Asian And Pacific Economic Review
ISSN: 1000-6052

INFLUENCE OF AGRONOMIC AND FINANCIAL FACTORS ON WHEAT PRODUCTION: A COMPREHENSIVE REVIEW

Bhawna Malik
Research Scholar, School of Commerce and Business Management, Geeta University, Panipat, India
Gulshan Chauhan
Professor, School of Commerce and Business Management, Geeta University, Panipat, India
***Yuvraj Yadav**
Associate Professor, School of Agricultural Sciences, Panipat, India
*corresponding author

https://doie.org/10.65985/APER.2025233589

Abstract

Agricultural Technology brings significant advancements in the field of wheat production and productivity but still considerable lapse is continuing between potential and actual wheat productivity, alongside fluctuating profitability for producers. This review article analyzes the influence of key agronomic and financial factors on the overall performance of wheat production methods. The article determines the extent to which agronomic practices such as the variety of choice, the rate of fertilizer application, timing and different stages of irrigation, and the most important aspect of sowing date schedule determine on-farm productivity. At the same time, the review will evaluate the effect of external and internal financial conditions including the input costs (fertilizer, fuel, seed), market output prices, availability of credit and consequent cost/return pattern to enable the actual profitability of the farmers. The main findings put emphasis on the fact that the profitability of farms is best maximized not by maximizing a single element, but by taking on an integrated approach that the marginal benefits of agronomically improved practices should always be greater than the rising marginal costs of money, in the form of financial inputs. This article offers important highlights to researchers, policymakers, and producers who are after sustainable practices that can increase the global supply of wheat as well as the economic sustainability of the agricultural communities.

Keywords: Wheat, Agronomic factors, Financial Factors, Productivity, Profitability

Introduction

Wheat (*Triticum aestivum* L.) stands as a cornerstone of global food security, providing nearly 20% of the calories and protein consumed by the world's population (FAO, 2023). Being the most actively grown grain crop in the world, it is one of the main staples in almost all areas and is a key economic asset of millions of agricultural lives (Curtis & Timsina, 2020). Both human welfare and geopolitical stability are, therefore, closely associated with the stability and productivity of wheat. With the world population expected to grow, given the fact that more population will require more cereals, because the world population is projected to increase by 2050, this would mean that there is a need to produce more cereals. Consequently, wheat production methods should be learned and maximized as soon as possible (United Nations, 2022). The further development of wheat production is difficult due to the poor environmental and economic factors (Lal et al., 2021). On the environmental side, the industry is struggling with the growing risk of climate change, which is in the form of more frequent cases of terminal heat stress, erratic rainfall, and extended droughts that directly reduce the yield and the quality of grain (IPCC, 2022). At the same time, decades of work with simple rotation systems and intensive use of agrochemicals have led to the destruction of the soil, loss of nutrients, and environmental externality such as greenhouse gas emissions and water pollution due to nutrient runoff (Tilman et al., 2018).

Volatility is a challenge to the system economically. Farmers are being increasingly faced with a continuously increasing input costs, especially of nitrogen fertilizers, pesticides and fuel and market prices of wheat are widely unpredictable, which squeezes profit margins (OECD, 2021). In addition to that, there is an aspect of financial and regulatory complexity in terms of policies concerning trade, subsidies, and sustainability standards which influence adoption rates of best practices (Hassan & Du, 2020). All these constant pressures have led to a transformation in the objective of wheat production whereby the focus is no longer on the maximization of yield but a sustainable balance of production, environmental and financial health.

The decades of agricultural research resulted in enormous amounts of knowledge about both the biotic and abiotic factors of wheat productivity, as well as the economical aspects of agricultural activities. On the one hand, agronomy research has paid much attention to the optimization of the relationship between inputs and outputs, the optimal planting rate, the economically optimal rate of fertilizer use, the effectiveness of integrated pest management (IPM) practices, and the physiological behavior of various cultivars to stress (Smith et al., 2020; Johnson & Lee, 2019). The studies tend to give an apparent direction of optimizing technical efficiency and possible yield under controlled or modeled conditions. The agricultural economics field, conversely, has offered comprehensive descriptions of market risks, price transmission, the effect of government policies (e.g., Minimum Support Price programs), and enterprise budgeting frameworks (Wong et al., 2020; Chen et al., 2021). These discoveries play an important role in comprehending economic sustainability and risk aversion at the farm gate.

The driving force behind this review is that in practice, agricultural production decisions are made by farmers not based on the agronomic potential of agricultural land or the economic feasibility of the production decision, but rather based on the dynamic relationship between agronomic opportunity and monetary constraint (Gardner & Perez, 2022). An example of this is high agronomic value of a new disease-resistant cultivar can be offset by costly seed prices or the financial choice to reduce nitrogen fertilizer can result in sub-optimal yield and long term sustainability risks. Arguing that the separation of these two critical elements ignores the trade-offs and complexities that define real world performance, this work presents an all-inclusive, integrated view: its major objectives are to systematically classify and analyze the underlying agronomic units (genetics, nutrient, and water management) and the overall main financial constraints (costs, market variability, and policy) that determine global wheat production, the key objective being to synthesize the notable relationship between agronomic efficiency and financial profitability to ultimately identify the critical knowledge gaps and suggest action research and policy priorities that can improve the overall sustainability.

1. Agronomic Factors that affect the production of wheat

The association between the genetics of the plants, environmental and agricultural management systems is the basic determinant of the productivity of wheat systems. These are the underlying factors (Figure 1) to which we need to master in order to comprehend the financial success of wheat because all economic returns are subject to the physical constraints.

1.1 Selection of Cultivar and Genetics

Genetic advancement has been the most influential driver of sustained yield improvement in wheat over the last century (Reynolds et al., 2017). Modern agronomy recognizes that yield enhancement is closely tied to the development and selection of superior cultivars that efficiently convert environmental resources into biomass and grain. Breeding programs have always focused on traits that have included; enhanced tillering capacity, enhanced harvest index, lodging resistance with dwarfing genes, nutrient-use efficiency and enhanced adaptability which have a direct correlation with higher yields in diverse agronomic situations.

In addition to yield potential, the current breeding trends emphasize on resilience-breeding varieties that can endure heat stress, drought, salinity, emergent pests and diseases and changing climatic conditions. To farmers, the choice of the appropriate genotype in accordance to the agro-ecology, the time of sowing, and the type of soil and level of inputs is very important as an agronomic decision. The response of a cultivar to fertilizers in the best management condition may greatly lead to increased production, and the stress-tolerant genotypes will guarantee the stability of yield under adverse environments. Genetic enhanced wheat varieties also affect the agronomic efficiency through ability to coordinate the period of growth, faster rate of grain-filling, better root system structure, and increased responsiveness to irrigation and nutrients. The introduction of bio-enriched and disease-resistant genes will decrease the reliance on chemical inputs, which reduces the costs of production and environmental impact and achieves similar yields. Thus, genetic enhancement and the cultivar choice is a core pillar in agronomy, i.e. integrating the biological potential of the wheat crop with the field-based management practices on how to achieve long-term and scalable improvements in wheat yield.

1.2 Nutrient and Soil management

Health and fertility of the soil is the foundation of the wheat production that is the relationship between the sustainable land use and sustained productivity. The quantity and quality of yield is largely dependent on the control of the macro and micronutrients and the preservation of the soil structure.

1.2.1 Recommended Doses and Sources of Nitrogen Phosphorous and Potassium Fertilizers

Nitrogen (N) is the nutrient that limits yield of wheat the most worldwide. The dose of N application, source (i.e., urea, ammonium nitrate), and timing (i.e. split applications) play a decisive role in the overall biomass and end-buttressed grain yield (Fageria & Baligar, 2022). Most importantly, N management has an extreme influence on grain protein content which is a major determinant of quality. Too much application or variable time of application of N may cause infertility in the soil, whereas insufficient N limits the crop and produces low-quality grain that cannot be sold in the premium markets (Dobermann & Fairhurst, 2020). The Economically Optimal N Rate (EONR) is applied using agronomic field experiments and is a process of trying to ensure equilibrium between the biological response of the plant and the input cost.

Phosphorus (P) and Potassium (K) plays an essential role in root development, energy transfer and initial vigor of crops particularly in cold soils. Potassium plays a significant role in water control (stomatology), disease resistance and stem strength (Havlin et al., 2019). Even though they do not typically require substantial amounts of N relative to P and K deficiencies, their serious yielding losses cannot be mitigated through sole action of N and that is why the application of a recommended fertilization strategy based on site-specific soil analysis.

1.2.2 Soil Health

The view of agronomy does not merely regard the soil as a growing medium but is instead a living ecosystem that plays the important role of the cycling of nutrients, water cycle, microbial activity and general growth of the plants.

The healthy soil is full of healthy microorganisms, organic matter, enzymes and nutrient-transforming biota, which actively help in availability of essential plant nutrition in a balanced form. The soil ecosystem is a biological factory and not merely a support medium of wheat roots, where nutrients like nitrogen, phosphorus, potassium and micronutrients are mineralized, mobilized and made available to the crop at the most important growth phases. An appropriate structured soil with good aggregation increases aeration, improves water infiltration and retention, minimizes compaction and facilitates deeper root penetration that permits the wheat plants to search a greater volume of soil as it becomes moist and nutrient rich during grain filling and stress conditions.

Moreover, organic matter is the most crucial indicator of soil health in itself, directly affecting the water-holding capacity, cation exchange capacity (retention of nutrients), and formation of stable aggregates (Lal, 2020). The OM enhancing management practices like cover cropping and retention of residue have direct and positive effects on yield stability particularly during drought periods.

Soil microbial communities are diverse and active, enabling the provision of the most important ecosystem services such as nitrogen fixation, phosphorus solubilization, which suppress soil-borne pathogens (Fraser et al., 2022). Ecofriendly friendly practices, which minimize soil disruption, facilitate positive fungal-root interactions (mycorrhizae), thereby improving nutrient and water absorption. Good soil structure is one that is stable in aggregation and porosity, and, therefore, has adequate aeration and permeability, which are essential to root respiration and water absorption to minimize runoff and erosion (Govaerts et al., 2021).

1.2.3 Tillage Practices

Tillage is an influential management practice that has a direct influence on the soil structure, OM breakdown and the energy requirements of the farming activity.

1.2.3.1 Conventional Tillage (CT)

This is the form of intensive soil inversion (ploughing), which has short-term advantages of seedbed preparation, incorporation of residues, and temporary control of weeds. Nonetheless, CT will accelerate the decline of soil organic carbon, weaken soil structure, and raise the chances of soil eroding, which will cause sustainability problems in the long term (Holland, 2019).

1.2.3.2 Conservation Agriculture (CA)

CA which is marked by partial soil erosion (no-till), constant soil cover (preservation of residues) and multidimensional crop rotations are famously known to have long term advantages. CA has a great impact in improving soil health, increasing water infiltration, and decreasing the energy use (fuel expenses) through reducing tractor passes (Kassam et al., 2009). Although CA systems can induce a short-term decrease in yield in the initial couple of years of the transition process, in the long-term perspective; CA systems are likely to achieve more yield stability and water-use efficiency as they provide a clear route towards an environmentally and economically resilient system.

1.3 Crop Protection and Use of Inputs

Yield potential can only be achieved with timely and effective control of biological threats (pests, weeds, and diseases) because the effect of uncontrolled biological stress can cause up to 30 percent of global crop losses (Oerke, 2022).

1.3.1 Weed, Disease and Pest Management

It has not only ceased its attention on blanket application of the chemicals in prophylaxis but also ensures strategic management using Integrated Pest Management (IPM). IPM is a knowledge intensive approach which is a combination of:

Cultural Control: Crop rotation, planting late and planting at the best density to minimize pest/disease pressure.

Biological Control: Biological control involves the use of natural enemies such as parasitoids, predators, microbial agents to reduce populations of pests.

Chemical Control: Pesticides are applied only when the population of pests or disease rises to an economic level and reduces the amount of chemicals applied (Pretty & Hine, 2021).

1.3.2 Effects of Pesticides and Herbicides

The use of chemical control is a critical instrument, and its use should be considered in relation to its impact. Excessive application of synthetic pesticides and herbicides also causes two key problems: development of resistance (e.g., herbicides resistant against the herbicides, such as Italian Ryegrass) and adverse environmental externalities (e.g., non-target effects on beneficial insects, water contamination, and safety of operators) (Loeza et al., 2019). As a result, the choice of whether to use a crop protection chemical is a complicated analysis of short-term benefits in terms of yield protection and long-term economic and ecological damages.

1.4 Climate and Water Management

The main limitation of wheat production in most of the arid and semi-arid states is water availability thus water management is one of the critical issues in ensuring stable yield and efficiency of land use.

1.4.1 Impact of Irrigation-Scheduling and Water-Use-Efficiency (WUE)

Water application timing and water application amount are critical in the irrigated wheat systems. Growth-phase irrigation such as during tillering and flowering can be used to avert stressful conditions that decrease yield and maximize the utility of applied water (Chowdhury et al., 2023). Nevertheless, the growing supply of water scarcity requires the emphasis on enhancing Water-Use Efficiency (WUE) which is the biomass or grain that is produced per unit of water utilized (transpired). The primary sustainable production in the water-stressed environment is the agronomic practices (e.g., CA, residue retention) and genetic characteristics (e.g., deep-rooting), which improve WUE. The use of improved irrigation methods, e.g., drip or sprinkler irrigation systems instead of flood irrigation, can significantly increase WUE, but the economic cost is high (Zotou et al., 2023).

1.4.2 Effects of Climate Change on the wheat production

The overall abiotic factor that determines the suitability of the region to wheat is climate. There are external pressures that cannot be avoided as a result of short-term variability and long-term climate change.

Increasing ambient temperatures, specifically those high temperatures at night and during heat waves at sensitive reproductive and grain-filling stages, causes crops to mature faster, shortening the grain-filling duration, and adversely affecting both the weight of the grains and the protein synthesis, causing considerable loss of yield in large areas of major wheat belts (Hatfield & Dold, 2019). Moreover, the variable precipitation such as increasing the frequency of heavy rainfall and prolonged durations of drought causes more uncertainties. Drought decreases the amount of moisture in the soil, whereas intense precipitation may result in waterlogging (poor health of roots) and predisposition to fungal infections (such as *Fusarium*). Flexible management systems and cultivars that are resistant to these seasonal variations have to be embraced by farmers to ensure that the output remains stable (Van Wart et al., 2013). The financial capacity of a farmer is tightly linked to the possibility of the farmer to reduce these climate risks by taking timely decisions in management, including the time to begin planting or invest in water storage.

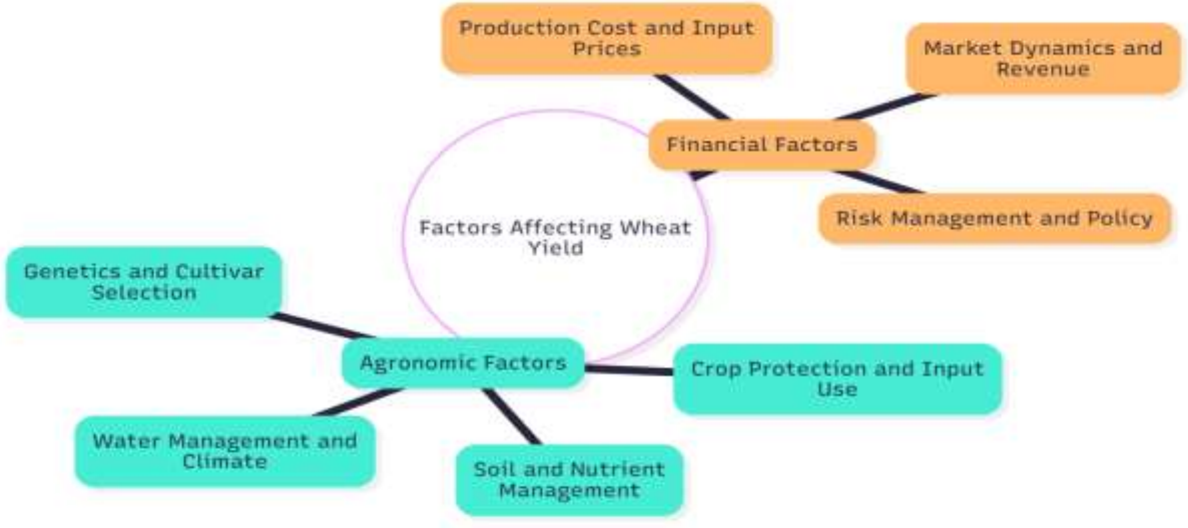

Figure 1: Key Agronomic and Economic Factors Affecting Wheat Yield

2. Financial Factors and Economic Viability

The economic sustainability and profitability of wheat production are not dependent only on the yield and quality but a dynamic interplay of the market forces, the production costs, and the government policies. Here, the analysis will examine the main financial determinants (Figure 1) that dictate the level of decision-making at the farm level and determine the level at which producers are able to invest in sustainable and resilience-enhancing agronomic activities.

2.1 Costs of Production and Price of Inputs

The variables are variable costs that are volatile in nature and they are complex in their cost structure of the wheat farming; these costs are a great financial risk to the producer. The ever-increasing trend and uncertainty of such input costs place an enormous burden on marginal profitability that forces the farmers to make trade-offs between the aim to maximize output (agronomic performance) and minimize costs. (Gardner & Perez, 2022). Fertilization, fuel/energy, and seed are generally the three most important categories of variable costs to wheat farmers in the rest of the world.

Nitrogen (N) fertilizer is the one largest variable cost in intensive wheat production, and in many countries, it is 25-40 percent of the total operating expenses (OECD, 2023). N cost is closely associated with the global natural gas prices and the local farming budgets which are extremely sensitive to international energy market and geopolitical shocks (Dobermann & Fairhurst, 2020). Balanced fertilization strategies are also dependent on the volatility of the prices of Phosphorus (P) and Potassium (K) as a result of mining, processing and transportation logistics. When fertilizer prices are high, there is often a motive to apply fertilizer at a rate lower than the Agronomically Optimal Rate (AOR), and instead apply farmers are tempted to apply the Economically Optimal Rate (EONR). Financial strains can even push the rates below the EONR and cause the decrease of the soil fertility and yield reduction alongside the decrease of the grain quality especially the protein content (Fageria & Baligar, 2022).

The price of the new modern cultivars with high potential yield is rising, as a result of the intellectual property prices of enhanced genetics, resistant to disease and particular qualities (Gupta et al., 2023). Although HYVs have greater yield potential, the upfront seed cost may be prohibitive to the smallholder or those farmers who have limited access to credit. The decision then becomes a trade-off where cheaper and less-resistant varieties having lower disease resistance cost less, but this is accompanied by increased cost of fungicides, and more expensive seed that reduces the risk of chemical usage.

Moreover, Fuel/energy is a significant contributor to the costs of operation, with a significant portion of the fuel used in the operations being diesel used in the running of the tractor. These expenses are directly proportional to the kind of tillage practice used. Traditional tillage (CT) consists of several, high-fuel consuming passes and is, therefore, economically susceptible to increased fuel costs. This economic pressure is a significant driving force to adopt Conservation Agriculture (CA) and no-till production, halting fuel demand up to 50% or more and turning an operation cost liability into a possible financial benefit (Kassam et al., 2009).

In systems that are highly mechanized, there are the costs of labour in the form of wages of skilled operators to operate specialized machinery. In labour intensive areas, an increase in manual labour costs can limit the cost of adopting labour-intensive methods (e.g. hand weeding) and hasten the switch to more mechanized or chemical weeds control, even though the latter would have greater environmental risks.

2.1.1 Analysis of High Input Costs and Farmer Risk

The cost of input is high and this is directly related to the financial risk that is faced by the farmer. Such inputs as seed and fertilizer should be bought and sprayed several months prior to harvesting, which can be considered a significant sunk cost. This enhances the operating leverage of a farmer. When a partial or complete failure of the crop is due to abiotic shock (drought, heat, flood) or biotic shock (pest outbreak), then the farmer is in financial distress, because the investment cannot be reclaimed (Wong et al., 2020). This loss fear usually makes risk adverse farmers, especially in less secure financial markets, invest below the optimum level of input, which has resulted in chronically sub-optimal output and has also spawned a poverty-low productivity cycle.

2.2 Market Dynamics and Revenue

The production of wheat is a volume based function of quality and price of a certain production that generates revenues. The latter two are the external factors that are mainly beyond the control of the farmer but they determine the final payoff of their agronomic practice.

2.2.1 Wheat Price Volatility

Wheat is an internationally traded commodity, which is extremely sensitive to a complex combination of global macro-economic and localized supply side forces:

Global Supply and Demand: The prices respond immediately to significant crop forecasts, large export/import choices of key players (e.g., Russia, EU, the US), and global stocks (IMF, 2024).

Geopolitical and Trade Policy Shocks: wars, trade embargo and tariffs can be quick to cut supply channels leading to acute price spikes. On the other hand, dumping of subsidized grain by the larger exporting countries can drive local prices down to a below cost of production level.

Speculative Trading: Financialization of agriculture commodities implies that most prices are instead driven by the non-agriculture market speculation that creates volatility and decouples the price messages with the supply fundamentals on the ground (Chen et al., 2021).

This volatility in prices leaves giant uncertainties that make it difficult to plan investments on long-term basis. A farmer who has budgeted to adopt costly accuracy farming apparatuses such as that of precision cultivating machines, will need a few years of continuous, lucrative harvests. The very nature of high price volatility dispels this kind of capital expenditure since the future worth of the investment is a guess (OECD, 2021).

2.2.2 Quality Premiums

When the grain is received under market specifications which may include receiving a high price based on high quality, revenue is maximized.

Specific industrial end-uses (e.g. pan bread, pasta) require high protein content, and carry a high premium over lower, feed-grade wheat. This premium is a strong economic motivation to farmers to invest in quality-enhancing agronomic methods, including timely N application at the end of the season, despite increasing operational risk (Morris & Bettge, 2017).

There are also high test weight and low foreign material premiums. On the contrary, discounts are charged on contamination like high inert matter and low test weight. Successful agronomic risk mitigation is directly associated between financial reward and the presence of quality premiums. It also aims at promoting specialized production systems by encouraging farmers to make management decisions that maximise the quantity of grain produced as well as its marketable value.

2.3 Risk Management and Policy

Government intercessions and financial market tools are meant to separate the natural biophysical and market hazards of the farmers immediate financial security, thus, promoting investment and stability.

2.3.1 The role of Subsidies, Crop Insurance, and Minimum Support Prices (MSPs)

These policy mechanisms constitute the safety net of protection of the wheat producers all over the world but not all of them are implemented or effective.

MSPs are common in such countries as India, where there is a certain price floor of some crops, such as wheat. MSPs play a key role in minimizing the risk associated with market prices and are a great incentive as it assures the farmer that he/she is guaranteed of a minimum price (Hassan & Du, 2020). Although the stability is effective, MSPs may also result in the inefficient allocation of resources, stimulating the growth of wheat in marginal regions, where the long-term agronomic viability of it is dubious, and putting a financial strain on the state.

Direct subsidies on inputs (e.g., fertilizer, water, electricity) are used to keep the cost of operations down in order to make farming profitable even at lower MSPs or fluctuating market prices. Although this makes short-term viability and sustainability more sustainable, input subsidies tend to be overutilized (e.g., much more N is used) and result in environmental destruction, resulting in a dilemma between short-term fiscal gain and sustainability (Tilman et al., 2018).

Government-subsidized reduced premium insurance and yield risk (agronomic failure). Crop insurance promotes the implementation of more productive but potentially riskier technologies and management strategies by compensating farmers who lose their crop because of a drought, disease, or extreme weather (Smith & Brown, 2024). Insurance stabilizes cash flow and facilitates agricultural entrepreneurship.

2.3.2 Effects of Availability of Credit and interest rates on Investment in the farm

Among other aspects, accessibility and the price of capital are perhaps the most important non-agronomic drivers of long-term sustainable development of wheat systems (Feder & Umali, 2020).

Significant changes in the structure of farming, e.g. changing CT to CA or building precision irrigation, demand capital investments that are large, lump-sum and specific to equipment (no-till drills, sensors, variable rate applicators). Farmers (smallholders, in particular) have no access to affordable credit (loans) and cannot use these technologies, no matter what agronomic and environmental advantages they can have (Zotou et al., 2023). When the interest rates are high the cost of equipment amortization is high extending the payback period and lowering net present value of the investment. This economic obstacle serves as a major obstacle to the modernization of wheat production that is required which will make it impossible to shift towards more efficient and less impactful production systems. Policies that subsidize agronomic credit or guaranteed loan programs are thus essential gears in converting agronomic innovation into much on-farm reality.

3. Relationship between Agronomic and Financial Factor

The linkage between agronomy and economic performance is that of dynamic interactions where the cost of inputs in the short-term should be balanced with the cost of resources in the long-term in terms of resource efficiency, profitability, and market requirements (Figure 2). It is a necessary synergy that will dictate how to the sustainable and economically viable farming systems. This is a very important synergy that defines the direction of sustainable and economically viable farming systems.

3.1 Agronomic Practices Cost-Benefit Analysis

An in-depth cost-benefit analysis shows that maximization of one agronomic value, like yield, seldom will result in maximization of profit. The return on investment is a very sensitive indicator about the input rates and long-term effects.

` The Economic Return on Investment (ROI) of Optimal vs. Excessive Fertilizer has demonstrated over and over that the net economic benefit of a given application of optimal fertilization management strategies, especially of Nitrogen (N), is much higher. An example is the case of winter wheat production, which has been reported to yield better strategies of increasing net economic benefit by 6.83-11.29% relative to the conventional methods, which are typically excessive and mostly by the farmers (Wei et al., 2023). It is so due to the fact that the fertilization level above some optimal level results in diminishing returns in yield, i.e. the expenditure of the additional input will exceed the income earned (Li et al., 2022; Yu et al., 2023). At high prices of fertilizers, when the recovery rate of N in cereals is less than 40 percent, rapid loss of profit margins can occur due to inefficient use of N, which must be controlled with precision to obtain a positive ROI (Thaler, 2025).

Moreover, Financial Advantages in the Long run of Conservation Agriculture (CA) vs. Financial Disadvantages in the Short run of adopting the Conservation Agriculture (CA) associated with an initial financial trade-off. In the long run, CA can prove significant financial profits because of lower operating expenses. Savings in machinery, fuel, labour costs are significant to the farmers due to reduction in the number of passes in the field. More importantly, the ultimate enhancement of the soil health and water retention results into enhanced and stabilised yields and profitability. The net returns of long-term research on CA systems in wheat have been reported to increase by 19.4% compared to the conventional tillage in the system (Nath et al., 2023). The long-term payoff leads to a high financial sustainability and one study has estimated the internal rate of return (IRR) of CA investment at 28% (Kassam et al., 2009).

3.2 Financial Limitations to Sustainable Practices

The presence of financial constraints is a significant structural constraint to the use of the good but costly agronomic technologies including, but not limited to, precision farming (PF) tools. The risk of making big capital investments is more because of high prices of inputs such as fertilizers and additional chemicals, and the market is volatile (Fagnani et al., 2023). Such economic constraints render farmers reluctant to invest the scarce funds in costly PF machinery.

Initial investments in the more modern technologies such as precision planters, sensors, and data analytics software may be prohibitive. Limited access to credit or capital by farmers, especially smallholders, does not allow them to use the tools, even though they may help them cut their input expenses (fertilizer, water) and increase long-term profitability and sustainability (Liverpool-Tasie et al., 2021). Government funding and loans have been mentioned as essential policy measures to overcome this capital barrier and increase more people to adopt it.

3.3 Yield, Quality and Profitability Trade-offs

Agronomic decisions are characterized by complicated trade-offs in which maximization of one variable usually limits another variable and a financial option needs to be made as a result of market indicators. Profit is not maximized when absolute yield is maximised because the cost of inputs necessary to produce the final marginal unit of yield is escalating (diminishing returns). Research on the application of fertilizers proves that policies that lower the application of nitrogen (N) fertilizers and nitrogen leaching that frequently result in a slight yield decrease (e.g., less than three percent) can also substantially alleviate financial losses, with the point of maximum yield being different than the point of maximum profit (Khoshnevisan et al., 2022). Thus, the farmers tend to follow a multi-objective optimization strategy, agronomic practices are adjusted to be more beneficial and environmentally efficient without always having to reduce high yield (Yang et al., 2020).

There is a close negative correlation between grain yield and grain protein concentration, one of the quality parameters in cereal production (Kobayashi et al., 2022). Bismarck yields may lower the quality of the resulting N in the grain, resulting in low protein quality. On the other hand, it is specific and expensive input management, e.g., a late-season N application, which will not add much biomass or yield but will be essential in protein content, to achieve higher quality (e.g., to higher wheat markets on premium bread) (Thaler, 2025; Zhang et al., 2021). The financial choice of the farmer is therefore a trade-off where he is to gain maximum volume (yield) in a large market or quality in a price-premium market.

3.3.1 Implications on Stakeholders

3.3.1.1 For Policymakers

The policies should go beyond blunt instrument subsidies (e.g. blanket fertilizer subsidy) and should aim at producing outcome-based subsidies. This involves subsidizing climate-specific crop insurance (drought, heat stress), and subsidizing credit specifically to capital-intensive, sustainable investment (no-till drills, precision planters, and water-efficient irrigation technologies) (Smith & Brown, 2024). Moreover, the market governance should be on a stable basis to reduce the volatility of the prices and promote long term planning.

3.3.1.2 For Farmers and Extension Agents

It should not be concerned about maximizing yield but should be concerned with maximizing profitability per unit of input and risk. Instead of merely relying on the short-term increase in yield, extension services should highlight the financial payoff of soil health practices in a 5 to 10 year outlook with a focus on knowledge-intensive practices, such as the implementation of the Economically Optimal N Rate (EONR) over Agronomically Optimal Rate (AOR) (Pretty & Hine, 2021).

3.3.1.3 For Researchers

The major research agenda should shift towards isolated disciplinary research to integrated interdisciplinary modelling. This necessitates the joint efforts of agricultural economists and crop scientists to conduct field experiments, which go beyond measuring the yield and quality of the crop but to combine real-time market prices, input cost volatility and farmer risk aversion with the analysis framework**.**

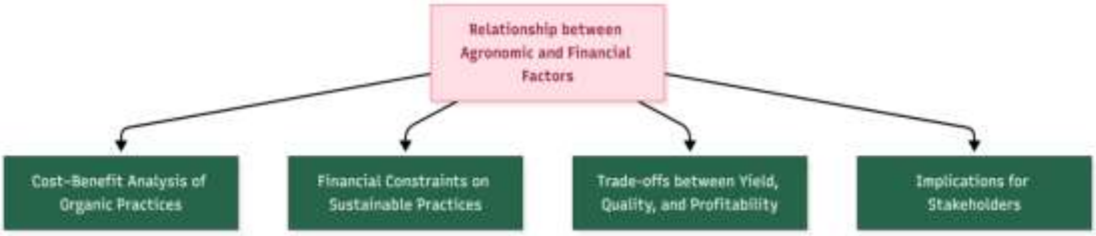

Figure 2: Relationship between agronomic and financial factors for wheat production

Conclusion and Future Research Needs

The answer to this is the distance between significant agronomic innovations, such as stress-tolerant genetic material and Conservation Agriculture and the economic limitations of the individual farmers themselves, who are usually scared off by the large initial investment and prolonged payback of this practice as no-till farming. This economic viability is the key filter of adoption, a clash has been made between short-term, output-distorting policies like input subsidies and long-term ecological health and the way ahead must be anchored upon win-

win synergies (e.g. genetic disease resistance at one gain making both yield and fungicides cheaper), and critically taking advantage of de-risking mechanisms such as effective crop insurance, flexible credit, and transparent market control, to enable the farmers to have the bravery to turn scientific potential into resilient and profitable practice.

To address the knowledge gaps and assist the world in going to resilient wheat systems, the future studies should be conducted in three interrelated spheres. To begin with, it is imperative that they need dynamic financial modelling that goes beyond the traditional single-year modelling to model the complex economic risks, market volatilities and cascading costs of climate variability in a real world manner. Second, it requires research to perform long-term Return on Investment (ROI) validation of sustainable practices, strictly quantifying the compounding economic and ecological gains (e.g., credits in carbon sequestration, need of reduced inputs) over a decade or beyond, to give evidence-based adoption pathways that are compelling to risk-averse farmers. Lastly, there is need to focus on the policy design of climate-specificity, going beyond generalized subsidies by creating specific, regional-based financial and insurance instruments that are efficient in de- risking the implementation of location-specific sustainable technology in different climatic and socio-economic settings.

References

Chen, H., Li, X., & Zhang, Q. (2021) Policy impact and market volatility in global grain trade. Agricultural Economics Review, 51(3), 45-62.

Chowdhury, S. H., Islam, M. T., & Rashid, A. (2023) Optimizing irrigation schedules for maximum yield and water-use efficiency in semi-arid wheat production. Agricultural Water Management, 280, 108345.

Curtis, B. C., & Timsina, J. (2020) Wheat: Global importance, challenges, and research priorities. In: Crop Production in Salt-Affected Soils. Springer.

Dobermann, A., & Fairhurst, T. H. (2020) Fertilizers and soil fertility: Nutrient cycling, input use efficiency and environmental impacts. In: Fertilizer, Food Security and the Environment. CABI.

Fageria, N. K., &Baligar, V. C. (2022) Nitrogen cycle and its importance for sustainable agriculture. In: Agroecosystem Management. CRC Press.

Fagnani, C., Morini, M., &Bozzetti, P. (2023) Does Precision Technologies Adoption Contribute to the Economic and Agri-Environmental Sustainability of Mediterranean Wheat Production? An Italian Case Study.Agronomy, 13(7), 1818.

Feder, G., and Umali, D. L. (2020) The adoption of agricultural innovations: A review. Technological Forecasting and Social Change, 43(3-4), 215–239.

Fraser, R., Smith, M., & Johnson, D. (2022)The role of soil microbial communities in nutrient acquisition and wheat health.Soil Biology and Biochemistry, 172, 108754.

Gardner, M. J., & Perez, L. A. (2022) Farmer decision-making under uncertainty: Integrating biophysical and financial risks. Journal of Sustainable Agriculture, 46(1), 12-25.

Gardner, M. J., & Perez, L. A. (2022) Farmer decision-making under uncertainty: Integrating biophysical and financial risks. Journal of Sustainable Agriculture, 46(1), 12-25.

Govaerts, B., Sayre, K. D., &Deckers, J. (2021) Soil health and sustainable crop production: the role of conservation agriculture. In: The Handbook of Soil Sciences. CRC Press.

Gupta, P. K., Mir, R. R., & Mohan, S. (2023) Exploiting wheat genomics for sustainable productivity. Nature Plants, 9(2), 171–178.

Hassan, A., & Du, Y. (2020) Government subsidies and adoption of sustainable farming practices in developing economies. World Development, 136, 105152.

Hatfield, J. L., &Dold, C. (2019) Temperature effects on grain yield and quality: Global implications for cereal crops. Crop Science, 59(1), 1-13.

Havlin, J. L., Tisdale, S. L., Nelson, W. L., & Beaton, J. D. (2019) Soil Fertility and Fertilizers: An Introduction to Nutrient Management. Pearson Education.

Holland, J. M. (2019) The environmental benefits of conservation tillage in Europe. Agriculture, Ecosystems & Environment, 276, 127-142.

International Monetary Fund (IMF). (2024) World Economic Outlook, April 2024: Steady but Slow: Resilience amid Divergence. Washington, D.C.

IPCC (Intergovernmental Panel on Climate Change) (2022) Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the IPCC.

Johnson, R., & Lee, S. (2019) Optimizing nitrogen use efficiency in wheat: A meta-analysis of application timing. Crop Science Journal, 112(4), 890-905.

Kassam, A., Friedrich, T., &Derpsch, R. (2009) Financial benefits of Conservation Agriculture in wheat production in Northern Kazakhstan (IRR = 28 per cent). ResearchGate.

Khoshnevisan, B., Janardhanan, R., Lathrop, N. R., et al. (2022) Exploring Trade-Offs Between Profit, Yield, and the Environmental Footprint of Potential Nitrogen Fertilizer Regulations in the US Midwest.Frontiers in Plant Science, 13, 852116.

Kobayashi, H., Arai-Sanoh, Y., &Hirasawa, T. (2022) Trade-off between grain yield and protein concentration is modulated by canopy photosynthesis in Japanese wheat cultivars. bioRxiv.

Lal , R. (2020) Soil organic carbon: A vital capital for food security and climate change mitigation. CAB Reviews, 15, 1-19.

Lal, R., Al-Kaisi, M., & Baker, J. M. (2021) Soil health and global food security: The role of sustainable intensification. Nature Sustainability, 4(7), 541-550.

Li, Y., Chen, J., Wang, R., et al. (2022) Efficient Irrigation Methods and Optimal Nitrogen Dose to Enhance Wheat Yield, Inputs Efficiency and Economic Benefits in the North China Plain.Agronomy, 12(2), 273.

Liverpool-Tasie, L.S.O., Tambo, S., Koundouri, P., et al. (2021) Credit Constraints and Agricultural Technology Adoption: Evidence from Nigeria. CGSpace.

Loeza, A., Ocampo, J., & Perez, R. (2019) Herbicide resistance in major wheat weed species: Current status and management challenges. Pest Management Science, 75(11), 2841-2852.

Morris, C. F., &Bettge, A. D. (2017) Wheat breeding for end-use quality and protein composition. Journal of Cereal Science, 75, 48-61.

Nath, J., Yadav, R. K., Yadav, M. R., et al. (2023) Long-Term Conservation Agriculture Influences Weed Diversity, Water Productivity, Grain Yield, and Energy Budgeting of Wheat in North-Western Indo-Gangetic Plains.Sustainability, 15(9), 7290.

OECD (Organisation for Economic Co-operation and Development). (2021) Agricultural Policy Monitoring and Evaluation 2021. OECD Publishing, Paris.

OECD. (2023) OECD Review of Agricultural Policies: Brazil 2023. OECD Publishing.

Oerke, E. C. (2022) Global crop production under attack: Crop losses and the future of plant protection. CAB Reviews, 17, 1-28.

Pretty, J., & Hine, R. (2021) Integrated Pest Management in the 21st Century: New approaches and challenges. Pest Management Science, 77(1), 1-10.

Pretty, J., & Hine, R. (2021) Integrated Pest Management in the 21st Century: New approaches and challenges. Pest Management Science, 77(1), 1-10.

Reynolds, M. P., Lewis, J. M., Ammar, K., Basnet, B. R., Crespo-Herrera, L., Crossa, J., ... & Dreisigacker, S. (2017) Physiology and Breeding of Wheat for Increased Yield Potential. In M. P. Reynolds & H.-J. Braun (Eds.), Food Security in a Changing Climate: International Challenges and Opportunities (pp. 37–57). Springer.

Smith, P., Jones, A., & Williams, B. (2020) The efficacy of fungicide application rates on Septoriatritici control in diverse wheat rotations. European Journal of Agronomy, 119, 126101.

Smith, R., & Brown, P. (2024) The economic efficacy of subsidized crop insurance in mitigating farm financial risk. Agricultural Finance Review, 84(1), 120-135.

Thaler, K. (2025) Winter Wheat and Nitrogen: Decisions for 2026 Growing Season. SDSU Extension.

Tilman, D., Balzer, C., Hill, J., &Befort, B. L. (2018) Global food demand and the sustainable intensification of agriculture. Proceedings of the National Academy of Sciences, 108(50), 20260-20264.

United Nations, Department of Economic and Social Affairs, Population Division. (2022) World Population Prospects 2022.

Van Wart, J., van Bussel, L. G. J., Wolf, J., et al. (2013) Global response of wheat yield to temperature and rainfall variability. Global Change Biology, 19(2), 478-490.

Wei, J., Wang, Z., Li, Y., et al. (2023) Optimal Fertilization Strategies for Winter Wheat Based on Yield Increase and Nitrogen Reduction on the North China Plain.Sustainability, 15(5), 4199.

Wong, K., Miller, T., & Zhao, F. (2020) Economic modeling of commodity price volatility and risk hedging strategies for grain producers. Applied Economic Perspectives and Policy, 42(2), 290-310.

Yang, H., Shi, L., Cui, Z., et al. (2020) Optimizing wheat production and reducing environmental impacts through scientist–farmer engagement. Agronomy for Sustainable Development, 40(5), 44.

Yu, Y., Zhang, X., Yang, R., et al. (2023) Optimal fertilizer rates towards the improvement of nitrogen use efficiency and reduction of nitrogen export in paddy rice-wheat intensive farming. Frontiers in Environmental Science, 11.

Zhang, P., Qi, Y-k., Wang, H-g., et al. (2021) Optimizing nitrogen fertilizer amount for best performance and highest economic return of winter wheat under limited irrigation conditions.PLoS ONE, 16(11), e0260379.

Zotou, S., Koutsoukis, K., &Tsiropoulou, M. (2023) Economic feasibility and water-saving performance of smart irrigation systems in wheat farming. Water Resources Management, 37(1), 299-315.