variable of control beliefs.

How likely do you think…	**1**	**2**	**3**	**4**	**5**	**6**	**7**
It is that the price of cattle per *arroba** will increase next semester?	4.8	1.4	2.4	1.0	2.9	7.7	79.9
You have skilled labor to use the semi-confinement system?	6.2	2.4	2.4	0.5	11.0	3.3	74.2
You have enough information to use the semi-confinement system?	4.8	2.4	3.8	1.9	12.0	12.4	62.7
That access to credit would facilitate the use of the semi-confinement system?	1.0	1.4	-	-	-	1.4	96.2
That tax incentives (i.e. tax reductions) would facilitate the use of the semi-confinement system?	1.4	-	-	-	-	2.4	96.2
That a network of specialized technical assistance would facilitate the use of the semi-confinement system?	0.5	1.0	0.5	0.5	5.3	8.6	83.7
That access to feed ingredients (by-products of the industry, corn, soybean meal, etc.) would facilitate the use of the semi-confinement system?	1.9	0.5	-	1.0	5.3	11.5	79.9
That nearby marketing channels for purchasing and selling animals would facilitate the use of the semi-confinement?	1.9	0.5	-	1.4	2.4	11.0	82.8
How much do you care about the increase in the price per *arroba*?							
	1	**2**	**3**	**4**	**5**	**6**	**7**
	-	-	-	-	-	1.0	99.0

When using the semi-confinement system, how important is it for you to:

	1	2	3	4	5	6	7
Have skilled labor	1.4	-	-	-	2.9	7.7	88.0
Have sufficient access to information	1.4	-	-	-	3.8	15.3	79.4
Have access to credit	1.0	1.0	0.5	0.5	1.4	1.4	94.3
Have more tax incentives?	0.5	0.5	-	-	-	3.8	95.2
Have more specialized technical assistance	1.0	0.5	-	0.5	4.3	9.6	84.2
Have more access to feed ingredients (industry by-products, corn, soybean meal)	1.4	-	1.0	0.5	14.8	10.5	71.8
Have more access to animal marketing channels	1.4	-	-	1.9	7.2	10.5	78.9

*arroba (@) is a standard unit used in the Brazilian beef market, and equals 15 kilos of carcass.

4. Discussion

Beef production in Brazil is predominantly pasture-based and low input, which has, as a consequence, low productivity and profitability, but high methane (CH_4) emissions per kilo of product (Cardoso et al., 2016). Tackling these issues altogether requires investments and a systemic approach to beef intensification.

The Brazilian Government has been promoting sustainable practices in agriculture, more effectively, since 2010, when it launched the Low Carbon Agricultural Plan, so-called the ABC Plan, and later, in 2020, the ABC+ Plan (MAPA, 2012), whereby the confinement and semi-confinement were stimulated amongst other strategies. Currently, only 18% of the 42.3 million head finished use confinement (ABIEC, 2023) and another 12% use semi-confinement.

In general, our results showed an overall positive and encouraging set of beliefs and intention for further uptake of the semi-confinement system to finish beef cattle. Findings suggest the majority of farmers know the benefits from adopting semi-confinement as a practice for production intensification. However, it is noteworthy that nearly half the farmers ignore how semi-confinement can reduce GHG emissions, which suggests the importance of actions that provide such knowledge to farmers.

Regarding the key actors influencing the adoption intention, our results corroborate other studies (Borges et al., 2016) that found family and neighbors (i.e. other farmers) are amongst the most important. To facilitate the adoption of semi-confinement, therefore, education should reach not only the farmers themselves, but the farming community as a whole. Farmers clubs and knowledge exchange groups, including the early adopters of the technology, are likely to have a major influence on the use of semi-confinement. On the contrary, farmers seem to have an unveiled perception that semi-confinement could be disapproved by the federal government, the media and the environmentalists, but they are not concerned with these groups in general. Perhaps, they perceive the higher use of grain in cattle feeding under semi-confinement is a practice that does not contribute to environmental sustainability and would not be supported by those. This suggests that the Federal government must improve their communication efforts to promote the confinement and semi-confinement within the ABC+ Plan, since they were not part of the first round of the Plan (2010-2020). For instance, the Plan provides farmers with special conditions to invest in sustainable practices (Vinholis et al., 2021), including the intensification of cattle finishing. Given the farmers' assessment on the importance of tax benefits and credit access in facilitating the uptake of semi-confinement, meso-institutions, including banks, rural consultants, associations and cooperatives (Vinholis et al., 2021), as well as government spokespeople should inform farmers how to reach those benefits and provide counseling and training services to those who never used the semi-confinement (i.e. no status quo bias). As argued by Pereira et al. (2011), there are economic and non-economic factors determining the non-adoption of cattle supplementation, and they must both be observed.

At a state level, the farmers highly regard the current state government and believe it is supportive of such practice. Given the MS state government public commitment to become Carbon Neutral by 2030 (WRI, 2016), this result is favorable to the attainment of the desired scenario.

The present study has some limitations that must be considered in future research. The measurements used were of the self-report type, which does not ensure a reliable measure of beef farmers' decisions to adopt semi-confinement systems. Future studies can consider the actual adoption of semi-confinement systems to increase the reliability of the measurement. The sample used in this study was non-probabilistic and by convenience. In addition, survey participants reside in the Midwest region of Brazil. Therefore, future studies may select samples at random that are more representative of the Brazilian population.

5. Conclusion

There is an overall positive institutional and informal web of influencers supportive of further adoption of the semi-confinement. Farmers in Mato Grosso do Sul seem to be well informed about advantages and possible costs and limitations to using high grain diets for fattening cattle. Yet, they indicated a high propensity to use it this year (2024).

Our findings suggest, therefore, a general positive prospect to increasing beef production in MS, with lower environmental impacts (e.g. avoided emissions and land saving), providing greater resilience to beef farming systems. This will also contribute to the achievement of the Carbon Neutral status by *Mato Grosso do Sul*. Nonetheless, acceleration of the uptake may depend on continuous campaigns about the ABC+ Plan contemplating specifically the confinement and semi-confinement practices. Rural consultants and policy makers may have an important role in this regard.

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Appendix A - Box A1. Statements and scales used to measure the sociopsychological constructs.

Items	Issues	Range (1-7)
ATT_1	Using, still this year, the semi-confined system for at least 60 days in the finishing production of beef cattle is	Disadvantageous – Advantageous
ATT_2	Using, still this year, the semi-confined system for at least 60 days in the finishing production of beef cattle is	Unnecessary – necessary
ATT_3	Using, still this year, the semi-confined system for at least 60 days in the finishing production of beef cattle:	Unimportant – Important
ATT_4	Using, still this year, the semi-confined system for at least 60 days in the finishing production of beef cattle is:	It's not risky – It's risky
SNI_1	Most people working on my farm expect me to use, still this year, the semi-confined system for at least 60 days in the finishing production of beef cattle:	Strongly Disagree – Strongly Agree
SNI_2	Most people in the beef cattle sector from whom I hear opinions would approve if I used, still this year, the semi-confined system for at least 60 days in the finishing production of beef cattle.	Strongly Disagree – Strongly Agree
SNI_3	Most people important to me expect me to use, still this year, the semi-confined system for at least 60 days in the finishing production of beef cattle:	Strongly Disagree – Strongly Agree
SND_1	Fellow cattle ranchers intend to use, still this year, the semi-confined system for at least 60 days in the finishing production of beef cattle:	Strongly Disagree – Strongly Agree
PBC_1	If I want to, I can use, still this year, the semi-confined system for at least 60 days in the finishing production of beef cattle.	Strongly Disagree – Strongly Agree
PBC_2	Using the semi-confined system still this year, for at least 60 days in the finishing production of beef cattle, depends only on me.	Strongly Disagree – Strongly Agree
PBC_3	I have the possibility of using, still this year, the semi-confined system for at least 60 days in the finishing production of beef cattle.	Strongly Disagree – Strongly Agree
PBC_4	I feel capable of using, still this year, the semi-confined system for at least 60 days in the finishing production of beef cattle.	Strongly Disagree – Strongly Agree
INT_1	I plan to use, still this year, the semi-confined system for at least 60 days in the finishing production of beef cattle.	Strongly Disagree – Strongly Agree
INT_2	I want to use, still this year, the semi-confined system for at least 60 days in the finishing production of beef cattle	Strongly Disagree – Strongly Agree
INT_3	I will try to use, still this year, the semi-confined system for at least 60 days in the finishing production of beef cattle.	Strongly Disagree – Strongly Agree

SQB_1	The beef cattle finishing system I use today is the one I have always used	Strongly Disagree – Strongly Agree
SQB_2	I have always used the same cattle finishing system. Changing this system would be a lot of work.	Strongly Disagree – Strongly Agree
LAB_1	I believe that if I use the semi-confined system for at least 60 days in the finishing production of beef cattle, I will lose money	Strongly Disagree – Strongly Agree
LaB_2	For me, the cost and work to use the semi-confined system for at least 60 days in the finishing production of beef cattle would be high.	Strongly Disagree – Strongly Agree

IFMA24: Resilience through Innovation

Rourke's General Farm Practice Change Theory

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Academic Paper

Abstract

A new farm practice change theory, frameworks, and assessment tools are presented to help with the adoption of new farming practices. The example used involves farm practices needed to mitigate global warming.

Keywords: Farm Practice Change Theory, Net Positive Farm Framework, Global Warming Mitigation Credits, BERT/E, Sustainable Farm Index, Net Positive Carbon Grain Farming

Introduction

Rourke's General Farm Practice Change Theory, shown in Figure 1 on the following page, is a generalized change theory. A Change Theory is defined as offering generalizable principles and frameworks applicable across various contexts and levels of analysis (Creswell and Creswell 2017; Reinholz and Andrews 2020).The change that I am using as an example is the opportunity for Western Canadian Grain Farmers to embrace global warming and help mitigate the negative effects farming has on our planet. In this case to become Net Positive Carbon Grain farmers.

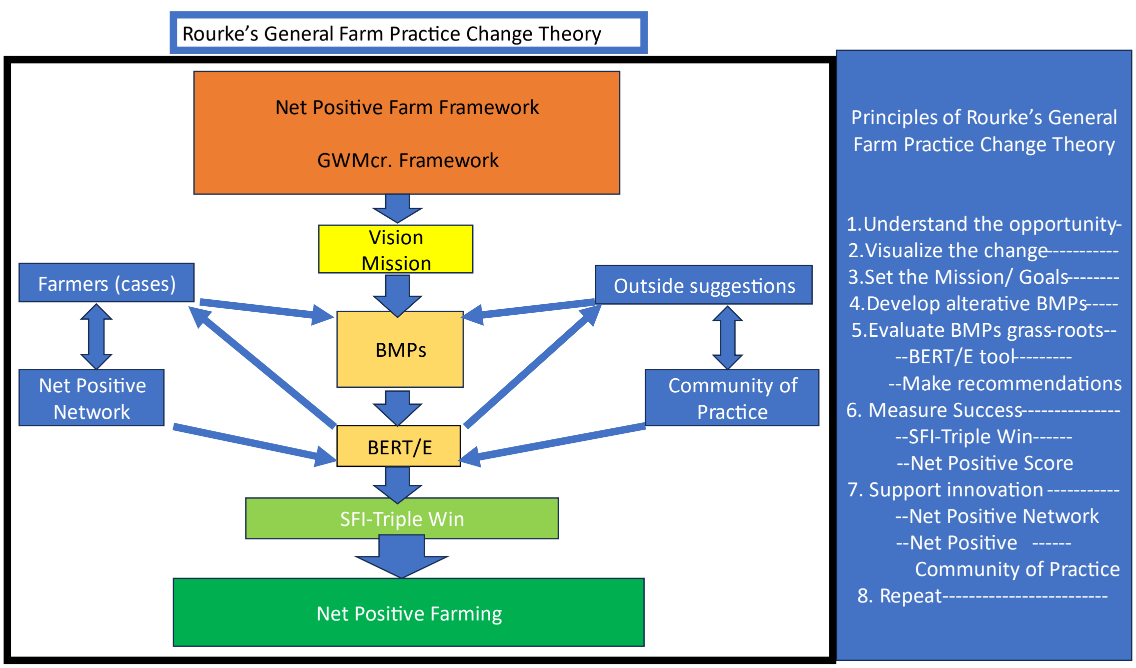

Figure 1 illustrates the components of Rourke's General Farm Practice Change Theory

Rourke's General Farm Practice Change Theory

The theory has seven steps or principles to address a new opportunity or overcome a problem on a farm. Step 1 identifies a problem or an opportunity. Step 2 involves creating a framework to help visualize interactions. Figure 2 further illustrates the Net Positive Farm Framework and the interaction with the Global Warming Mitigation credit (GWMcr.) Framework. The frameworks illustrate the change from farmers being food producers to having an expanded role in terms of having the opportunity to help with Global Warming Mitigation. Once the problem is identified—the need to Mitigate Global Warming, then Step 3 is to develop the Vision and Goals. In this case, the Vision is to have all Western Canadian Grain Farms become Net Positive. The Goal is to achieve this before 2050 at a rate of not less than 4% per year. Step 4 identifies potential methods to meet this goal. These methods are referred to as beneficial management practices (BMPs). The BMPs can be from farmers or from outside the farming community. This could include BMPs from previous research, literature, NGOs, Governments, and international bodies, such as UNIPCC. Unfortunately, some of the current BMPs are not suitable for broad application in the sub-humid semi-arid Canadian Prairies. Potential BMPs must be vetted for suitability. This is step 5. I devised a tool, BERT/E, which has proven effective in helping to understand farmers willingness to adopt these various BMPs. The vetting process will result in recommendations for further innovation. Step 6 measures progress. Two tools are suggested for this purpose. The first is the sustainable farm index (SFI), which is calculated from the balance between farm profit, farm output, and emissions. It is a measure of a Triple Win—Support the farm, Feed the cities (or demand for our products) and Heal the planet. The second is a Net Emission calculation. Farmers who sequester more carbon than they emit are Net Positive (NP). It is necessary to have a high SFI as well as being Net Positive in order to have a sustainable farm business and adequate output. Step 7 involves establishing a NP Network and an NP Community of Practices (C of P) to further improve BMPs. An NP Network can be established to facilitate peer-to-peer discussion of like-minded farm innovators and leaders. An NP C of P needs to compliment the NP farmer led Network. The C of P should be open to enthusiastic and innovative individuals who put their company, government, NGO interests away or use them to accomplish the mission. Figure 5 outlines a Manitoba based C of P.

Conceptual Frameworks—"Net Positive Farm Framework” and “GWMcredit Framework”

The conceptual frameworks to help visualize the opportunity for Global Warming Mitigation, GWM, are found in Figure 2.

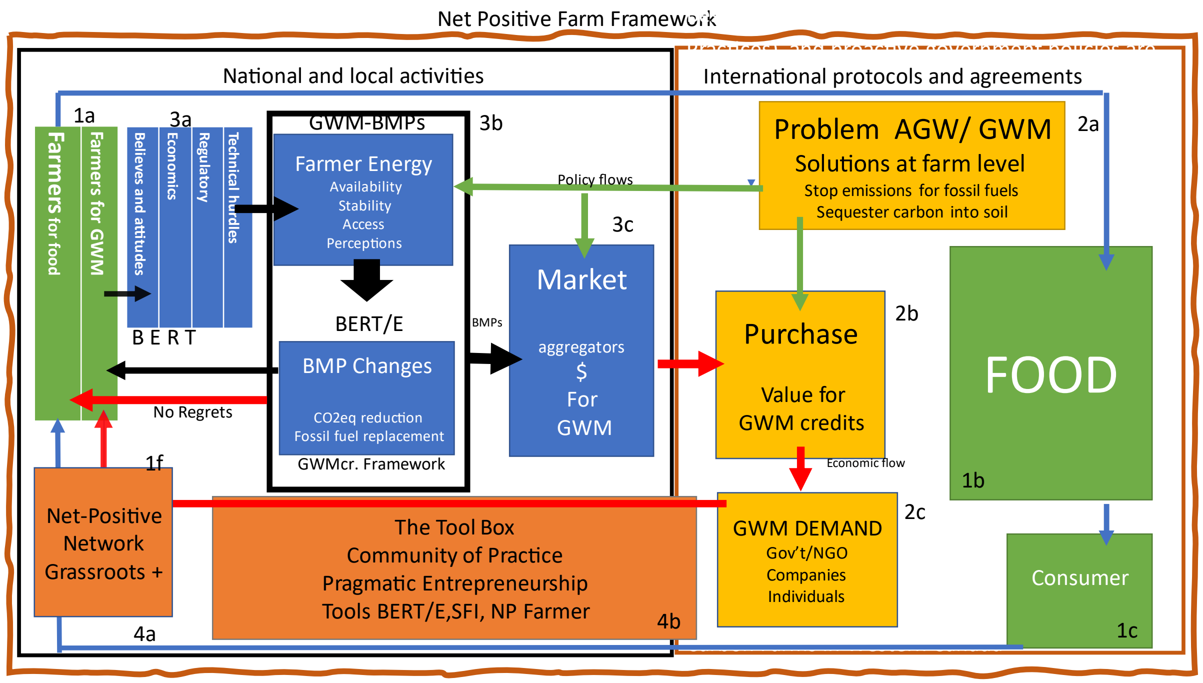

Figure 2. Illustration of The Net Positive Farm and Global Warming Mitigation credit Frameworks.

In this figure the interaction between the two frameworks is illustrated along with the components of each. This is the primary theoretical framework which I developed and utilize for my qualitative research, which utilized an exploratory, participatory, and narrative case study design. The Net Positive Framework is shown in Figure 1 as a single box. Figure 2 shows an expanded view of this framework.

The problem or opportunity is identified in the yellow boxes 2 a, b, and c through the international recognition that anthropogenic global warming (AGW) is a serious threat and there is a need for global warming mitigation (GWM). Box 2b represents the value of GWM credits and Box2c represents demand for GWM. The problem is transferred to the left side with the creation of a second role for farmers in green box 1a,Farmers for GWM. Food and Consumer interests are also shown in green boxes 1b and c. They connect with the entire diagram by the blue arrow and return to the Farmer for Food in Box 1a. Since food is a main priority, the food arrow goes through the Net Positive Network, orange Box 4a, where it will see further innovation balanced with GWM. The second orange box 4b is the toolbox. It helps bring innovation, including the Community of Practice, pragmatic entrepreneurship, and tools such as BERT/E, the Sustainability Index, and methods to measure Net Positive farming achievements. Blue boxes 3 a, b, and c represent the GWMcr.-ASAP Framework. GWM-BMPs are vetted using BERT/E in Boxes 3a and b and make GWM credits available in Box 3c. These concepts are explained further below.

The black and red arrows that start at box 3a and go to box 1a represent BMPs in which cash flows positively and do not need GWM incentives. The red arrow goes to the Farmer for Food. An example would be a BMP for Zero Till, where it is profitable, and it also increases food supply. It would be a “No Regret BMP.” The black arrow may be a BMP, perhaps a renewable diesel BMP, where it does not cost more and is not difficult to implement, but it does not change the food supply.

The second component is GWMcr-ASAP, designed to balance the need for food with the need to restore our ecosystem—restoration of the Commons. Farmers now have two jobs within the overall framework. The first is to produce food and the second is to mitigate global warming. Figure 2: Box 1a represents the dual role of farmers. Box 1b shows the BERT/E framework of the five internal hurdles farmers face before adopting GWM practices. B refers to Beliefs; E refers to Economics; R refers to Regulations; T refers to practical alternative Technologies or Tools. The second, E, is the energy of the farmer mentally and physically to make a change. BERT/E can be used wherever BMPs are being considered. This is be included in boxes 1e and 1f.

The second half of the farm-practice change theory was GWMcr which helps to integrate international influence on our farms. Box 1c is the GWMcr framework for appropriations and adoption of GWM practices. With in the GWMcr -ASAP framework is the Appropriation model, where ASAP, Availability, Stability, Access, and Perceptions, affect adoption. This is dependent on the Energy of the farmer to make the change.

The Market (box1d) is where Aggregators work to join the supply of GMW credits to GWM Demand (Box 2c). The outflows from the Creation of Value for GWM credits (Box 2a) are policy flows (green arrows), empowering the GWM-BMPs through the Market and Purchase (boxes 1c, 1d, and 2b). With adequate thought and planning, the quest for GWM solutions should not negatively impact Food (Box 3a). The toolbox (gray box, box 1e) represents our concern for global commons and contains tools and resources to support the changes needed at the farm level.

A closer look at the Assessment Tools

BERT/E is a tool that helps assess the potential adoption of BMPs. BERT/E was derived as part of my conceptual framework from the literature as part of Rourke's General Farm Practice Change Theory. I have since transformed it into an equation and investigated some potential uses and sample calculations of adaptation scores for action.

BMP Adoption Score = B x E x R x T / E. The Max score is 5x5x5x5/1 = 625.

The factors and drivers that influence farmers' implementation of GWM-BMPs can be categorized into the following five categories.

B—Beliefs

Of the five components of BERT/E, Beliefs can be the most difficult to change. Arbuckle (2013) suggests that humans are hardwired to stay in their belief groups and actively look for support of those continued beliefs. Arbuckle, Morton, and Hobbs (2015) surveyed Iowa farmers for over 20 years and found reluctance to change practices to help mitigate GW. In 2013, an overwhelming number of Iowa farmers believed that global warming did not exist, and if it did, it was not human-caused (Arbuckle et al. 2013). Davidson et al. (2019) and Davidson (2016) found a similar reaction to the potential role of farming in GWM in Alberta. Beliefs are strong drivers of action (or inaction). Beliefs stimulate passion, which drives action.

E—Economics

Innovation is key to tackling global warming. Farmers require mitigation solutions that can be economically employed, resulting in a positive balance sheet. A report from McKinsey &

Company, “Successful agricultural transformations: Six core elements of planning and delivery,” suggests that successful agricultural transformation is linked to improved household income (Boettiger et al., 2017). Davidson et al. (2019) found from a survey conducted with 301 larger Alberta farmers that economic factors were four times more likely to motivate farmers to adopt mitigation practices than consideration for greenhouse gas reductions. Economic factors include reduced cost, increased efficiency, and increased revenue. They also found that farmers adopted global warming mitigation practices, even though they did not believe in anthropogenic global warming; adoption was based on making more money or conservation measures that would improve their soils, water, or habitat. These pragmatic factors were more predictive than the various models and theories tested. These included the expectancy model, the theory of planned behavior, and the Values-Beliefs-Norms Theory. Research work in the United States, primarily centered in Iowa, seldom mentioned economics as a variable in their search for factors affecting farmers' adoption of conservation or global warming mitigation practices (Prokopy et al. 2019). In the conclusion of a 2013 study, Arbuckle et al. (2013) suggested that different mitigation approaches could imply different costs and benefits for farmers. However, unlike the Davidson et al. (2019) paper cited above, they did not test for the adoption of mitigation practices that may or may not have been more profitable to the farm. Meier et al. (2017), studying greenhouse gas abatement in southern Australian grain farms, concluded that abatement practices for the grain industry should focus on those that are also profitable. Unfortunately, the only profitable abatement practice was an improved pasture treatment.

I found very few papers examining profit as a motivator for GWM farm practice change.
This was surprising given that farm adoption of practices to mitigate global warming must be profitable either through the Market for food, feed, and fibre, or fuel, or from the public for delivery of GWM credits and on-farm EG&S payments. Another motivation is to lower costs with green input substitutes that lack a Green Premium and, conversely, have a Green Discount (Gates 2021). These products are less costly than fossil fuel-based products and may include Green electricity, Green NH_3, Green biofuels, and Green H_2. A carbon tax influences this balance.

R—Regulation

Government or industry regulations affect how farmers respond to new problems and the need to change. Suffice it to say, the world is now paying attention to global warming and what can be done to mitigate and avoid worst-case scenarios. Good policies and regulations are required to move everyone in the same direction to reach the net-zero 2050 goal.

The Scientific Based Target initiative, SBTi, is a major initiative starting to take hold of over 8000 companies, including the largest food company, making pledges for Net Zero on or before 2050. 80-90% of food companies' total emissions are from Scope 3, which is the supply chain of farm production (SBTi 2023; SBTi-FLAG 2023).

T—Technology

Farmers cannot be asked to change unless there is something to adopt that puts their farms in a better position. Various types of technology will make a difference, some with immediate environmental and financial returns and others that only produce desired results sometime in the future. Farmers cannot be blamed for being reluctant to jump into a full suite of GWM practices when, as Arbuckle pointed out, mitigation practices have uncertain outcomes, have a lag time, are government-led, benefits tend to accrue partially or wholly to the commons, and can be a net cost (Gardezi and Arbuckle 2020). For example, current BMPs for cover crops are logistically impossible on a large scale in Western Canada. When cover crops either are not established or are late in establishment, many of their potential advantages are lost; lack of technology is to blame, not farmers.

E—Energy

This second E is used as a denominator and is the Energy physically and mentally to make a change. If a farmer is overwhelmed by just trying to put food on the table and keep the bills paid, they will not have the ability or desire to take on more debt, more work or exploration, and training. On the other hand, farmers with no stress and who are doing excellent financially may not have any desire to risk that position with mitigation practices for the good of the world.

GWMcr.- ASAP

I have proposed Rourke's Farm Practice Change Theory as an interaction between BERT/E and GWMcr-ASAP, which helps farmers adopt BMPs that optimize their ability to produce and be compensated for food, feed, fiber, fuel, and GWM/EGS within the "Net Positive Farm Framework." GWMcr.-ASAP is the second part of this framework, and is a highly modified framework based on a model known as PiN-People in Nature (Davidson-Hunt et al. 2016). In the report Suich suggests, "the aim of the PiN knowledge basket is to promote the uptake of existing knowledge and generate new knowledge on the interrelationships between humans and nature.
I adapted the PiN framework (IUCN 2021) to help visualize the process needed for farmers to manage the adoption of GWM practices. Farmers need to keep producing food, but they now need help with GWM. Figure 3 illustrates GWMcr. -ASAP framework, where the PiN model moves from a balanced extraction of nature to a balanced restoration of nature.

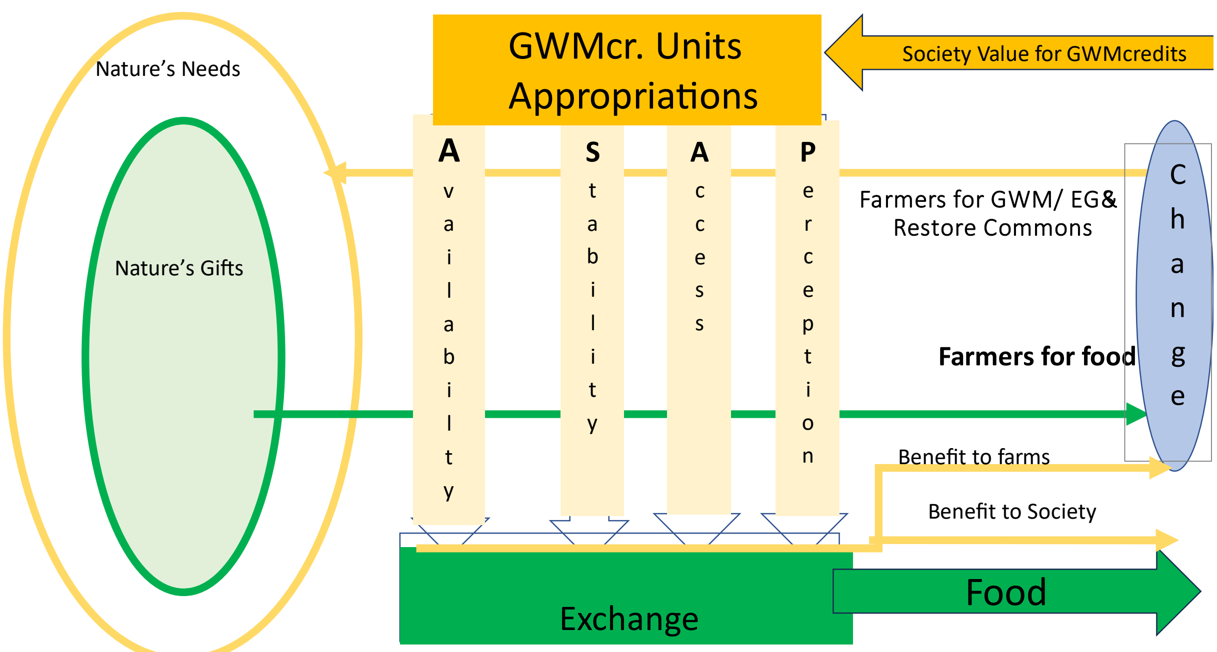

Figure 3. GWMcr. -ASAP framework.

The Framework addresses the need for a balanced restoration of nature. This includes Global Warming Mitigation and sequestering excess CO_2 from the atmosphere. It can also be used to prevent negative emission land use, such as turning forests into pastureland or grasslands into croplands. It should also include a whole host of other Environmental Goods and Services

(EG&S), such as restoration of habitats for biodiversity and wetlands for water quality. Increasing biodiversity is also an important goal. In this model, GWM credits are appropriated based on the ability of farmers to adopt GWMcr -BMPs.

GWM credits can include but are not limited to the following:

1. Cash payments for BMP adoption.
2. Cash Payment for output, such as increased SOC or decreased emissions.
3. Support for research to develop improved GWM-BMPs.
4. Support for GWM-BMP demonstrations and workshops.
5. Payment for the Conservation or Restoration of grasslands, wetlands, or treed areas.
6. Tax credit to purchase new GWM technologies.
7. Discounts for crop insurance and/or enhanced crop insurance coverage.
8. Premiums for Net Positive produced food (SBTi Net Zero Pledges).
9. Inset and Offset credits.
10. Bans or Fines

The GWMcr -ASAP framework illustrates that the market for GWMcr must be ASAP, where A stands for Availability of GWM credits. S stands for Stability, which is the reliability of the market to compensate for the GWM credits as well as the farmers to supply the credits. The second A is Access, referring to the ability of all farmers to benefit from the market for GWM credit. Is there local infrastructure to measure and reward? P is for Perception. Do farmers perceive the new GWM-BMPs will make a difference, for example. When these ASAP criteria are satisfied, there is a potential reward for adopting GWM-BMPs. This is where potential turns into the actual adoption and implementation of GWM-BMPs.

Before spending a lot of money to cash flow negative global warming mitigation BMPs, I suggest spending money on research and technology to minimize the cost to farmers and society.

GWM is not a problem that an individual or farmer can solve independently. If a specific farm is the only one that is Net Positive, this will not mean much in a global context. Therefore, knowledge and technology must be shared. A Net Positive Network is a first step.

Net Positive Carbon Grain Farm Network.

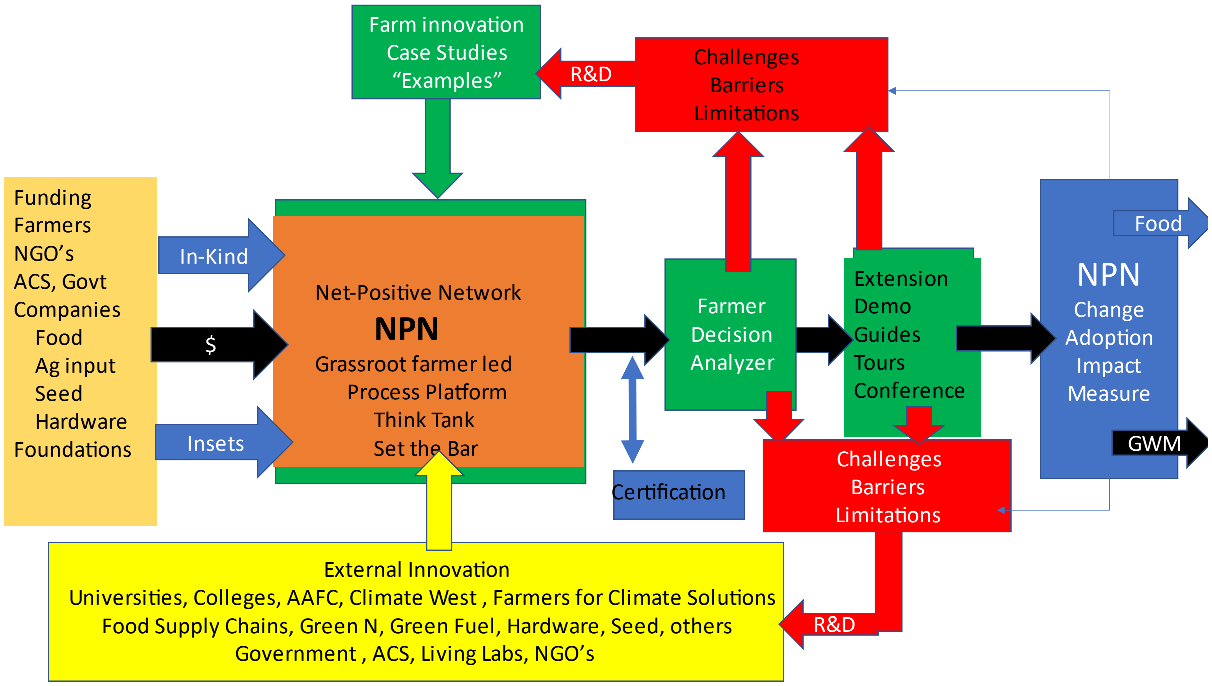

Figure 4. Detailed view of a Net Positive Carbon Grain Network.

This is an expanded view of the Net Positive Network, previously shown as single boxes in Figure 1 and 2. It has on-farm extension and adoption, represented in the far-right green and blue boxes. The model shows innovation from both the farm community and external organizations. To aid the Net Positive Network in growing quickly, outside organizations may wish to help support the NPN. (far left box) and expand innovation through the bottom yellow box. A further extension of the Net Positive Network is to develop an NP Community of Practice (Wenger, McDermott, & Snyder, 2002), as shown in Figure 5.

Net Positive Community of Practice

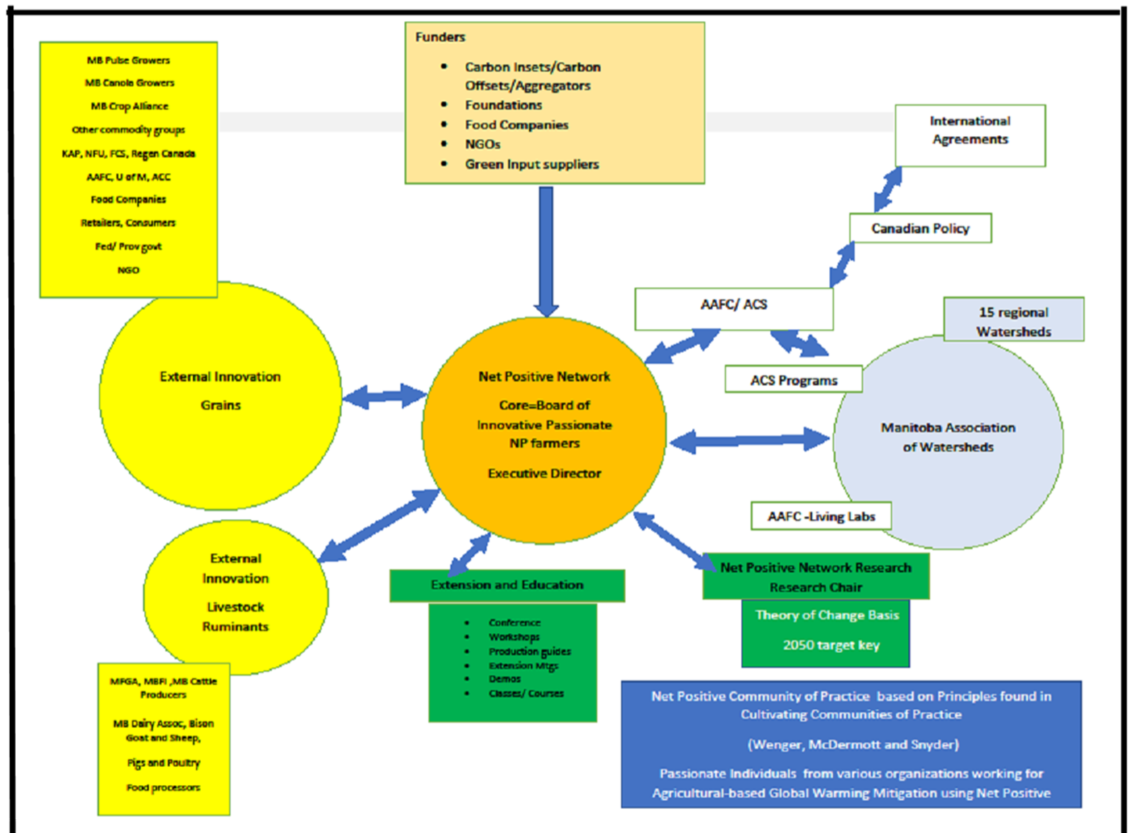

Figure 5 Illustration of a Grass Roots led Net Positive Community of Practice.

The Net Positive Community of Practice recognizes that the opportunity for farmers to tackle global warming mitigation is not an individualistic endeavor. The NP C of P concept helps bring innovators and support together to provide additional momentum and innovation. It helps ensure that all players can be involved in developing and implementing pragmatic, economical solutions with as much external support as is necessary—farmers cannot do this alone.

Conclusions—Don't make it too scary.

My thesis deals with encouraging change to a Net Positive paradigm. The word paradigm suggests a transformation, or a change in mindset, as suggested by several participants. For many farms in Western Canada, moving to a Net Positive sounds like a transformation. It would be asking them to believe in AGW—something that many do believe in, and, for some reason, many do not and will not. However, if we change the ask to Soil Health, then it is just the adoption of a practice(s) that helps them flourish now and in the future. If the new BMP pays, then it is a simple change. My conceptual framework—Farm Practice Change Theory—helps to identify BMPs that work, have a positive cash flow, and can be readily adopted. Then, we need to identify the ways and means to fix the "broken" BMPs that we still need to reach the objective of Net Positive.

This cannot be a transformation, or a transition. It must be whittled down to a simple change: one guided by the Farm Practice Change Theory, which relies on a Net Positive Farm Framework supported by the understanding obtained by BERT/E vetted BMPs and the inclusion of additional roles and possible sources of income for farmers supported by GWMcr.-ASAP and a Net Positive Network and Community of Practice.

Through this process, my research has also identified and described at least two Net Positive farmers. It is possible.

Further, these farmers have high Sustainable Farm Index scores, which means they have high Contribution Margins × good Farm Output and low GHG emissions--- a triple win.

"The only thing that needs fixing on my farm is the NUT behind the steering wheel."

Dave Ediger—Glenboro MB. Regenerative Agriculture farmer

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IFMA24: Resilience through Innovation

ASSESSING SOLUTIONS FOR RESILIENT DAIRY FARMING IN EUROPE

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Abstract

The EU-project Resilience for Dairy (R4D) deals with the challenges for the future facing the sector (https://resilience4dairy.eu). The overall objective is to develop and strengthen a self-sustainable EU Thematic Network on "resilient and robust dairy farms" designed to stimulate knowledge exchanges and cross-fertilisation on the topic of resilience among a wide range of actors and stakeholders. This article focusses on those solutions (practices, techniques, and tools) that are assessed to contribute to a resilient dairy farm sector. In this study, three key contributing fields/levers are included: the need for economic and social resilience, an efficient use of local resources, and the need to adapt systems to address environmental and animal welfare standards. The main criterium is resilience, but, additionally, attractiveness and readiness of the solutions are also considered.

Keywords: Solutions, Practices, Techniques, Expert analysis, Workshops, Future of Dairy

Introduction

The European dairy sector is facing major challenges. Milk production represents the highest proportion of EU agricultural output by value and has the potential to be a key driver of future economic growth. The dairy sector plays a significant role for the maintenance of human population in many rural areas thanks to economic activities, such as production, processing, marketing, technical and economic support, and to their support for the local economy: trade, utilities, tourism, production of traditional and/or high-quality food products, etc. Dairy farming is also crucial for the provision of key ecosystem services for the society: nutrient cycling for crop production, conservation of biodiversity, fixing carbon in the soil, etc.

However, to achieve this potential, growth must be delivered from sustainable production systems, which provide viable incomes and an adequate quality of life to dairy farmers, which impact less on the environment and are valued by consumers and the wider society. These challenges and opportunities have been brought into sharp focus by the ending of milk quotas in the European Union in 2015, which removed regulatory constraints to expansion in milk production. The abolition of milk quotas coupled with a reduction in direct market support has been associated with increased uncertainty in the marketplace, more extreme price volatility, and shifts in relative competitiveness between different milk producing regions of the EU (Thorsøea et al., 2020; Kuipers et al., 2021).

This new production background has also created major changes in livestock farming: many dairy farmers are committed to increasing working hours with deteriorated working conditions and work/life balance, and interest in farm succession. This situation is linked to the increased size and intensity of the farms which farmers have had to undertake alleviating the effects of the cost/price squeeze they have faced over the last 25 years. Moreover, the societal demands from citizens and consumers put farmers under pressure as they are questioning their production systems and techniques often through an uninformed lens that is nurtured by social media rather than science. The great challenge for dairy farming is to achieve economic and environmental objectives within the current context of climate change, market trends and societal demands. This must be done under a set of EU-regulations concerning, among other, Water Quality directives, Nature 2000 areas, and recently the EU Green Deal.

Several studies dealt with the structure of the cattle and dairy sectors in Europe (Gorton et al. 2008); Kuipers et al. 2014) and elsewhere (Dairy Australia, 2013; Dooley et al., 2018 about New-Zealand; Britt et al., 2017 worldwide), and strategy formulation for individual farms (Malak-Rawlikowska et al., 2018; Ruska et al. 2023). However, few work has been done on picturing the route forward to a resilient and robust dairy farming sector.

Darnhofer (2010) addressed the framework of resilience as follows (citation):
"Resilience thinking offers a framework to emphasize dynamics and interdependencies across time, space and domains. It is based on understanding social–ecological systems as complex, and future developments as unpredictable, thus emphasizing adaptive approaches to management."

The global concept of resilience applied to agriculture was also described by Miranda Meuwissen et al. (2021) (citation):

"*Resilience is a latent property of a system. The concept denotes a potential which is activated – and can be observed – only when a system is hit by stress or shocks. It can thus be understood by learning from past trajectories and discussing future scenarios, and from assessing how actual shocks are dealt with*". Van Dijkshoorn (2024) explains the concept of resilience from the viewpoint of a herd of animals or the individual animal.

The EU-project Resilience for Dairy (R4D) deals with the challenges for the future facing the sector (https://resilience4dairy.eu). The overall objective is to develop and strengthen a self-sustainable EU Thematic Network on "resilient and robust dairy farms" designed to stimulate knowledge exchanges and cross-fertilisation on the topic of resilience among a wide range of actors and stakeholders. This article focusses on those solutions (practices, techniques, and tools) that are assessed to contribute to a resilient dairy farm sector. In this study, three key contributing fields/levers are included: the need for economic and social resilience, an efficient use of local resources, and the need to adapt systems to address environmental and animal welfare standards. The main criterium is resilience, but, additionally, also attractiveness and readiness of the solutions are considered.

Material and methods

The R4D project encompasses 15 EU-countries and 16 partners (see Figure 1).

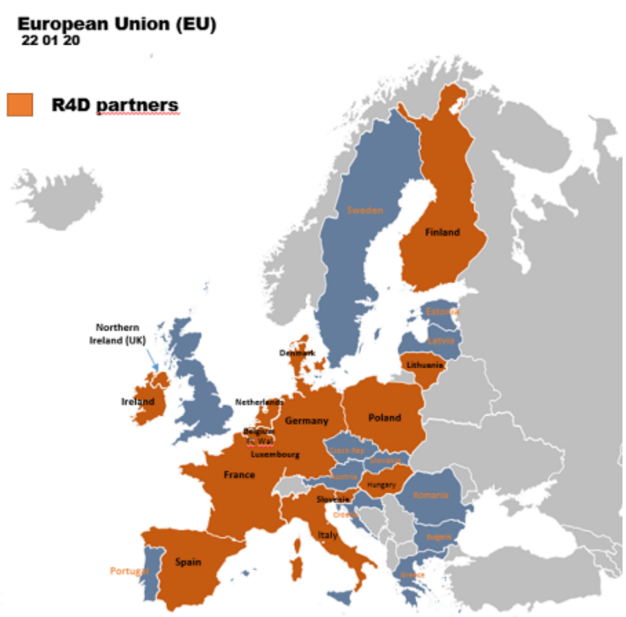


Figure 1. Resilience for Dairy (R4D) partner countries

The workflow of the project is illustrated in Figure 2. Main discussion fora are the international expert meetings and the national dairy AKIS (NDA) workshops. Experts in the three key contributing knowledge fields were recruited by the R4D participating universities, research institutes, innovation centers and extension services. The participants in the NDA workshops varied from 15 to 30 persons, including the R4D pilot farmers in each country (from 4 to 12 farms per country; thus, in total around 100 farmers) and extension and educative workers.

Farmer needs were captured in the international experts' meetings and in the NDA workshops, held in 2021. This resulted in a list of 43 more widely defined farmer needs, such as work/life balance, income, effective communication, improvement of animal welfare conditions, energy efficiency, reducing environmental losses, etc. These needs could be rated by using a GOOGLE questionnaire (needs were rated from no interest to very interested). In total 535 stakeholders (of which 70% farmers and 30% other stakeholders) in the 15 participating countries filled in this questionnaire by scoring the pre-printed list of needs. Missing needs could be added. The results of the questionnaire were discussed in the national dairy AKIS meetings (one or two per country) and in a European expert workshop, which was organized during a consortium meeting in 2022. These discussions resulted in prioritizing the needs, and as follow up the formulation of 190 solutions, i.e. practices, techniques, tools, systems, selected for assessment in 2022. Part of the chosen solutions which were assessed as possibly not yet ready for practice or raised questions about content, were monitored in the field for better understanding.

The final step of the R4D project is to disseminate the accepted solutions in fact sheets and practice abstracts, and as videos.

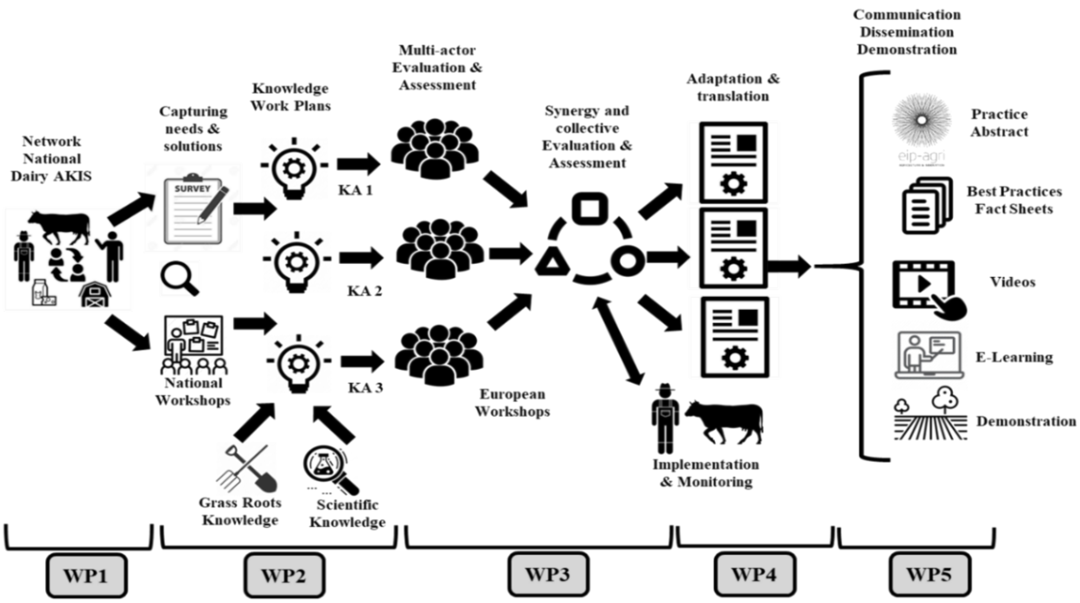


Figure 2. Organisation scheme Resilience for Dairy (R4D)

This article deals with the assessment of the solutions. The 190 solutions were divided in three knowledge areas (KA1, KA2 and KA3), being the three key know-how fields thought to contribute to a resilient farming system: economic and social resilience, farm technical resilience, and environmental & animal welfare/health resilience.

Experts' input

Expert assessments of the 190 solutions were organised. An online survey was prepared to evaluate each solution separately. The composition of the survey is illustrated in Figure 3. For this study, 32 of the total of 57 survey questions were used (indicated in red colour), belonging to knowledge areas KA1, KA2 and KA3. As guideline was stated: "To answer the question about the impact of the solution on resilience, take the average dairy farm in your region where this solution would be applicable and attractive as reference to assess the impact you expect".

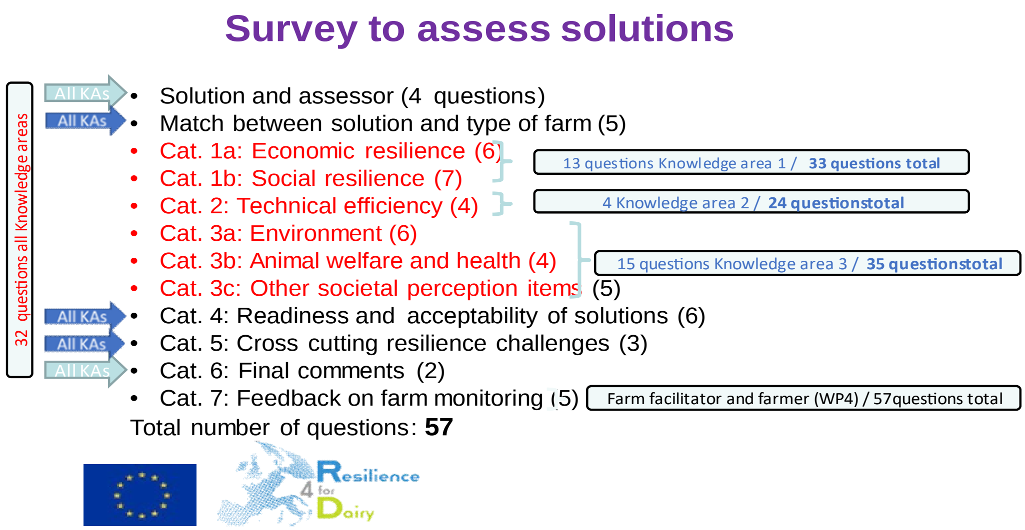
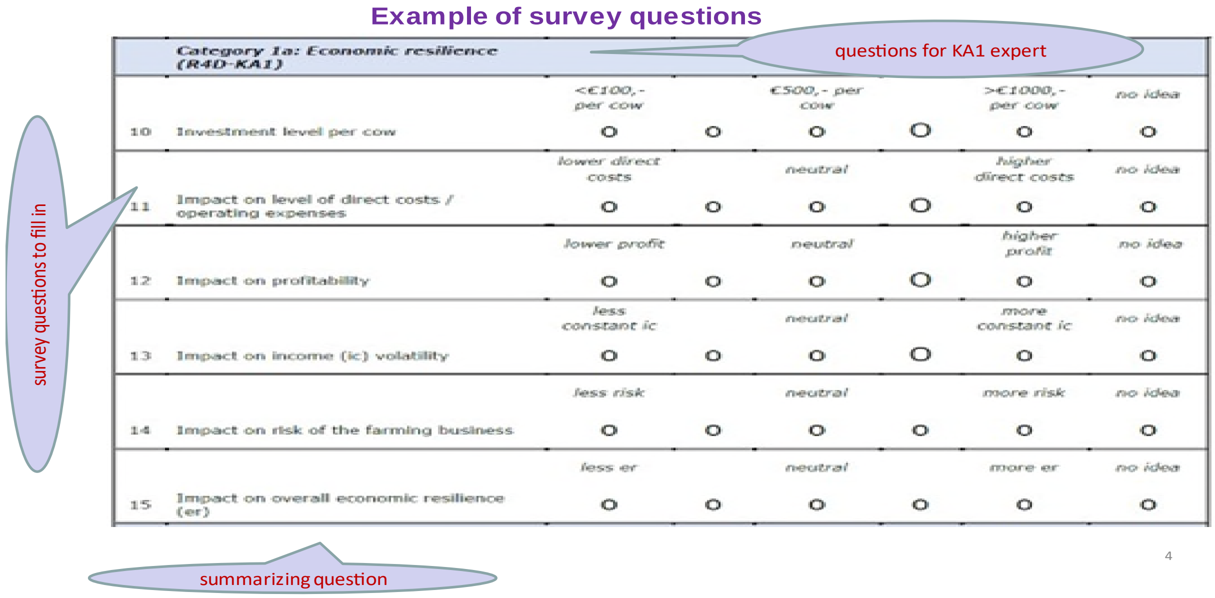


Figure 3. Survey to assess solutions

All questions had 5 pre-printed answers and the answer “no idea”. A total of 66 expert assessors, selected by the participating partner organizations from the 15 European countries did perform 3329 assessments with focus on resilience. Thus, on average, about 53 solutions per assessor were done. The number of assessments per solution ranged mostly between 15 and 30 evaluations. Solutions with less than 15 assessments were excluded from this study. More attractive solutions were in general evaluated more times than less interesting solutions. The expert performed his/her assessments within their area of know-how. Therefore, different groups of experts were involved in the assessments in the three knowledge areas, implying that the comparison of the scores of solutions should preferably be done within each knowledge area.

An example of one category of questions, i.e. related to economic resilience, is shown in Figure 4. The answers are ranked from low to high or less to more (or not important to very important) and coded from 1 to 5. However, for some questions, like questions 10 and 14 in Figure 4, the scores had to be reversed because in general a low investment and less risk are seen as favorable compared to a high investment and more risk.



	Category 1a: Economic resilience (R4D-KA1)						
10	Investment level per cow	<€100,- per cow		€500,- per cow		>€1000,- per cow	no idea
11	Impact on level of direct costs / operating expenses	lower direct costs		neutral		higher direct costs	no idea
12	Impact on profitability	lower profit		neutral		higher profit	no idea
13	Impact on income (ic) volatility	less constant ic		neutral		more constant ic	no idea
14	Impact on risk of the farming business	less risk		neutral		more risk	no idea
15	Impact on overall economic resilience (er)	less er		neutral		more er	no idea

Figure 4. An example of survey questions

National Dairy AKIS (NDA) meetings' input

Two National Dairy AKIS (NDA) meetings in 15 countries were held to discuss the expert scored solutions. Each meeting had from 15 to 30 participants, usually including the R4D pilot farmers and some other stakeholders, mostly extension workers and consultants. Focus was on the criteria attractiveness and readiness for practice, but also resilience was again included in the evaluation. The NDA group was asked to select the 20 solutions with highest attractiveness. Next, this sample of solutions was scored from 1, least attractive, to 20, most attractive. The same procedure was followed for resilience and readiness for practice. The scores were transformed to percentages by dividing the accumulated score of all countries involved through the maximum possible score.

A data base was prepared to contain all data derived from the expert group meetings and from the NDA workshops.

Results

Expert assessments of solutions

The results of the experts' assessments of the 190 solutions are presented separately for the three knowledge fields, i.e. socioeconomics, technical efficiency, and animal health, welfare, and environment. Only the result of the assessments by the knowledge area experts for each field are presented because the number of assessments by other knowledge area experts was for some solutions rather limited.

Table 1. Experts' choice and scores of the top six and two low scoring socio-economic solutions in relation to resilience

Title of solution	Economic resilience		Social resilience		Economic + Social resilience	
	mean	SD	mean	SD	mean	SD
Lean management	4.17	0.48	3.70	0.57	3.97	0.41
Reparceling of land	3.86	0.31	4.03	0.41	3.95	0.29
Manage cash flows, Investment, and risks to increase mental health and resilience of farmer	4.12	0.30	3.50	0.67	3.81	0.42
Improve quality consultancy services, engage advisory in farm management	3.84	0.48	3.50	0.60	3.65	0.50
Tools to make business plans to support strategic decisions	3.76	0.53	3.53	0.51	3.64	0.39
Peer groups of farmers to share knowledge using facilitation methods	3.78	0.43	3.46	0.42	3.62	0.34
On-farm dairy heifer valorization	3.43	0.59	2.50	0.49	2.96	0.51
Exploring on farm milk-processing	3.20	0.36	2.54	0.38	2.87	0.27

Table 1 shows that the reparcelling of land is an urgent need in several countries where history has caused the present farms to be composed of a whole set of small parcels spread over a large area. Lean management was available as a learning package in the R4D project, without doubt affecting the scoring upwards. Solutions that require additional labour like on farm milk-processing and fattening of heifers score low on the social component of resilience.

Table 2. Experts' choice and score of the top six and two low scoring technical solutions in relation to resilience

Title of solution	Technical efficiency	
	mean	SD
Strategic hoof trimming	4.72	0.40
Calf colostrum management	4.46	0.60
Sensors monitoring insight in health and fertility	4.17	0.54
Manure application tailored to needs plant	4.13	0.82
Early detection of diseases	4.11	0.59
Cross-breeding with beef cattle	4.06	0.80
Conservation tillage to reduce erosion	3.36	1.01
Combining efficient grazing with robotic milking	3.13	0.74

Table 2 shows a high interest for hoof trimming, calf management and monitoring and detection of health and fertility characteristics of individual cows. Although considered surely of importance in some regions of Europe, tillage to reduce erosion and grazing combined with automatic milking was rated relatively low.

Table 3. Experts' choice and score of the top six and two low scoring environmental, animal welfare & health and societal perception solutions in relation to resilience

Title of solution	Environment		Animal welfare and health		Societal perception		Welfare/ health, + Environment, + Perception	
	mean	SD	mean	SD	mean	SD	mean	SD
Improvement of health, fertility and longevity in herds	3.41	0.40	4.30	0.62	3.88	0.46	3.90	0.44
Freewalk farming system	3.68	0.56	4.26	0.51	3.54	0.46	3.84	0.41
Agroforestry on dairy farms	3.81	0.44	3.46	0.57	3.74	0.39	3.95	0.38
Barns for more animal welfare with access to outside	3.15	0.43	4.31	0.51	3.55	0.50	3.69	0.32
Biodiversity implemenatation package for dairy farms	3.94	0.41	3.38	0.55	3.43	0.50	3.60	0.27
Apply sand as deep bedding in cubicles to improve health, welfare and productivity	3.20	0.30	4.12	0.56	3.48	0.36	3.60	0.31
Use solid part of slurry as bedding material in cubicles	3.59	0.35	3.20	0.27	2.91	0.24	3.22	0.18
Feed additives to reduce rumen methane production	3.51	0.42	2.96	0.54	3.00	0.32	3.17	0.26

Table 3 shows a great interest in practices related to housing of the animals and to improving health and fertility. Biodiversity has become a societal and political topic of attention and is expressed as a challenge to work on. Contrarily, feed additives to reduce rumen methane and dried manure as bedding are considered animal unfriendly and are expected to receive a low appreciation from society.

National Dairy AKIS groups evaluating solutions

Figure 5: Discussions in stakeholder groups about attractiveness, resilience and readiness of solutions

The three criteria attractiveness, resilience and readiness were discussed in the stakeholder (NDA) groups In each of the NDA meeting in the 15 partner countries (Belgium had two NDA groups), the 20 most preferred solutions were chosen and ranked from 1^{st} to 20^{th} place. Of the total of 190 solutions, 123 solutions were chosen to be discussed at least in one NDA meeting, of which:

53 solutions were discussed in only 1 NDA meeting; 21 solutions were discussed in 2 NDA meetings; 23 solutions were discussed in 3 NDA meetings, and 17 solutions were discussed in 4 to 9 NDA meetings. The outcomes were split up into results from North & West Europe and from South & East Europe. In figures 6, 7 and 8 are the outcomes presented of the farmers' opinions about attractiveness, resilience and readiness of the solutions.

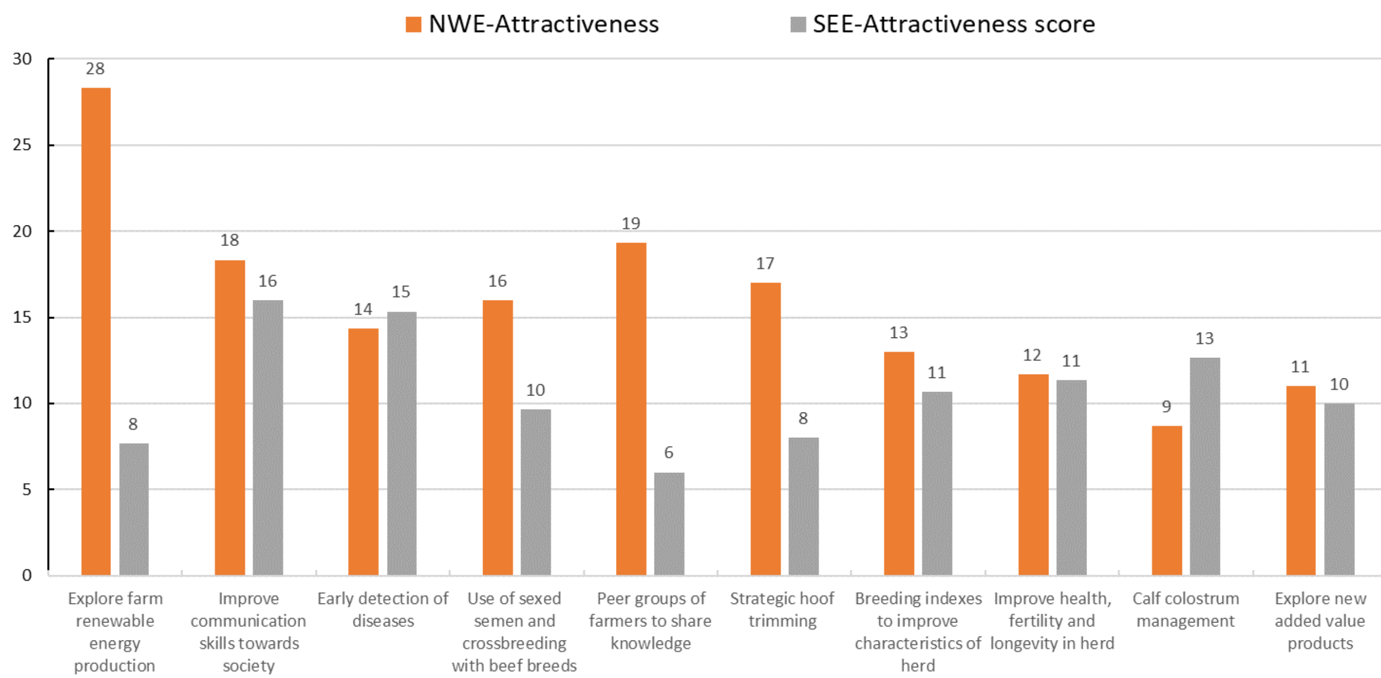


Figure 6. Scoring by stakeholder groups of the 20 solutions with highest attractiveness; this sample of solutions was scored from 1, least attractive, to 20, most attractive; the percentage illustrated in graphic is the accumulated score of all countries involved divided by the maximum possible score (NWE = North&West Europe and SEE = South&East Europe)

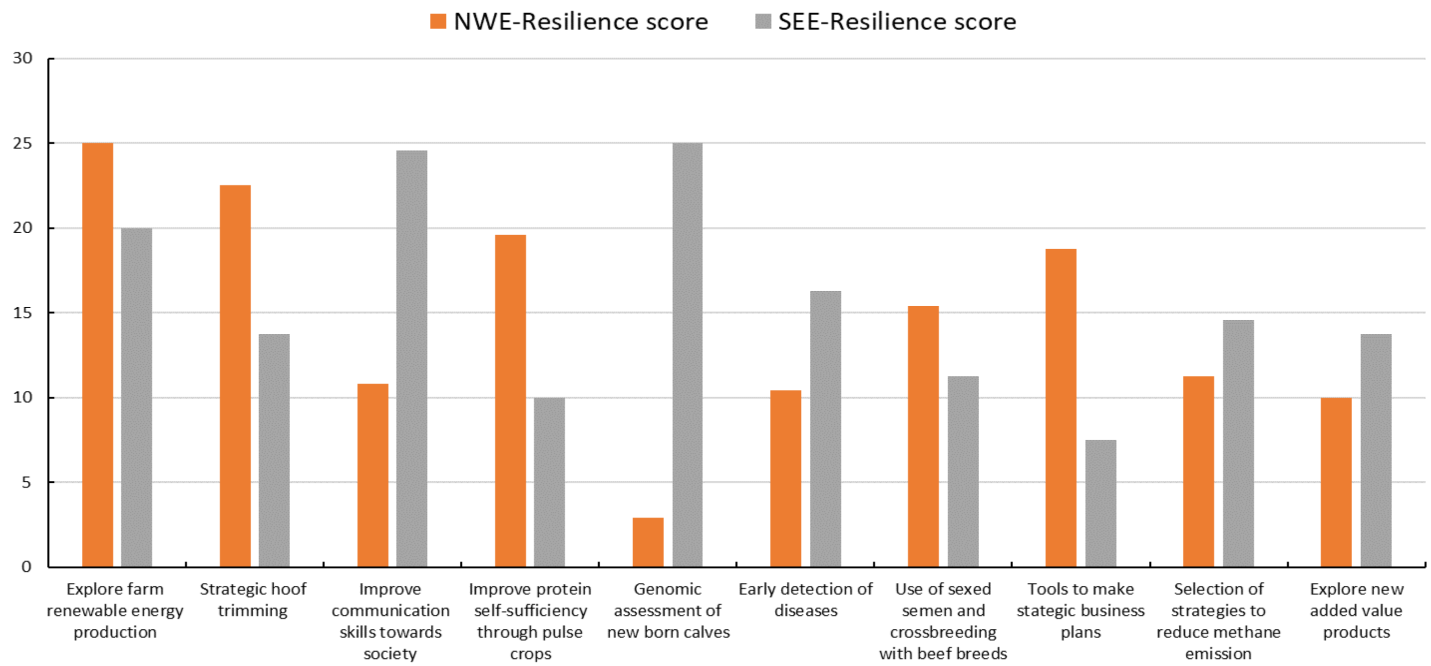


Figure 7. Scoring by stakeholder groups of the 20 solutions with highest contribution to resilience; this sample of solutions was scored from 1, least resilient, to 20, most resilient; the percentage illustrated in graphic is the accumulated score of all countries involved (NWE or SEE) divided by the maximum possible score

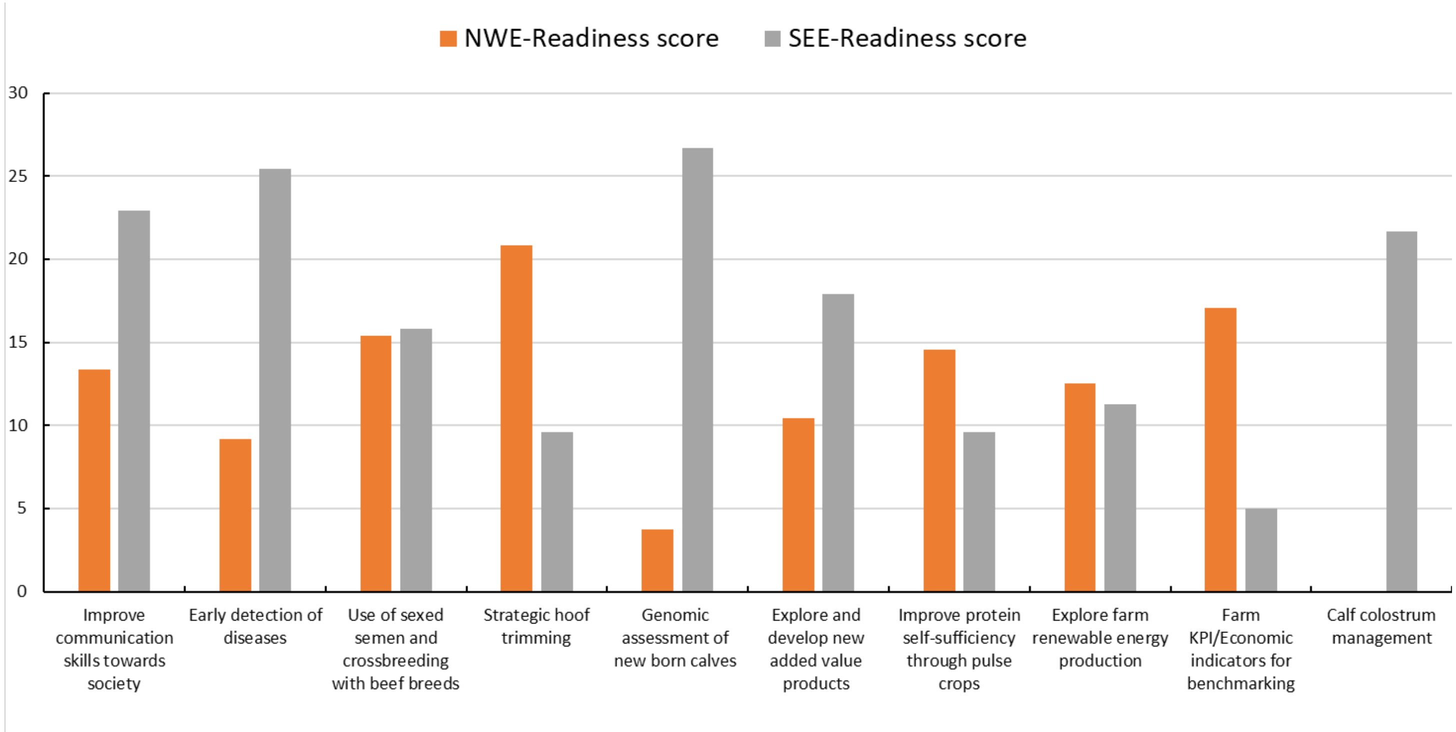


Figure 8. Scoring by stakeholder groups of the chosen 20 solutions most ready for implementation; this sample of solutions was scored from 1, least ready, to 20, most ready for implementation; the percentage illustrated in graphic is the accumulated score of all countries involved (NWE or SEE) divided by the maximum possible score

Exploring the implementation of renewable energy equipment and practices, working with peer groups of farmers and strategic hoof trimming were more targeted as attractive activities by the groups of farmers and stakeholders from North-Western Europe than by the farmers from South-Eastern Europe. The improvement of communication skills and the genomic assessment of calves were thought to contribute more to the farm and farm family resilience by the farmers in South-Eastern Europe than those in North-Western Europe. It is somewhat curious to see that genomics seems to be of high interest in this part of Europe. Colostrum management and genomics receive a high applicability and readiness level from the farmers from Southern and Eastern Europe. Those farmers seem to be overall somewhat more positive about the applicability of the most favoured solutions.

Conclusions

- It was a challenging process to collect and assess the series of solutions from the 15 countries;
- Choices of solutions were likely affected by facilitation, choice of farmers, etc.
- There are differences in focus over Europe (especially East versus West)
- Expert' and farmer / stakeholder' opinions appeared to be not the same
- Technical efficiency is a leading strategy at farm level
- Communication with society, renewable energy production, hoof trimming, early detection of diseases and calf rearing are much mentioned topics of interest.

Acknowledgement

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