Economic Viability of Yield Monitoring Systems in Potato Farming:
A Comparative Study between New Zealand and India

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Abstract

India is one of the largest global producers of potatoes by volume. At the same time, New Zealand, with its significantly smaller land area and farming population, consistently achieves higher yields, better produce quality, and greater per-hectare productivity. This study investigates the economic viability of adopting Yield Monitoring Systems (YMS) in potato farming across both countries to determine whether such precision agriculture technologies can enhance profitability and efficiency in India.

The research draws on secondary data from official sources, including Potato New Zealand and the Government of India, covering regional potato yields in Canterbury, Pukekohe, and Manawatu (NZ), and six Indian states. Using economic evaluation metrics—Return on Investment (ROI), Payback Period (PP), and Cost-Benefit Ratio (CBR)—the study compares outcomes across two adoption models: individual farmer-based adoption and service-based adoption via contractors or Farmer Producer Organisations (FPOs).

Findings reveal that while YMS significantly improves farm-level profitability and efficiency in New Zealand due to larger landholdings and advanced mechanisation, direct replication of this model in India is economically unfeasible for smallholder farmers. The high initial investment, lack of economies of scale, post-harvest losses, and limited access to institutional credit act as significant barriers.

The study concludes that for YMS to be viable in India, adaptation is essential—either through modular integration of YMS into existing machinery or via collective access through FPOs and Custom Hiring Centres. This comparative analysis offers a pathway for scalable YMS adoption in India, promoting precision agriculture not by direct transfer but through context-specific adaptation, institutional support, and strategic policy reallocation.

Keywords: Yield Monitoring Systems (YMS), Precision Agriculture, Economic Viability, Cost-Benefit Ratio (CBR), Return on Investment (ROI), Payback Period (PP), Potato Farming, New Zealand Agriculture, India Agriculture, Smallholder Farmers, Farmer Producer Organisations (FPOs), Custom Hiring Centres (CHCs), Agricultural Policy, Cooperative Farming Models, Digital Agriculture, Scale Economies in Agriculture

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Abbreviations

YMS	Yield Monitoring System(s)
ROI	Return on Investment
CBR	Cost-Benefit Ratio
PP	Payback Period
GPS	Global Positioning System
GIS	Geographic Information System
PA	Precision Agriculture
IOT	Internet of Things
USD	United States Dollar
MSP	Minimum Support Price
PM-KISAN	Pradhan Mantri Kisan Samman Nidhi
CPRI	Central Potato Research Institute
ICAR	Indian Council of Agricultural Research
PMKSY	Pradhan Mantri Krishi Sinchayee Yojana
ICT	Information and Communication Technology
SAUs	State Agricultural Universities
NICRA	National Innovations in Climate Resilience Agriculture

PPPs	Public Private Partnerships
MIS	Market Intervention Scheme
PSS	Price Support Scheme
KCC	Kisan Credit Card
PMFBY	Pradhan Mantri Fasal Bima Yojana
SC	Scheduled Castes
ST	Scheduled Tribes
PKVY	Paramparagat Krishi Vikas Yojana
NMSA	National Mission for Sustainable Agriculture
VRT	Variable Rate Application
CHC	Custom Hiring Centre
FPO	Farner Producer Organisation
MPI	Ministry of Primary Industries
MoAFW	Ministry of Agriculture and Farmers Welfare
NHB	National Horticulture Board
CACP	Commission for Agriculture Costs and Prices
NABARD	National Bank for Agriculture and Rural Development
HI	Harvest index

- Note $1 NZD = 50 INR

Chapter 1 . Introduction

1.1 Background of the research

In over 125 countries, Potatoes are one of the most widely grown crops, ranking as the 4th most consumed staple food after rice, wheat, and maize. Their versatility in cooking and high caloric value per hectare make the crop an essential food source, particularly in regions with higher population densities. They are a primary carbohydrate source and essential for nutrient consumption, significantly contributing to global food security (Tadesse et al., 2025).

Potato farming plays an important role in maintaining the livelihood of smallholder farmers, supporting food production, and generating income. Global demand for potato consumption is expanding as the population in developing nations grows. Thus, the adaptability of potatoes in developing Nations, where crops adapted to different climates offer policymakers and stakeholders opportunities to improve food security, is also beneficial.

By 2050, global food demand is expected to increase by 50%. Nearly 193 million people in 53 nations experienced acute hunger in 2021, representing a 40 million-person increase compared to 2020. Providing people and an expanding population with sustainable and nutritious food requires substantial improvements in the global agri-food system (van Dijk et al., 2021).

Nevertheless, significant disparities in yields persist between developed and developing Nations. For this thesis, New Zealand is chosen from the pool of developed nations, and India is chosen as a developing nation. Potatoes have significant value in the Indian agriculture sector. They were first introduced in Indian agriculture in the late 16th century and have been widely cultivated since then (Prakash et al., 2004). In contrast, in New Zealand, they were introduced in the late 18th century. According to Gernet (1984), Captain James Cook gave potatoes to the Māori chiefs during his first voyage in 1769.

India now cultivates potatoes in 2.33 million hectares. It produces 60 million tonnes of potatoes annually (Ministry of Agriculture & Farmers Welfare, 2023). In contrast, New Zealand has over 8,000 hectares used to cultivate potatoes, producing approximately 400,000 tonnes (Sinton et al., 2024). Despite being smaller in land area and total production than India, New Zealand's average yield per hectare stands at 50.9 tonnes, while India's average yield per hectare is 26 tonnes. The difference in yield per hectare between New Zealand and India is attributed to the extensive land holdings per farmer in New Zealand and the use of precision technologies, such as yield monitoring systems, and mechanisation to reduce dependency on manual labour, which improves efficiency. (Potatoes New Zealand, 2023)

Beyond differences in landholding size, mechanisation, and precision technology use, New Zealand's consistently high potato yields are fundamentally driven by its agro-climatic advantages and the physiological determinants of crop growth. Potato crops, like other temperate species, require the accumulation of thermal time (growing degree days) to reach physiological maturity. New Zealand's cool maritime summers slow thermal time accumulation, extending the duration of canopy growth. Because potato yield is primarily determined by total canopy light interception over time, this longer leaf area duration allows more photosynthate to be produced and allocated to tuber growth (Wilson & Jamieson, 1991). In addition, New Zealand experiences longer daylengths during the primary potato production season and a cleaner atmosphere with very low particulate pollution, which enhances solar radiation interception (Ministry for the Environment, 2023). When combined with adequate soil moisture, often supported through irrigation, balanced nutrient management, and effective pest and disease control, these conditions enable potato crops in New Zealand to photosynthesise efficiently for an extended period. This longer canopy duration allows greater cumulative radiation interception and photosynthate production, contributing to the significantly higher yields observed in New Zealand compared to India's warmer and more variable continental climate. (Sinton et al., 2024; Wilson & Jamieson, 1991)

Yield monitoring systems (YMS) are modern precision agriculture technologies that provide farmers with real-time data on crops during harvest. These systems, integrated with yield sensors, GPS technology, and data processing units, enable the collection and mapping of the yield variability in the field. The information generated by YMS helps identify high and low-yielding zones within the farmed area, which can be used to optimise input use and improve overall farm profitability. In crops such as potatoes, yield monitoring not only supports better management decisions but also accommodates on-farm research and long-term productivity gains. (Farmonaut, 2025)

Yield monitoring systems (YMS) have emerged as a method to address yield variability and enhance resource efficiency. YMS in developed countries, such as New Zealand, is widely adopted, contributing to both increased productivity and reduced input costs (Mahilum et al., 2022). However, in developing countries like India, adoption remains limited due to high capital costs, a lack of proper education, inadequate technology, and small farm sizes (Mondal & Basu, 2009).

1.2 Problem Statement

Even after the proven agronomic and economic benefits of YMS in developed countries, the adoption rate in developing countries remains very low. In New Zealand, YMS is a standard farm management practice, driven by significant yield improvements and input cost reductions (Mahilum et al., 2022). In contrast, the majority of potato farmers in India operate on less than two hectares of land, making YMS economically unfeasible for them to invest in high-cost precision agriculture tools without targeted subsidies (Prsindia, 2025).

The primary issue to be examined in this thesis is whether a yield monitoring system can be economically viable and scalable for the Indian small landholding-dominated potato farming sector, and what aspects of New Zealand's successful model can be adapted. Problems like high capital investment, limited digital literacy, small-scale landholding, and inadequate extension services hinder the adoption of YMS (Kumar et al., 2020). There is a significant gap in cross-country evaluation of YMS using metrics such as Return On Investment (ROI), Cost-Benefit Ratio (CBR), and Payback Period (PP) (Shockley et al., 2012). This thesis aims to fill that gap by providing a comparative economic analysis of YMS adoption in potato farming in New Zealand and India, utilising financial metrics and surrounding circumstances within each country's unique policy environment.

1.3 Research questions

a) Are the Yield monitoring systems used in New Zealand potato farming economically viable in the Indian potato farming sector?
b) If not, how can the yield monitoring systems be adopted in the Indian potato farming sector?

1.4 Research objective

This research addresses whether yield monitoring systems can be economically viable in India's context and what lessons can be drawn from the successful adoption of these technologies in New Zealand.

Two objectives guide this research:

a) To study the viability in economics of New Zealand and India by using different indicators such as Cost-Benefit Ratio (CBR), Payback Period (PP), and Return on Investment (ROI).

b) To provide a scalable productivity and profitability improvement solution for India's potato crop yield with better precision agriculture tools.

1.5 Significance of research

The research is significant because it can influence policy and practice regarding the adoption of yield monitoring systems in potato farming. It compares the developed country of New Zealand with the developing country of India. Analysing the economic viability and operational challenges of YMS surrounding two different agricultural contexts, addressing a critical knowledge gap in precision agriculture

The research provides insights for enhancing farm profitability and improving food security. Potatoes are a staple crop in both New Zealand and India. In New Zealand, people mostly consume them as fries, while in India, they are commonly eaten as a vegetable in various forms. However, yield disparities persist due to technological differences, farm size, and unequal access to resources. By evaluating how YMS improves cost-effectiveness and yield improvements in New Zealand and comparing this with the barriers faced in India, the study proposes practical ways to improve productivity in resource-limited settings.

This study presents a comprehensive economic assessment utilising financial metrics, including Return on Investment (ROI), Payback Period, and Cost-Benefit Ratio. These help farmers and policymakers understand the long-term values and risks of adopting YMS. The comparative approach emphasises context-specific strategies. While New Zealand demonstrates the benefits of large-scale, mechanised farming and institutional support, India’s experience points towards cooperative models, custom hiring centres, and incentives to make advanced technologies accessible to smallholders.

Finally, this study contributes to the broader explanation of sustainable agriculture by showing how YMS can optimise input usage, reduce environmental impact, and build resilience against market and climate shocks.

1.6 Thesis Overview

This thesis is divided into seven chapters. Chapter 1 provides the research background, explains the problem statement, outlines the research questions, objectives, and significance of the research. Chapter 2 provides a comparative overview of the agricultural and potato farming landscape in New Zealand and India. It includes regional/state-specific data, farming practices, the economic condition of the farmers, and relevant government policies that influence potato farming and technology adoption. Chapter 3 examines literature on potato farming, precision agriculture, yield monitoring systems, and economic evaluation methods. It highlights global adoption trends and identifies gaps that justify this study. Chapter 4 describes the research design, data collection process, and financial metrics (ROI, CBR, and PP) used to assess the economic viability of YMS adoption in both countries. It outlines assumptions and models used in the analysis. Chapter 5 presents a detailed comparative economic analysis of YMS adoption. It explores individual and service-based adoption models across different regions in New Zealand and India using ROI, CBR, and PP. Chapter 6 interprets the results, discusses the implications of YMS adoption in both countries, and addresses the research questions by integrating findings with the policy and technological framework. Chapter 7 summarises the study, offers policy recommendations, discusses limitations, and suggests directions for future research related to the economics of precision agriculture.

Chapter 2: Overview of the study, Country and Crop Context

2.1 An overview of New Zealand

New Zealand is an island nation located in the southwestern Pacific Ocean, comprising two main landmasses: the North Island, also known as Te Ika-a-Māui, and the South Island, also known as Te Waipounamu. There are also 600 smaller islands. New Zealand has a total land mass of approximately 267,710 square kilometres. It also has a coastline of over 15,134 kilometres. The country lies about 1600 kilometres southeast of Australia and is geographically isolated. It has unique biodiversity and ecological systems (Britannica, 2025)

Wellington is the capital city, while Auckland is the biggest urban centre and economic hub. New Zealand is divided into 16 administrative regions, each with distinct climate, soil types, and topographical features that support various agricultural activities (Ballingall, 2004). The country's landscape is characterised by mountains, rolling plains, volcanic plateaus, and extensive river systems, which support diverse agricultural systems (Sinton et al., 2022).

New Zealand's population is approximately 5.1 million, with the majority residing in urban areas; however, rural communities remain integral to the nation's identity and economy. The country is recognised for its multicultural society, which includes significant Maori, Pacific, and Asian communities (Ballingall, 2004).

New Zealand's highly developed and export-oriented economy is based on agriculture, horticulture, forestry, and tourism, which play significant roles. The exports primarily consist of dairy products, meat, wool, fruits, and vegetables. New Zealand is well known for its advanced agricultural practices and high productivity per worker. The agricultural sector benefits from large-scale mechanisation, the adoption of modern technology, and strong institutional support (Curran Cournane & Rush, 2021).

New Zealand is a geographically diverse nation that is economically developed and advanced, with a strong agricultural sector, modern infrastructure, and a multicultural society. Its unique location and landscape contribute to both its natural beauty and its agricultural productivity.

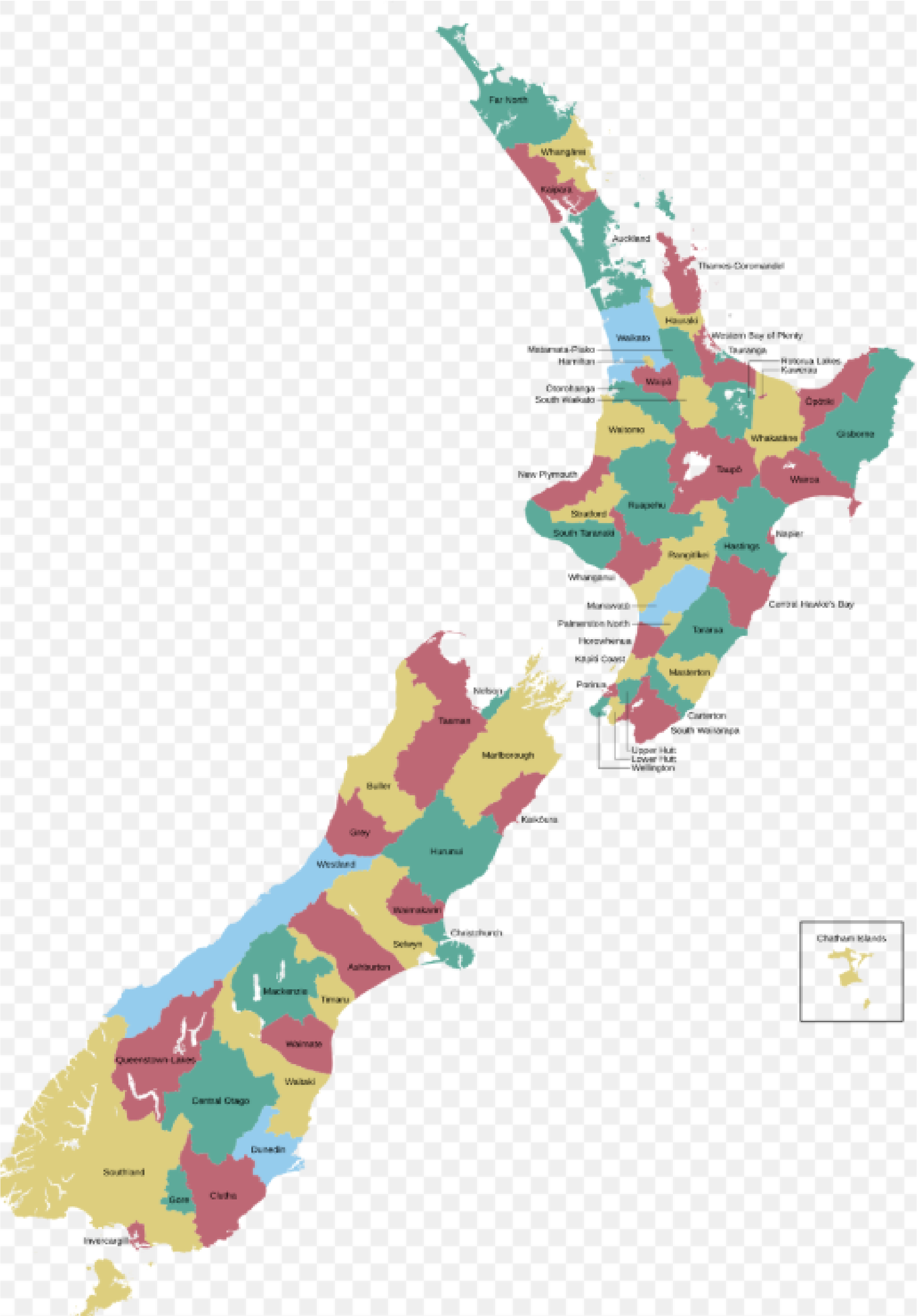

Figure 1: Administrative map of New Zealand. Source (Territorial authority areas of New Zealand)

2.1.1 Agriculture Sector in New Zealand

In New Zealand, agriculture is the primary sector, serving as the cornerstone of the country's economy, accounting for approximately 17% of the GDP and more than half of the country's export revenues (Apatov et al., 2016). This sector utilises approximately 11.2 million hectares of farmland to support diverse activities, including dairy, meat, wool, horticulture, and arable cropping (Zawar-Reza & Bellamy, 2022). New Zealand's temperate climate and abundant resources provide a comparative advantage, enabling efficient, pasture-based production systems and high yields across major commodities (Graham, 2011).

Agriculture in New Zealand involves large-scale, highly mechanised farms, with an average farm size of around 230 hectares (Graham, 2011). The sector is dominated by pastoral farming, which includes dairy, sheep, and beef production, while horticulture and arable crops, such as potatoes, also play a significant role. The country's agricultural products are exported worldwide, with dairy and meat as the leading earners, followed by fruits, vegetables, and wool (Apatov et al., 2016).

New Zealand is recognised for its early adoption of precision agriculture(PA) technologies. The adoption of precision technologies, such as GPS-guided machinery, remote sensing, variable-rate application systems, and advanced data analytics, enhances input use and operational efficiency in the fields (Knowles, 2019). The integration of Internet of Things (IoT) devices and real-time data collection enables farmers to monitor soil moisture, soil nutrient levels, and crop health, thereby tackling pests and diseases, and leading to more informed and targeted management decisions (Lawrence, 2007).

One precision technology is the yield monitoring system (YMS). YMS is a central component of New Zealand's precision agriculture, particularly in the arable and horticultural sectors. YMS uses sensors on harvesters to collect yield data that is referenced spatially; this specially referenced data is then used to generate yield maps and analyse field variability (Yule,1999). This information is used in specific site management, optimising fertiliser, water, and pesticide applications, and improving productivity and sustainability. Lawrence (2007) found that optimised fertiliser application using precision technologies reduced input losses and improved overall farm profitability. He also found that YMS enables farmers to identify underperforming Zones, refine management practices, and enhance long-term planning.

New Zealand’s agriculture sector is globally competitive and technologically advanced. The integration of precision agriculture and yield monitoring systems has played a significant role in maintaining high productivity, economic viability, and environmental stewardship.

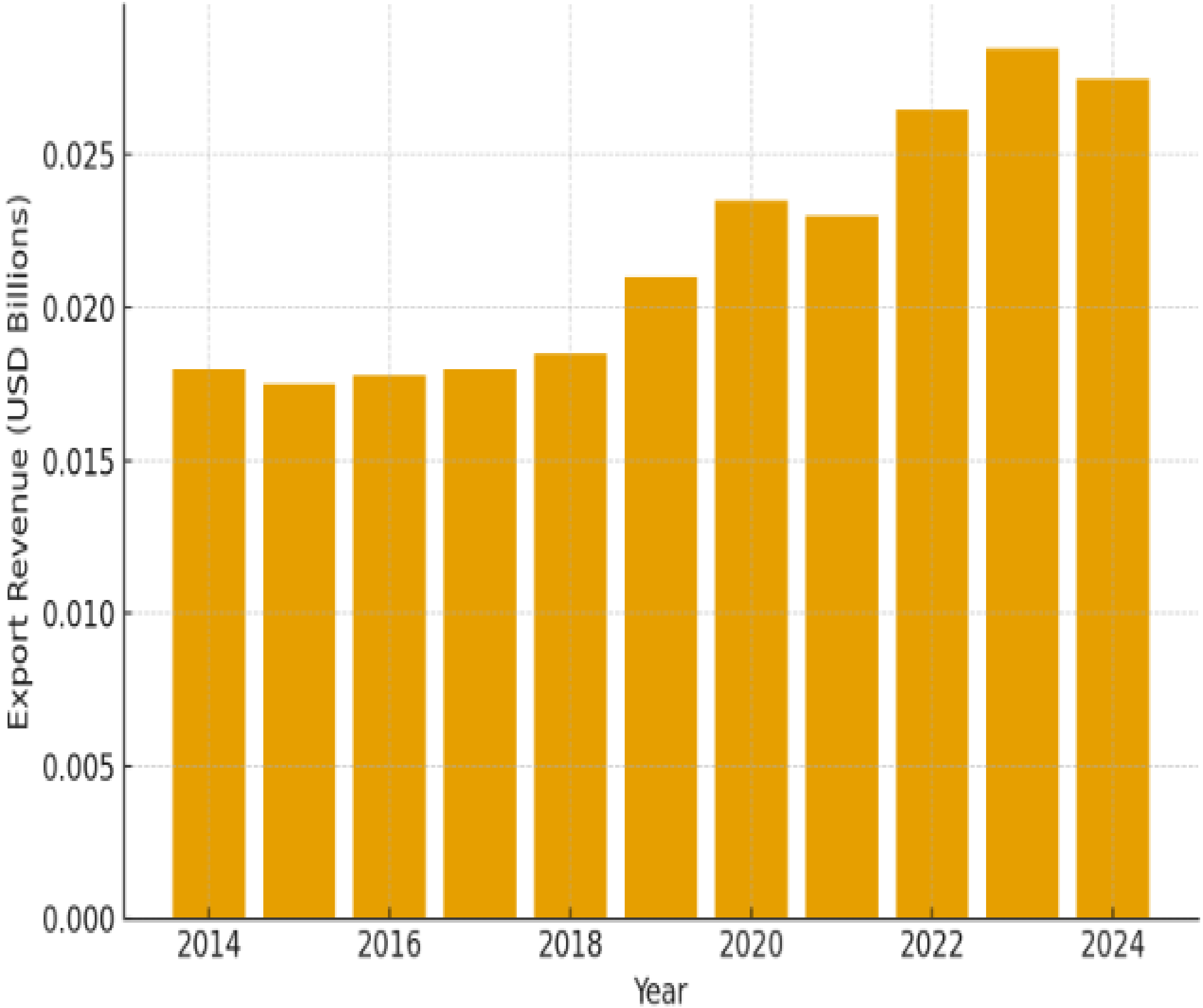

Figure 2: New Zealand's total agriculture exports in USD

Source: stats. Govt.nz

2.1.2 Economic Conditions of Farmers in New Zealand

New Zealand farmers operate within a highly developed, export-driven agricultural system which delivers high productivity and world-class yields but also exposes them to unique economic pressures and risks. Most commercial farmers manage relatively large holdings, benefiting from advanced mechanisation, and have access to strong institutional support, including research, extension, and a well-developed supply chain (Sinton et al., 2022).

Farm incomes in New Zealand are closely tied to global commodity prices, as over 80 % of agricultural output is exported. In recent years, farmgate prices for major commodities, including dairy, red meat, and horticulture, have improved, leading to a cautiously optimistic outlook for 2025, with profitability expected to rise for many producers (Rabobank, 2025). Volatility remains a feature of the sector. Fluctuations in global demand, exchange rates, and input costs, including fertilisers, fuel, and labour, can quickly erode margins, and farm profitability can swing from year to year (MyNoke, 2024).

New Zealand farmers face high operating costs, including land, machinery, compliance, and environmental regulations. Input prices inflation, especially for fertilisers and energy, has been a challenge, though recent reports show easing in 2025, with farm input prices falling by 0.6 % in the year to March 2025, primarily due to lower interest rates and modest decreases in some input prices (Beef + lamb New Zealand, 2025). Many farmers carry significant debt, particularly in the dairy sector, where investments in land and herds are substantial. Debt servicing is sensitive to interest rate changes, and the Reserve Bank has noted that prolonged periods of low output prices or high input costs could lead to increased financial stress and defaults (Reserve Bank of New Zealand, 2025).

Labour shortage and an ageing workforce are ongoing challenges, especially for horticulture and cropping farms. The food and fibre sector has reported significant labour shortages, with an estimated shortfall of 13,000 workers in horticulture for 2021, and ongoing demographic shifts continue to affect productivity (PwC New Zealand, 2022).

Many growers are investing in automation and new technologies to address these issues, but smaller farms may struggle to afford such transitions. Despite these headwinds, New Zealand farmers have demonstrated resilience to both market and climatic shocks. The sector's strong institutional support, robust supply chain, and ongoing innovation in precision agriculture continue to underpin its global competitiveness and capacity for future growth

2.1.3 Potato farming in New Zealand

Potato farming in New Zealand is highly productive and technologically advanced. Potato farming in New Zealand reflects the advantages of a high-income, technologically integrated agricultural sector. With mechanised operations spread across extensive farm holdings and supported by a well-developed infrastructure (Curran-Cournane & Rush, 2021). Reliable supply chains and strong institutional support, including research and extension services, reinforce these outcomes.

New Zealand, according to the latest data from Potatoes New Zealand (2024), produced potatoes on 8500 hectares in 2024, yielding around 420,200 tonnes of potatoes. The three central regions in New Zealand where potatoes are grown are Canterbury (South Island), Manawatu, and Pukekohe (North Island). The country produces a wide range of potato varieties suited to various market segments, including fresh consumption, frozen fries processing, crisps and seed production.

Frozen processed potatoes (primarily fries) make up the bulk of exports, with Australia as the largest market, accounting for over 75% of frozen exports. Other significant markets include Japan, French Polynesia, and Papua New Guinea, each contributing around 6%. Fresh potato exports are smaller due to strict phytosanitary regulations. Fiji is the largest market for fresh potatoes, receiving over 75% of exports in recent years. Other Pacific and Asian countries, such as Samoa and French Polynesia, also import fresh potatoes (Potatoes New Zealand, 2024).

Figure 3: Export destinations of New Zealand potatoes by volume percentage for frozen processed and fresh potatoes. Source: (Potato New Zealand)

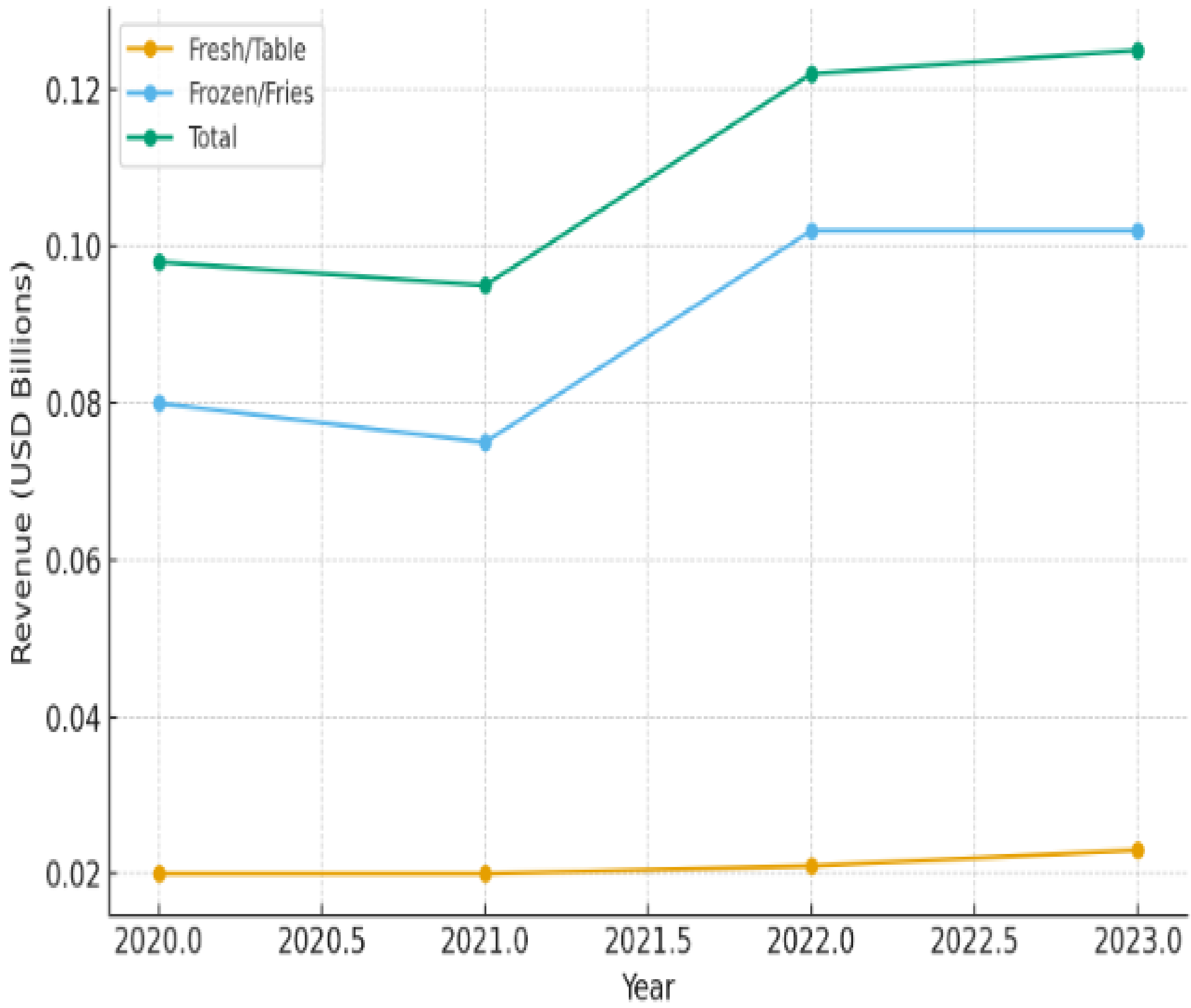

Figure 4: New Zealand's potato exports in USD, source: (Potatoes New Zealand, 2023)

2.1.3.1 Regional potato production and yield in New Zealand

New Zealand's potato production is concentrated in three regions: Canterbury (on the South Island), Pukekohe, and Manawatu (on the North Island).

Pukekohe

Located just south of Auckland, Pukekohe is unique for its ability to produce two potato crops per year – summer and winter - due to its mild climate and well-drained volcanic soil (Sinton et al., 2022).

Summer yields are highest, with frozen fry processing (FF processing) and fresh market potatoes achieving yields of 50 to 55 tonnes per hectare. Winter yields are marginally lower than summer yields, at 40 to 45 t/ha across all segments. This dual cropping ability enables higher annual land productivity, making Pukekohe a vital supplier for both domestic and export markets (Sinton et al., 2022).

Manawatu

This region specialises in summer potato production with yields averaging around 55-60 tonnes per hectare. The region's fertile alluvial soils and moderate climate support consistent yields, benefiting domestic processors and supermarkets(Siano et al., 2018).

Canterbury

Canterbury is New Zealand's largest potato-producing region and consistently yields the highest average per hectare, both nationally and globally. According to Potatoes New Zealand (2025), this region produces potatoes only once a year. In the summer, this region produces FF processing potatoes, yielding 70 to 80 tonnes per hectare, and produces crisp potato varieties with yields reaching 65 to 75 tonnes per hectare. Additionally, it produces seed potatoes with yields of up to 25 to 30 tonnes per hectare.

Region	Season	FF Processing	crisping	Fresh Market	Seed
Pukekohe	Summer	50 – 55	40 - 45	50 -55	--
	Winter	40 – 50	40 -50	40 - 45	--
Manawatu	Summer	--	55-60	55-60	--
Canterbury	Summer	70 – 80 +	60- 65	65- 70	25 - 30

Table 1: Regional yields by segments, tonnes per hectare

source : (Potatoes New Zealand, 2025)

Canterbury's dominance in yield is a direct result of scale, mechanisation, and technological leadership, while Pukekohe's flexibility in cropping cycles ensures a steady year-round supply.

According to Holmes (2024), YMS enables farmers to convert geospatial yield data into gross margin and profit/loss maps, which help identify the most and least yield generating areas of paddock, a three year project fitting yield monitor to potato harvesters in Waikato and South Canterbury showed that integrating multiyear yield data with profitability analysis helped growers make informed decisions about input allocation, crop rotation, and irrigation investments. These studies found that removing unprofitable zones from production or improving their management could increase overall profitability by over 25%.

Figure 5 : Potato harvester fitted with yield monitors, source : Holmes (2024)

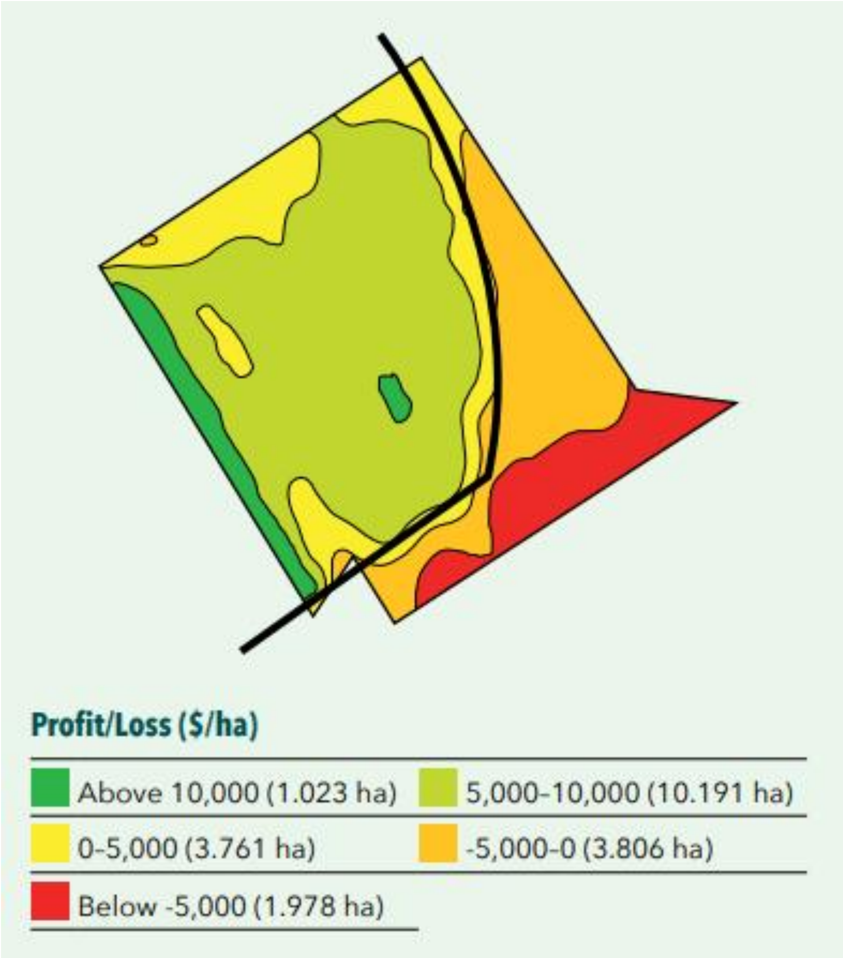

Figure 6: profit & loss map showing the gross margins ($/ha), source (Holmes,2024)

The integration of digital mapping further supports the adoption of YMS, Geographic Information Systems (GIS), and data analysis platforms, enabling growers to collect benchmark performance data across seasons and fields.

A recent study by Guopeng Jiang et al. (2021) presents data from the yield monitoring system used during potato harvesting in various fields of AS Wilcox and Sons, a company with multiple farms that grows a range of potatoes, onions and carrots. Jiang utilised the yield data from the company's potato fields and integrated it with GIS to produce yield maps, as shown below. The maps shown below are how a yield monitoring system shows yield data to a potato farmer.

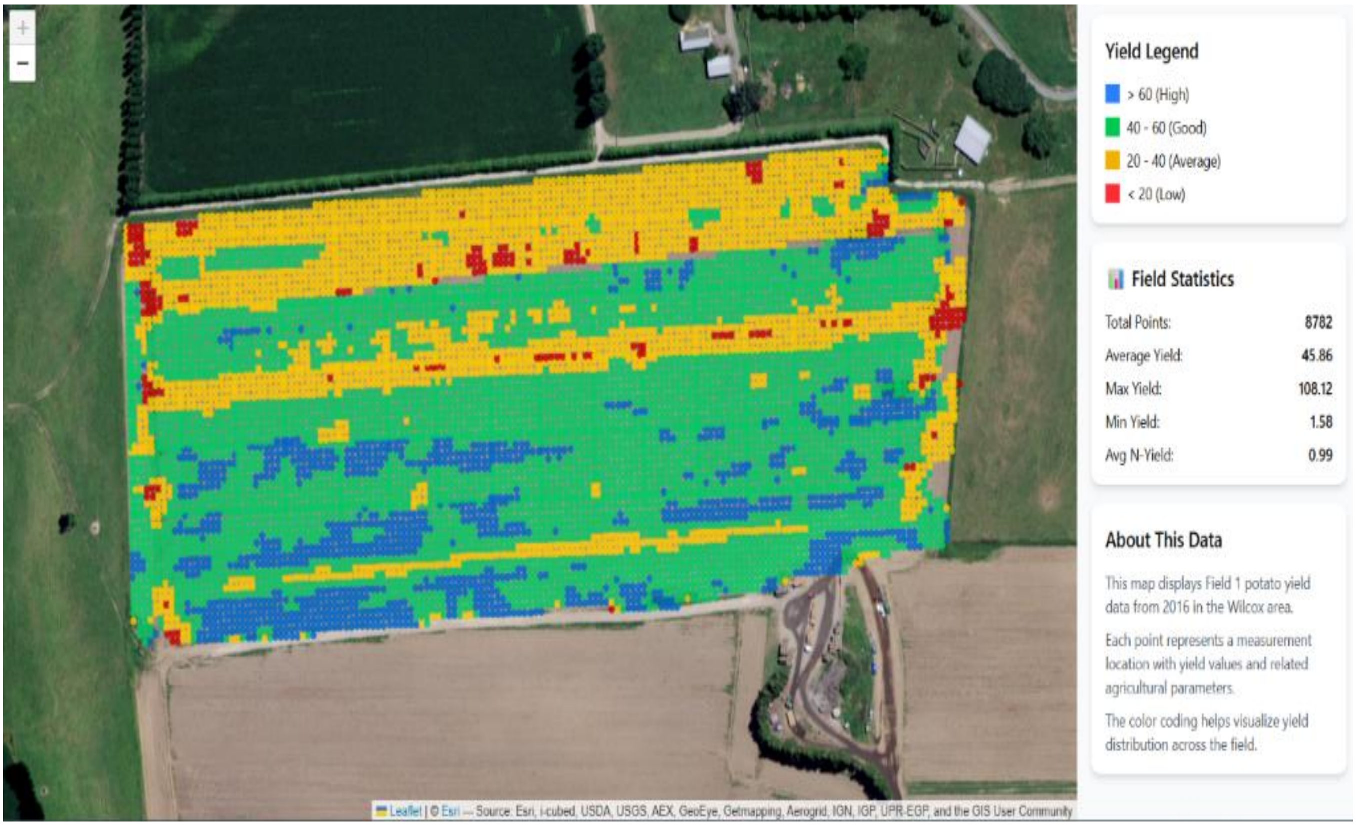

Figure 7: AS Wilcox potato field 1, source: (Jiang et al., 2021)

Figure 8: AS Wilcox potato field 3, source: (Jiang et al., 2021)

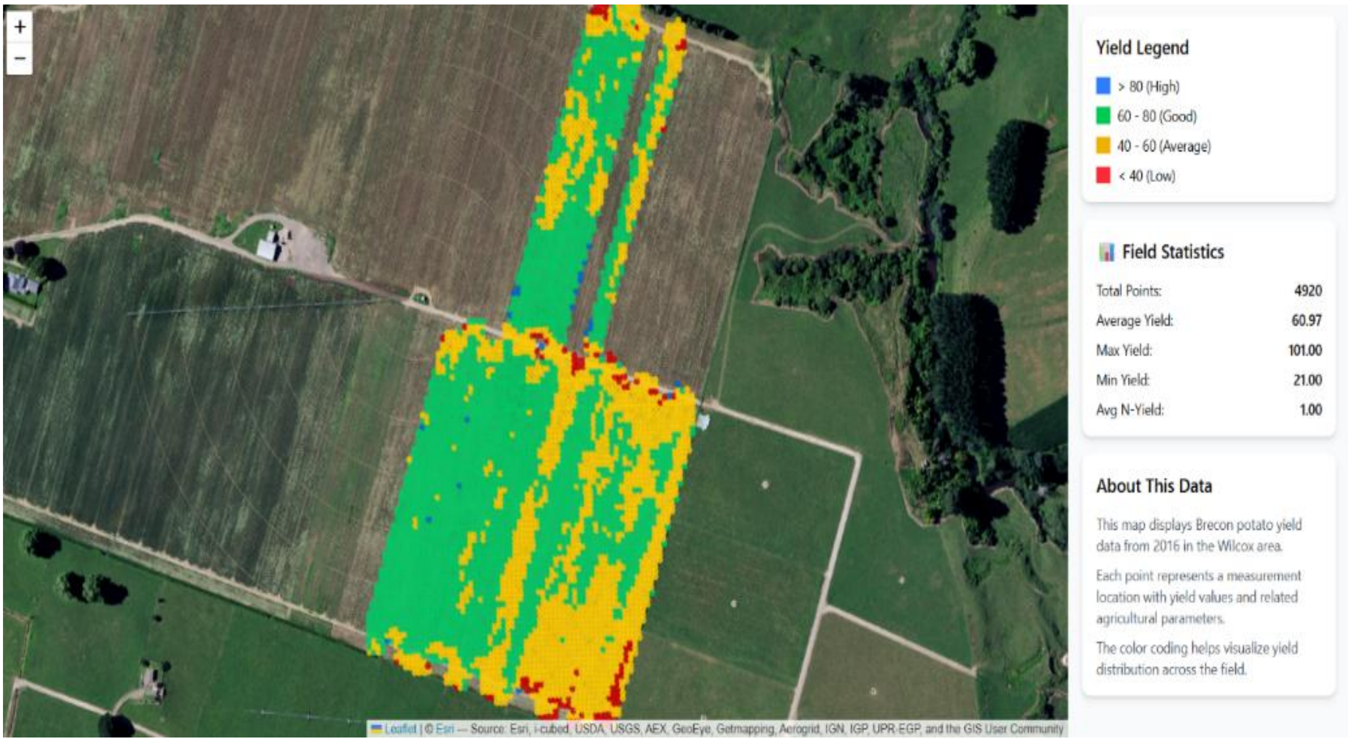

Figure 9: AS Wilcox potato field 4 Brecon, source: (Jiang et al., 2021)

Figure 10: AS Wilcox potato field 4 Jaggers Rd, source: (Jiang et al., 2021)

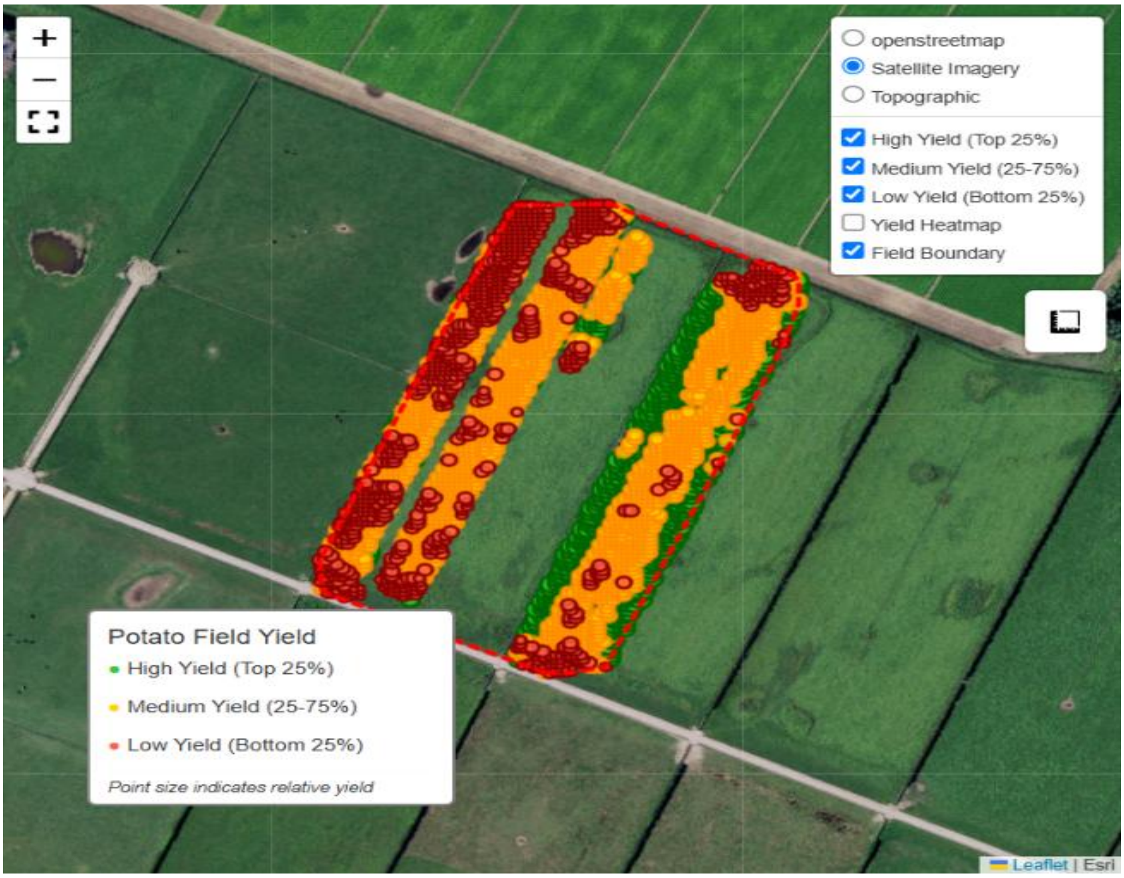

Figure 11: AS Wilcox potato field 10, source: (Jiang et al., 2021)

Figure 12: AS Wilcox potato field 6, source: (Jiang et al., 2021)

2.1.4 Government policies on potato farming in New Zealand

Potato farming in New Zealand supports both productivity and sustainability. The government has recently moved to streamline resource consent requirements, making vegetable growing a permitted activity on highly productive land. This policy shift is designed to reduce unnecessary regulatory barriers, boost grower confidence, and enhance food security. Industry bodies like Potatoes New Zealand have welcomed these reforms, highlighting the importance of practical land management that considers soil quality, water access, climate, and proximity to markets (Potatoes New Zealand, 2025).

Environmental regulations are an aspect of policy for potato growers. The National Policy Statements for Freshwater Management (NPSFM) 2020 provide direction to local authorities on managing freshwater resources under the Resource Management Act 1991. Many regions require potato growers to develop farm environment plans (FEPs), outlining how they will manage environmental impacts, like nutrient management and irrigation. Compliance with these plans is essential for sustainable farming and helps growers meet local council requirements (Tupu.nz,2020).

Integrated farm planning (IFP) is another initiative supported by government and industry. The IFP aims to standardise data reporting, reduce compliance burdens, and improve coordination between regulators and growers. This initiative integrates environmental, animal welfare, and biodiversity regulations for growers. (Potatoes NZ & Trust Alliance NZ, 2020).

Industry levies play a significant role in supporting research, development, and market access for potato growers. Under the Commodity Levies Act 1990, potato growers pay compulsory levies to Potatoes New Zealand and Horticulture New Zealand. These levies fund industry support, research, and market development activities, ensuring the sector remains competitive and innovative (Tupu.nz, 2020). Together, these policies and regulations create a supportive and sustainable environment for potato farming in New Zealand.

2.2: An overview of India

India is a diverse country located on the Asian continent. It covers approximately 3.29 million square kilometres, and it is the seventh-largest country in the world (FAO, 2018). It shares borders with several countries, namely Pakistan, China, Bangladesh, and Myanmar, and has a coastline of over 7,500 kilometres along the Indian Ocean (FAO, 2018). India is a collection of 28 states and eight union territories, where each state has its administrative structure and cultural identity (Britannica, 2025).

The Himalayas in the north, the fertile Indo-Gangetic plains, the arid Thar Desert in the west, the Deccan Plateau in the south, and the extensive river systems, such as the Ganges, the Brahmaputra, and the Yamuna, uniquely define India’s topography. This geographical advantage and diversity support a wide range of ecosystems and agricultural activities in India (Sanyal, 2012).

The capital city of India is New Delhi, Mumbai is the financial capital and the largest urban centre(Britannica, 2025). India has been divided administratively into states, union territories and further into districts. The number of districts has grown from 356 in 1971 to over 780 in recent years. This increase reflects the ongoing process of administrative decentralisation for the improvement of governance and local development (Rajan & Malghan, 2022).

The population in India is estimated to be over 1.4 billion. Most Indians live in urban areas, with projections indicating that more than 40 % of the population will reside in cities by 2030. But rural communities remain vital to the country's identity and economy (PIB, 2024). India is well known for its multicultural society, with hundreds of languages spoken and numerous communities of Hindus, Christians, Sikhs, Buddhists, and other faiths. India officially recognises 22 languages in its constitution, and cultural diversity is celebrated through festivals, cuisine, and traditions (FAO, 2018).

The country's natural resources include fertile soils, diverse forests, abundant water bodies, and significant mineral reserves. India is recognised as one of the world's 17 megadiverse countries, comprising around 8% of all recorded species, including over 45,000 plant and 91,000 animal species (FAO, 2018).

Figure 13: Administrative Map of India, source: mapsforupse.com (2025)

2.2.1 Agriculture sector in India

India's agricultural sector is a key pillar of the national economy, providing livelihoods for nearly half of the country's workforce, which contributes to both food security and rural development (Gulati, 2022). According to the Press Information Bureau (2025), the Indian agriculture sector, despite facing structural and climate challenges, has demonstrated strong growth in recent years, averaging around 5% annually from 2017 to 2023, agriculture and allied activities remain central to national income and employment, with sectors gross value added (GVA) improving from 24.38% in 2015 to over 30% by 2023.

With one of the world's largest areas under cultivation, India supports a diverse range of crops, including rice, wheat, pulses, sugarcane, cotton, fruits, and vegetables (Jana et al., 2023). This has transformed the country from a food-deficient nation to a marginally food-surplus nation, now producing sufficient food, feed, and fibre for a large and growing population (Gulati, 2022). This transformation has been driven by the Green Revolution, ongoing public investment, and a series of policy initiatives aimed at improving productivity, promoting crop diversification, and increasing farmers' incomes (Hans, 2025).

The Indian government has implemented targeted programs to enhance agricultural productivity and sustainability. The 'per drop more crop' initiative for efficient water use, the National Mission for Sustainable Agriculture (NMSA), and the promotion of organic and alternative fertilisers (Gulati, 2022). Digital initiatives, the digital agriculture mission, and the e-National Agriculture Market (e-NAM) have been launched to adopt innovative technologies and enhance price discovery mechanisms (Hans, 2025). Income support schemes, Pradhan Mantri Kisan Samman Nidhi (PM-KISAN) and the provision of minimum support prices (MSP) for key crops, aim to ensure price stability and financial security for farmers (Gulati, 2022).

According to the Directorate General of Foreign Trade (2025), the Indian agricultural sector generates export revenue with annual figures from $30 billion to over USD 50 billion. But due to the fragmented nature of Indian agriculture, most farmers with small landholdings do not directly benefit from these revenues. According to Tantri & Nair (2024), smallholder farmers lack direct access to export markets, and middlemen procure produce from numerous farms, making it feasible to meet export volumes and quality standards. This enables middlemen to set prices and control market access, which is a disadvantage for primary producers.

Despite the government's support, Indian agriculture continues to face numerous challenges. Landholdings are highly fragmented, with over 86% of farmers classified as small who own less than two hectares of land, low rates of mechanisation, water scarcity in some regions, soil degradation, and the sector is vulnerable to climate change as many farmers still depend on rain for irrigation of the farmlands (Jana et al., 2023). However, the agriculture sector in India continues to be a vital engine for economic growth, poverty reduction, and food security as India moves towards 2030.

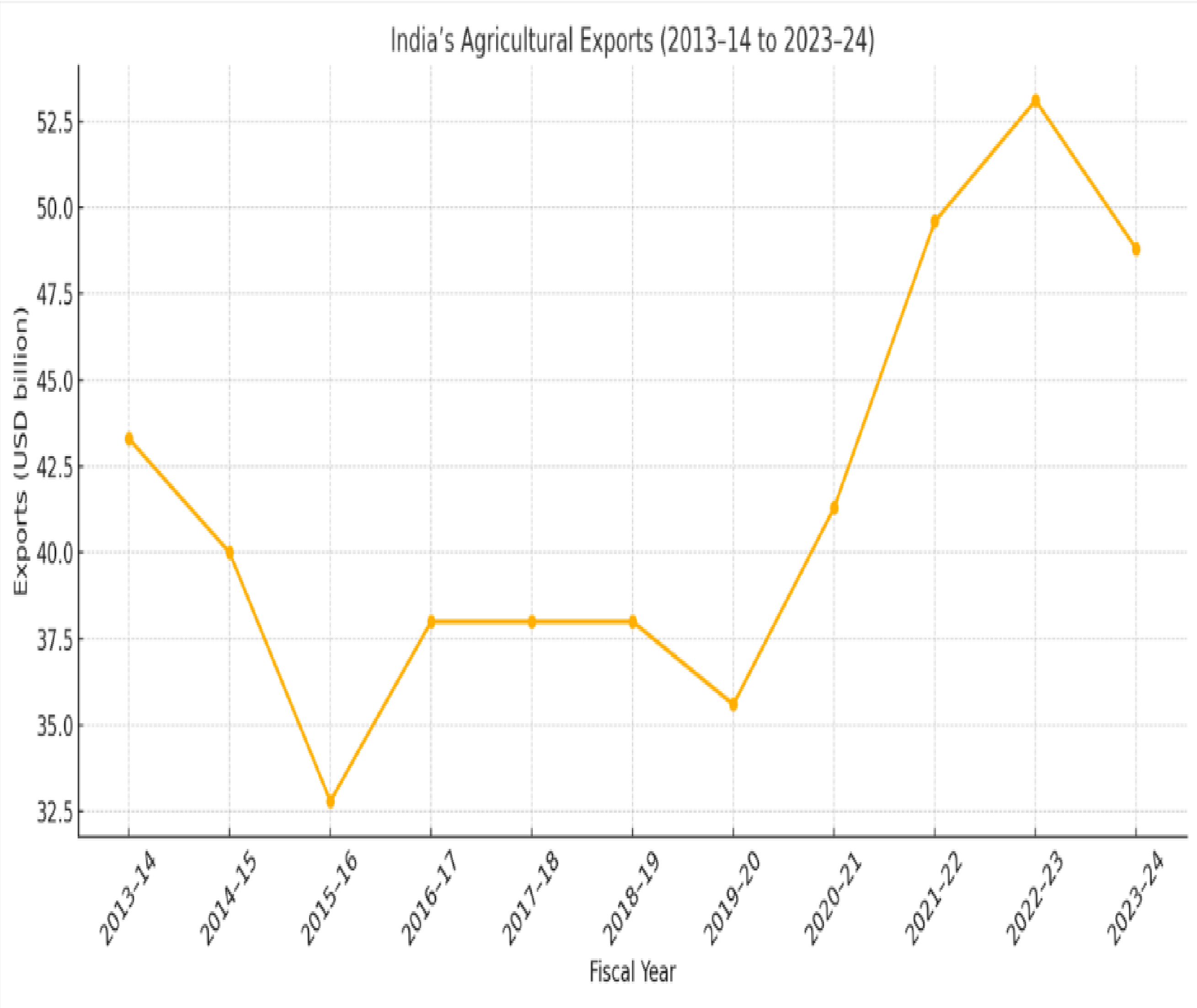

Figure 14: India's agricultural exports revenue

Source: adapted from dgft.gov.in (2025)

2.2.2 Economic conditions of farmers in India

A mix of challenges and emerging opportunities defines the economic conditions of farmers in India, creating an environment in which they are constantly exposed to risk and have a need to adopt new practices. According to a survey conducted in 2024 by McKinsey & Company (2025), a significant portion of farmers remain optimistic about their short-term prospects. The survey indicates that 76% of farmers anticipate higher profits over the next two years, primarily due to improved yields and rising crop prices. This optimism among farmers represents a sharp turnaround from previous years, indicating both recovery from disruptions and increased adoption of new products and services, such as bio-based inputs and digital payment systems. However, adoption of digital technologies remains limited, especially when the return on investment is unclear.

Income inequalities among the smallholder farmers remain a significant challenge. According to Ramachandran & Rawal (2010), annual per capita income for smallholder households varies widely, from as low as INR 6,167 in certain areas in Uttar Pradesh to INR 31,005 in Karnataka, with only a few states like Punjab and Gujarat reporting relatively higher earnings, they also says that many small farmers despite low earnings continue to do farming, this is due to the lack of alternative employment options outside agriculture. When available, these alternatives tend to be low-paying and insecure, underscoring the incomplete nature of structural transformation in rural India and the depressed state of rural wages.

Climate change and environmental changes are increasingly undermining farm incomes. Increasingly erratic rainfall patterns, heatwaves, and extreme events have led to notable declines in the yields of staple crops such as wheat and rice. For example, the intense heatwave in March 2022 resulted in a substantial reduction in wheat production, while inconsistent monsoon patterns have caused significant fluctuation in rice output. These climatic disruptions not only diminish farm income but also contribute to rising food prices, placing a significant burden on the poorest households (Farmonaut, 2025).

Post-harvest losses continue to be a significant drain on farmers' earnings. According to Kader (2005), Inadequate and poor post-harvest infrastructure, such as cold storage and transportation, leads to significant losses, with 20- 30 % of perishable produce being lost annually. This not only reduces potential income but also increases market volatility and discourages investment in high-value crops and farm technologies (Farmonaut, 2025).

Many farmers engage in income diversification and risk management by keeping livestock and participating in allied activities. In many regions, three-fourths of smallholder families own livestock, generating an additional INR 10,000 to INR 15,000 per month, while a significant share also participates in horticulture. This diversification is crucial for smoothing income during crop failure and market volatility (Yadav & Singh, 2024).

Finally, despite the country's economic growth, the share of the workforce in agriculture has increased in recent years, rising from 44.1% in 2017 to 46% in 2024. This shows the ongoing challenge of creating quality jobs outside agriculture and the reliance of rural households on farm-based livelihoods (Down to Earth, 2025).

2.2.3 Potato farming in India

Potatoes in India are a significant crop in the country's horticulture sector, with a large scale and considerable economic importance. India is the second-largest producer of potatoes in the world, with 60.18 million tonnes of potatoes produced in the 2024-25 crop year, up from 57.05 million tonnes in the previous year. This surge in production is due to the dedication of farmers, advances in scientific research, and supportive government policies, with potatoes playing a crucial role in stabilising vegetable prices (Indian Potatoes, 2025).

Potato farming in India is carried out across a wide range of agro-climatic zones. The crop is grown in multiple seasons, namely Rabhi (winter), Kharif (monsoon), and summer. Uttar Pradesh, West Bengal, and Bihar account for nearly 70% to 75% of the national output, while smaller shares are grown in plateau and hill regions (Pandey et al., 2018).

India's potato sector is marked by adaptability, with cultivation spanning lowland plains, plateaus, and hills, and occurring in summer, autumn, and winter seasons. According to Pandey et al. (2018), the Central Potato Research Institute (CPRI) has classified the country’s potato-growing regions into eight agroclimatic zones: North-Western Plains, North-Central Plains, North-Eastern Plains, Plateau Regions, North-Western Hills, North-Eastern Hills, Southern Hills, and Eastern Hills. Popular varieties, such as Kufri Bahar, Kufri Badshah, Kufri Pukhraj, and Kufri Jyothi, cover approximately 70% of the potato area. Farmers select these varieties based on factors such as farm size, region, and market demand (Pandey et al., 2018).

Potato consumption in India is mainly driven by domestic consumption. Potatoes are a staple in Indian diets, consumed in a wide variety of forms and serving as an affordable source of nutrients for millions (Pandey et al., 2018). Although exports of potatoes, whether fresh, frozen, or chilled, generate a significant amount of revenue, it is relatively small in comparison. According to the Directorate General of Foreign Trade (DGFT) (2025), India exported approximately $102 million worth of potatoes to countries such as Nepal, Bangladesh, and others, including Oman, Saudi Arabia, and Indonesia, in 2023.

Despite significant achievements, such as overall production improvements, India’s average yield remains around 24 to 26 tonnes per hectare, which is below the global average yield. This is due to the limited adoption of mechanisation, suboptimal input usage, and post-harvest losses (Ahmad et al., 2023). According to the Directorate of Economics and Statistics (2025), Uttar Pradesh lead in production and area, but has a lower yield per hectare, reaching only 24 tonnes per hectare. At the same time, states like Gujarat, Punjab, and West Bengal have yields per hectare reaching 29.77, 34.01, and 34.01, respectively. This is the case because these states have a more suitable climate for potato production, good seed quality, better infrastructure, such as irrigation systems and cold storage (Gupta, 2012).

Mechanisation in potato farming is limited, but it is advancing slowly in many states. According to Joe Lilly Bovas (2022), tractor-drawn planters, diggers, and semi-automated machinery are increasingly used in India, reducing labour requirements and improving operational efficiency. However, mechanisation levels are still low, with smallholders often relying on manual labour due to fragmented landholdings and a lack of capital investment.

Precision agriculture tools are becoming attractive to Indian potato farmers as they seek to boost productivity and enhance overall profitability. The Indian potato sector has seen gains in production through improvements in irrigation and seed quality; however, average yields remain below the global average, highlighting the need for further technological advancements (Pandey et al., 2018; Ahmad & Sharma, 2023). One avenue is the adoption of precision agriculture (PA), which is well-suited to Indian potato farming, aiming to improve management practices by optimising inputs and maximising productivity to cater to specific field requirements (Mondel & Basu, 2009).

A component of PA is the Yield Monitoring System (YMS). The YMS has improved yield estimation and resource allocation, providing accurate, site-specific yield data that supports better decision-making in potato farming (Mulla, 2013). YMS has several barriers, which make it less appealing to potato farmers in India. These barriers include high equipment costs, a lack of technical expertise, and the need for compatible mechanisation, all of which continue to limit the adoption of YMS among smallholders (Kumar et al., 2020).

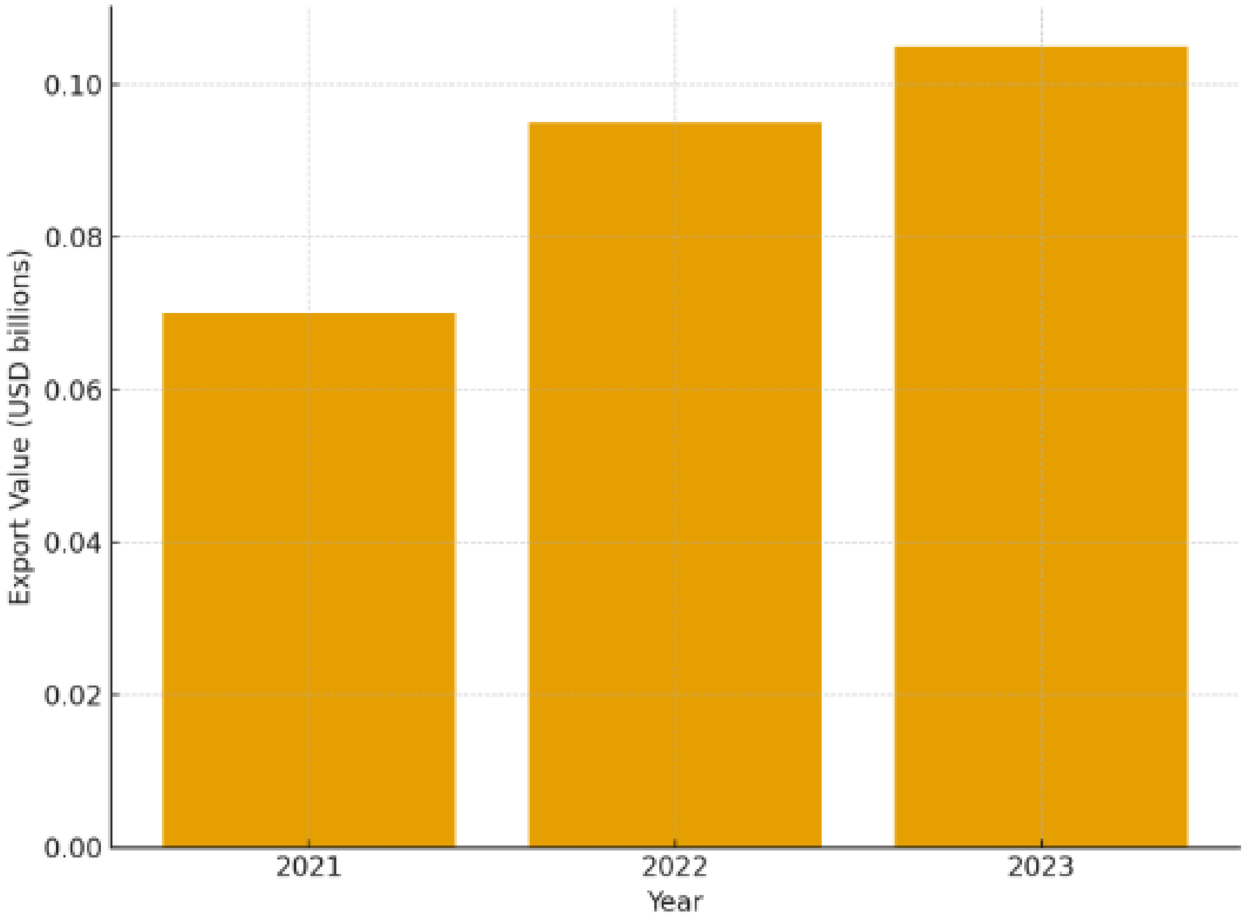

Figure 15: India's potato exports from 2021 to 2023. source: adapted from dgft.gov.in (2025)

2.2.3.1 State-wise Potato production and yield in India

India is one of the world's leading producers of potatoes. Potato production in India is widespread across the country, but a handful of states benefit from favourable agroclimatic conditions and established irrigation infrastructure. Over 90% of the country's potato output comes from six states: Uttar Pradesh, West Bengal, Bihar, Gujarat, Madhya Pradesh, and Punjab.

Uttar Pradesh is the largest potato-producing state in the country, leading both in area under cultivation and total potato production, with approximately 600,000 hectares and 20.1 million tonnes (FreshPlaza, 2024). The state's favourable climate and adoption of high-yielding varieties, such as Kufri Chandramuki, Kufri Sindhuri, Kufri Chipsona, and Kufri Jyoti, enable an average yield of 20 to 25 tonnes per hectare. Uttar Pradesh serves both the table and processing markets (TractorKarvan, 2024).

West Bengal is the second-largest potato-producing state, with 500,000 hectares under cultivation, producing 14 million tonnes of potatoes, which yields an average of 25 to 30 tonnes per hectare(TractorKarvan, 2024). The state features varieties such as Kufri Joyti, Kufri Chandramuki, and Kufri Sindhuri, which are sold to fresh markets and local processors (Jain Irrigation Systems Ltd,2021)

Bihar is India's third-largest potato-producing state, with 320,000 hectares under cultivation, producing approximately 8 million tonnes of potatoes annually, with average yields ranging from 25 to 30 tonnes per hectare (CIMMYT, 2024). Popular varieties include Kufri Chipsona, widely grown for processing; Kufri Sindhuri; Kufri Jyoti; Kufri Pukhraj; and the local, red-skinned variety, Bhura aloo. This state serves both the table and processing markets (Indian Potato Team, 2024).

Gujarat is one of the central potato-producing states in India, with 150,000 hectares under potato cultivation, producing between 3 and 5 million tonnes of potatoes annually. The average yield in Gujrat is around 30 to 35 tonnes per hectare. Gujarat is a hub for potato processing industries. The state is known for its high-quality seeds. This state serves both the table and potato processing markets (IPRC, 2025).

Madhya Pradesh has an area of approximately 1500,000 hectares under potato cultivation, producing around 4.5 million tonnes per year. The average yield in Madhya Pradesh is around 20 to 25 tonnes per hectare. Major varieties grown include Kufri Bahar, Kufri Jyoti, Kuri Pukhraj, and Kufri Chipsona. This state supplies potatoes to both the table consumption and processing markets (Indian Potato Team, 2024).

Lastly, the state of Punjab has approximately 120,000 hectares of potato cultivation land, producing around 3.3 million tonnes of potatoes per year, with average yields ranging from 20 to 25 tonnes per hectare. Varieties grown popularly are Kufri Jyoti, Kufri Pukhraj, Kufri Badshah, Kufri Chipsona, and Diamant. Punjab is renowned as the “seed bowl of India”, with approximately 60% of its potato output dedicated to seed production, supplying neighbouring states as well as countries (Indian Potato Team, 2024).

State	Table/fresh market(t/ha)	Processing (Chips/Fries) (t/ha)	Seed (t/ha)
Uttar Pradesh	20 -25	25 -30	20-25
West Bengal	25 -30	22 -28	18 to 22
Bihar	25-30	26 -34	18 - 22
Gujarat	30 -35	30-35	22 - 30
Madhya Pradesh	28 -32	24 - 28	20 - 25
Punjab	27 -28	27-34	20-22

Table 2: State-wise yields and segmentation

source: adapted from Directorate of Economics and Statistics (2025)

2.2.4 Government policies on potato farming in India

Government policies have significantly influenced the growth of potato farming in India. This was achieved through seed development, research, market support, and infrastructure development. Policy attention to potato farming in India intensified during the Green Revolution, with a focus mainly on cereals. But the establishment of crop-specific institutions marked a crucial point. The Central Potato Research Institute (CPRI) was established in 1949 under the Indian Council of Agricultural Research (ICAR), making significant contributions to the breeding of high-yielding, disease-resistant potato varieties (., 2017).

According to Acharya and Kumar (2015), during the 1970s and 1980s, national seed production and distribution schemes included potatoes in certified seed programs, which laid the groundwork for future programs, such as the Technology Mission on Horticulture (1988).

Currently, a series of national-level policies and schemes have been implemented directly in the potato sector. Operation Greens is focused on tomatoes, onions, and potatoes. This scheme aims to stabilise prices through value chain development, farmer-producer organisations (FPOs), and cold chain investment (Ministry of Food Processing Industries, 2022). Another scheme is the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY), a scheme that supports irrigation expansion and Efficiency, indirectly benefiting potato cultivation, which is highly water-sensitive (Rao et al., 2020). These programs operate through a combination of central funding, state administration, and institutional support. But the gap in last-mile delivery and inter-agency coordination remains a significant constraint (Kumar et al., 2022).

There are also state-level initiatives, such as Uttar Pradesh, Bihar, and West Bengal, which are the largest potato-producing states, that have adopted region-specific interventions. Uttar Pradesh provides seed subsidies to incentivise the use of certified seeds among small landholding farmers, aiming to enhance productivity and quality (Department of Agriculture, Government of UP, 2021). Odisha launched a dedicated cold storage policy (2015) with capital subsidies to attract private investment and reduce post-harvest losses (Pattnaik & Mishra, 2020). Gujarat's Precision Farming Initiative integrates ICT-based advisories and fertigation tools tailored to potato, reflecting state-led innovation (Deshmuckh et al., 2019).

Institutions like CPRI, ICAR, and SAUs (State Agricultural Universities) drive technological innovation in potato farming. These institutions research and develop climate-resilient and region-specific seed varieties (ICAR, 2021). Krishi Vigyan Kendras (KVKs) conduct extension work and ensure that farmers receive education, while programs under the National Innovations in Climate Resilient Agriculture (NICRA) promote adaptive agronomic practices (ICAR, 2021). According to Sharma and Jha (2021), Public-Private Partnerships (PPPs) are increasingly being leveraged under the PMKSY and Operation Greens, particularly with seed companies and cold chain developers.

Potato prices in India are highly volatile due to seasonal oversupply, perishability, and a lack of market intelligence; these price crashes are common, especially in states such as Uttar Pradesh, West Bengal, and Bihar (Mishra & Rajan, 2019). To address this, the government introduced mechanisms such as the Market Intervention Scheme (MIS) and the Price Support Scheme (PSS), which provide procurement and buffer stock options, particularly during periods of stress (NABARD, 2022).

Apart from production, policies such as the Kisan Credit Card (KCC) and the PM Fasal Bima Yojana (PMFBY) for crop insurance, as well as schemes for Scheduled Castes (SC) and Scheduled Tribes (ST), target inclusive growth (Bera & Sahu, 2021). On the environmental side, the government support for organic potato production (Via PKVY) and climate adaptation (via NMSA) is increasing (Ravindrenath et al., 2022).

Chapter 3: Literature Review

This chapter examines the significance of potato cultivation in global and national food systems, highlighting the crop's importance in both income generation and food security. It explores the benefits of yield monitoring systems as a component of precision agriculture and how these technologies transform traditional farming practices. Finally, evaluate the economic models used in existing studies to determine the financial viability of similar systems and identify areas for further research.

3.1 The role of potato farming in food security

Potato is recognised in the literature as an important crop for enhancing food and nutritional security. With a high yield per unit of input and a short growing cycle, potatoes provide more calories per hectare than most staple cereals, making potatoes a significant crop for tackling hunger and malnutrition (FAO, 2022; Scott, 2021). Its adaptability to various agroclimatic conditions strengthens its role in diversified farming systems globally (Tadesse et al., 2025).

A central physiological characteristic underpinning the potato's contribution to food security is its exceptionally high harvest index (HI), the proportion of total biomass allocated to the economic yield. Potatoes demonstrate some of the highest HI values among field crops, commonly ranging from 0.70 to 0.85 under favourable conditions (Mackerron & Jefferies,1989; Belanger et al., 2001). Empirical studies confirm this pattern; for example, Mazurczyk et al. (2009) reported HI values between 0.70 and 0.80 across different nitrogen and water supply regimes, highlighting that even under variable environmental and nutritional conditions, a large share of the plant's biomass is consistently allocated to tubers

Potatoes have dual importance as both a food security and an income-generating crop for smallholder farmers in countries like India, as mentioned in many studies (Ministry of Agriculture & Farmers Welfare, 2023; Singh et al., 2017). In developing countries, potatoes serve as a buffer against seasonal food shortages due to their storability and potential for off-season production (Scott & Suarez, 2012).

The global significance of the potato is being increasingly discussed in terms of the adoption of precision agriculture, value chain enhancement, and sustainable intensification (Gebbers & Adanchuk, 2010). Therefore, the crop serves as an appropriate and policy-relevant case for evaluating the economic viability of yield monitoring systems in agricultural systems, such as those in New Zealand and India.

Climatic factors also play a substantial role in shaping potato yield potential and its stability across environments. Physiological research on field crops demonstrates that yield accumulation depends heavily on the duration and efficiency of solar radiation interception, which is influenced by temperature, photoperiod, and crop canopy longevity (Wilson & Jamieson, 1991). Potatoes, like many temperate crops, achieve higher yields when cooler temperatures prolong the vegetative growth period, allowing more time for radiation capture and tuber bulking. Studies by Wilson and Jamieson (1991) show that in cool-maritime environments, such as New Zealand and northern Europe, extended canopy duration enhances biomass production and thereby increases attainable yield. In contrast, in warmer regions—common across South Asia—higher temperatures accelerate crop development, shorten growth duration, and limit total biomass accumulation unless supported by irrigation and careful nutrient management.

Overall, the potato's combination of high harvest index, adaptability, short crop duration, and suitability for both subsistence and commercial markets underscores its relevance for global food systems. These physiological and agronomic characteristics also justify the crop's selection for analysing the applicability and economic viability of precision agriculture tools, including yield monitoring systems, in both developed and developing country contexts.

3.2 precision agriculture and yield monitoring systems (YMS)

Precision agriculture (PA) is a data-driven approach to farm management that aims to improve crop production and input efficiency in agricultural fields (Zhang et al., 2002). This method enables farmers to obtain site-specific data, which can be used for specific management based on real-time or georeferenced data. The principle of PA is to apply the correct input at the right place, at the right time, and in the right amount (Pierce & Nowak, 1999). PA is a cluster of technologies which includes remote sensing, geographic information systems (GIS), global positioning systems (GPS), and variable rate technology (VRT), each of which is designed to enhance decision-making on the farm (Lowenberg-DeBoer & Erickson, 2019).

Among all the precision technologies in agriculture, Yield Monitoring Systems (YMS) play a crucial role. YMS generate spatially explicit yield data during harvest. YMS uses sensors mounted on harvesters to record crop flow, moisture levels, and GPS coordinates in real-time. These datasets are then transformed into Yield maps that reflect within-field variability in production (Blackmore, 2000). YMS forms the basis for evaluating field performance, which can be used to diagnose productivity constraints and plan future actions, such as input zoning or drainage improvements (Stafford, 2000).

In potato farming, yield variability is influenced by factors such as soil texture, water availability, disease pressure, and nutrient imbalances, all of which can vary over short distances. Potatoes are susceptible to micro environmental changes, and the quality of the output, such as tuber size, skin finish, and specific gravity, has a direct impact on their market value (Martens et al., 2018). Yield monitoring is highly valuable in tuber crops, where economic returns depend not only on quantity but also on quality, which is segmented by market classes such as table potatoes and processing-grade potatoes.

Integrating YMS into potato farming enables growers to identify spatial patterns in yield that are not visible through conventional scouting or yield averages. Grisso et al. (2014) highlighted that site variability detected by YMS helps farmers adjust input applications and seed spacing to improve uniformity. Similarly, in a Canadian study, Martens et al. (2018) observed that historical yield maps enabled producers to implement site-specific potassium applications, maintaining yield while reducing input costs.

YMS data, integrated with other precision tools such as NDVI (Normalised Difference Vegetation Index) maps or electromagnetic soil surveys, supported a holistic understanding of field performance. Gebbers and Adamchuk (2010) demonstrated that multi-year yield mapping helps in managing zones and identifying underperforming field areas that require drainage, organic matter improvement, or a change in crop rotation.

The effectiveness of YMS is contingent upon digital readiness, machinery compatibility, and operator expertise. According to Mahilum et al. (2022), the full benefits of YMS are realised only when data is consistently collected, calibrated, and used in conjunction with VRT and decision support systems. This is especially critical in potato systems where inaccuracies in tuber weight estimation or equipment lag can affect yield maps and lead to flawed conclusions.

3.3 Adoption of yield monitoring systems in developed countries(New Zealand Focus)

The adoption of Yield Monitoring Systems (YMS) in developed countries, such as New Zealand, is highly influenced by farm scale, technological infrastructure, and a favourable institutional environment. A key factor underpinning New Zealand's potato productivity is its cool maritime climate, which provides optimal physiological conditions for prolonged crop growth. Field crop physiology studies demonstrate that crop yields are strongly influenced by the duration of canopy radiation interception, which is in turn controlled by temperature-mediated growth and senescence processes (Wilson & Jamieson, 1991). In cooler environments, potatoes accumulate thermal time more slowly, extending leaf area duration and allowing longer periods of tuber bulking. As a result, New Zealand often records some of the highest potato yields globally, not solely because of mechanisation or precision technologies, but also because of the climatic advantage that delays maturity, increases light interception, and enhances total biomass accumulation. This climatic advantage is further strengthened by generally high light quality, attributable to low atmospheric pollution, which increases the availability of photosynthetically active radiation. These factors collectively enable YMS to become a commercially viable and agronomically impactful tool for managing potato production at scale (Mahilum et al., 2022).

In countries like New Zealand, which operates within a highly mechanised environment, creating optimal conditions for digital integration is crucial. Commercial potato farms, particularly in Canterbury, Pukekohe, and Manawatu, typically exceed 100 hectares (Potatoes New Zealand, 2023). The Benefits of YMS adoption in New Zealand are well documented. Mahilum et al. (2022) observed a yield increase of 14 to 18% and a reduction in input costs of 10 to 15% due to the implementation of improved nutrient zoning and seed distribution strategies. These results are similar to those of McBrantney et al. (2005), who noted that precision agriculture, when combined with accurate yield maps, enhances the marginal productivity of inputs, particularly nitrogen in root crops. Similarly, Shockley et al. (2012) found that integrating YMS with variable-rate application (VRA) systems reduces the payback period to as little as 2 years under favourable field conditions.

Yield data can also improve post-harvest efficiency. According to Sinton et al. (2024), Otago growers using a real-time grading system experienced a 12% reduction in tuber loss. Meanwhile, Lowenberg-DeBoer and Erickson (2019) noted that improved classification accuracy leads to enhanced price segmentation. In New Zealand, this is particularly valuable, as premium export markets demand higher tuber uniformity and traceability (Plant & Food Research, 2022). Martens et al. (2018) also supported their earlier findings, noting that real-time yield data reduces segregation costs and improves quality-based returns.

Institutional support has played an important role. The Sustainable Food and Fibre Futures Fund (SFFF), administered by MPI, provides innovation support through co-funding to lower the barriers to YMS adoption (MPI, 2022). These subsidies are supported by in-field demonstrations, digital readiness assessments, and cost-benefit calculations offered by Potatoes New Zealand and Food Research.

The teamwork of hardware and software systems makes precision agriculture more accessible in New Zealand. Potato farms already operate GPS-enabled harvesters compatible with YMS add-ons and mapping tools (CropLife NZ, 2023). Software such as FARMAX, Agworld, and CropX enables real-time visualisation, while mobile dashboards reduce data lag between harvest and decision-making (Zang, 2022).

Economic outcomes vary by farm size and operator capacity, despite all these advantages. Mahilum et al. (2022) reported that farms under 40 hectares found it hard to justify the upfront cost unless they used cooperative machinery pools or accessed custom hiring services. A similar study done by Schimmelpfenning (2016) found that in the US Midwest, small farms benefited only when supported by a strong extension system and shared infrastructure.

The adoption of YMS in the New Zealand potato sector is driven by advantages such as large-scale farming, technical compatibility, and institutional support. Economic outcomes, such as reduced input use, higher yields, lower post-harvest losses, and price differentiation, as demonstrated in several studies, show that YMS technology is viable. However, these benefits are made possible by digital literacy, interoperability, and access to co-sharing machines. New Zealand thus provides a reference model for high-efficiency, economically viable deployment of YMS in developed farming contexts.

3.4 Adoption of yield monitoring systems in developing countries (India focus)

In developing countries such as India, the adoption of yield monitoring systems (YMS) in potato farming remains limited, primarily due to low mechanisation, small farm sizes, and high initial costs (Kumar et al., 2020; Mondel et al., 2009).

The Agriculture census of India (2021) stated that over 86% of farmers in the country are smallholders managing less than two hectares of land. Most Indian potato farmers fall into this category. This makes large-scale capital investments in equipment like YMS economically infeasible at the individual level. In many Indian districts, harvesting is still done manually or with semi-mechanical diggers. According to a report by the Indian Council of Agricultural Research (ICAR, 2023), less than 15% of potato farms use mechanised harvesters, creating a gap between available equipment and digital agriculture tools. Efforts have demonstrated that YMS can be economically viable when deployed through shared ownership models or custom hiring centres (CHCs). Mehta et al. (2021) conducted a case study in Punjab and Uttar Pradesh, where CHCs equipped with GPS-based yield monitors were made available to farmers on a pay-per-use basis. They found that farmers experienced yield increases of 6-9% and input cost savings of 5-7%, with the payback period of the technology dropping from over 6 years in individual ownership models to under 3 years in the shared use model.

Similar results were seen when a producer organisation and a farmer cooperative attempted to adopt a collective YMS model. According to NABARD (2024), in Andhra Pradesh, a Farmer Producer Organisation (FPO) piloted a GPS yield monitoring system on 20 member farms, covering a total of 50 hectares. By pooling harvest data and jointly procuring inputs, the group was able to cut costs by 12% and increase gross margins by 10% in just one season. These results show that cooperative approaches enhance the economic viability of YMS.

Another barrier to the adoption of YMS is the absence of localised YMS calibration software. Most available systems are imported and designed for temperate climates, which differ from the high-density planting and loamy soils typical in Indian potato regions. Without region-specific algorithms, yield maps often misrepresent field variability, reducing their practical value and weakening farmer trust (Singh & Kumar, 2019).

Government policy in India attempted to support the adoption of smart farming through programs like the Sub-Mission on Agriculture Mechanisation (SMAM) and the Digital Agriculture Mission, which offer subsidies on precision tools, including GPS units and digital sensors. However, these programs have suffered from inconsistent implementation across states and a lack of support services for installation and training (Prsindia, 2025). According to Kumar et al. (2020), farmers who received subsidised equipment under pilot schemes in Bihar and West Bengal were unable to interpret yield maps or use them in future crop planning due to a lack of training. As a result, the utilisation rate of the installed system was less than 30%, severely limiting economic returns. This suggests that without strong extension services and digital training, the theoretical benefits of YMS do not materialise.

3.5 Economic Evaluation and Cross-Country Comparisons in Yield Monitoring Systems

Evaluating the economic viability of yield monitoring systems (YMS) requires metrics that consider monetary benefits and long-term gains. Commonly used tools include Return on Investment (ROI), Payback Period (PP), and Cost-Benefit Ratio (CBR). These tools are particularly relevant in potato farming, where decisions about YMS involve upfront costs (Lowenberg-DeBoer & Erickson, 2019; Kay et al., 2016; Shockley et al., 2012).

ROI is the most used metric to assess the profitability of yield monitoring systems, as it calculates profitability as a percentage of the initial investment. Martens et al. (2018) and Mahilum et al. (2022) implemented ROI as a metric to assess the profitability of YMS in potato farms. Martens et al. (2018) used ROI to indicate that YMS yielded a positive ROI when paired with variable-rate fertilisation in Canada. In contrast, Mahilum et al. (2022) found that in New Zealand, the implementation of YMS on a large potato farm resulted in ROI values of 15 to 20% within two years.

The payback period (PP) measures how long it takes to recoup the initial investment from the returns generated and is widely used in evaluating the short-term financial feasibility of YMS (Shockley et al., 2012). Potatoes New Zealand (2023) reported that a typical PP of 2to 3 years for YMS in potato farming, and Lowenberg-DeBoer (2019) found that PP under 3 years is more likely to be adopted by farmers.

CBR is commonly used in developing country assessments, where it is employed in economic evaluations that compare the total benefits of a technology or intervention to its total associated costs. A CBR greater than 1.0 indicates that the investment is profitable; a ratio below 1.0 suggests that the investment is not economically viable. CBR is relevant in developing countries as they assess technologies promoted through government or donor programs, where profitability is influenced by the external support structure (Szott & Motamed, 2024). In potato farming in India, Singh and Kumar (2019) utilised CBR for the implementation of a GPS-enabled plantation system and found that the CBR was 1.42.

The economic performance of developed and developing countries varies drastically, mainly due to differences in farm size, access to machinery, and policy environments. Shockley et al. (2012) reported that in the US, YMS paid off within a three-year time in grain production, especially when paid with technical support and variable rate technology. At the same time, Zhang et al. (2016) found that in China, adoption was dependent on cooperative extension services and digital readiness more than profitability. In India, challenges such as fragmented land, limited access to technical support, and the economic situation of potato farmers make the adoption of YMS difficult (Mehta et al., 2021).

Overall, the academic literature suggests that ROI, CBR, and PP were frequently used to assess the viability of the YMS.

3.6 Conclusion

Precision agriculture technologies are well-integrated and financially rewarding in advanced agricultural systems, such as those in New Zealand. However, their adoption remains limited in developing countries, such as India, due to a complex interplay of economic, infrastructural, and institutional barriers. This chapter highlights a key research gap: a standardised metric-based comparison of YMS adoption across countries using financial tools is lacking. Given this gap, the present study aims to contribute a comparative economic analysis of yield monitoring systems in New Zealand and India, applying standardised financial performance indicators. By situating its analysis within the broader context of existing literature, this thesis aims to address this gap by applying a comparative economic evaluation of YMS in potato farming in New Zealand and India, using ROI, PP, and CBR.

Chapter 4: Methodology

4.1 Research design

A comparative quantitative research design is employed to evaluate the economic viability of yield monitoring systems (YMS) in potato farming across two contrasting agricultural economies: New Zealand and India. The research utilises established methodologies commonly used in the field of precision agriculture and farm-level economic analysis (Lowenberg-Deboer & Erickson, 2019; Shockley et al., 2012).

This study utilises secondary data and financial evaluation metrics, namely Return on Investment (ROI), Cost-Benefit Ratio (CBR), and Payback Period (PP), to assess the profitability of YMS adoption. These are widely used in the literature as tools to evaluate the financial viability of farm technologies (Mahilum et al., 2022; Martens et al., 2018). The analysis is built upon existing studies, official statistics, and reports from government bodies, industry organisations, and academic sources to ensure real-world relevance (Poatoes New Zealand, 2024; NABARD, 2024; Kumar et al., 2020).

This study focuses on three major potato-producing regions in New Zealand: the Manawatu, Canterbury, and Pukekohe regions. The six central potato-producing states in India are Uttar Pradesh, Bihar, Madhya Pradesh, West Bengal, Gujarat, and Punjab. These locations were selected based on their significant contribution to the total national potato output in both countries.

4.2 Data Collection

The study utilises secondary data from national agricultural databases, institutional reports, and peer-reviewed literature. This approach was selected due to the inaccessibility of primary farm-level data in India and data confidentiality issues in New Zealand. Although secondary data lacks real-time granularity, it offers reliable long-term trends and is appropriate for macro-level comparative analysis.

Data on New Zealand potato farming, including potato yield statistics, production levels, and regional trends, were obtained from Potatoes New Zealand (2024). This data was used to determine industry performance, regional yield variations, and to gain an understanding of the potato supply chain in New Zealand, categorised by region. For farm-level input costsEfforts were made to obtain region-specific farm-level input cost data for potato production in New Zealand; however, detailed cost of cultivation figures at the regional level were not publicly accessible through industry or government databases. Therefore, this study adopts a standardised national estimate for potato production costs based on the Tupu.nz Potatoes Factsheet, which reports an average production cost of approximately NZD 5,000 per hectare.. Similarly, potato price data were taken from the same Tupu.nz report, which provides an indicative price range of NZD 400–700 per tonne. For this economic evaluation, a mid-range value of NZD 550 per tonne is used for all three regions. This approach allows the study to maintain comparability across regions while relying on verified and industry-endorsed benchmark values. The benefits of adopting yield monitoring systems (YMS) in New Zealand are compiled based on academic literature by Mahilum et al. (2022) and McBrantney et al. (2005), who analysed the economic implications of adopting YMS in New Zealand.

Data for Indian potato farming, including regional yield data and total production, were obtained from the Ministry of Agriculture and Farmers Welfare (MoAFW, 2023) and the National Horticulture Board (NHB, 2024). These data sources provided a state-level breakdown across central potato-growing states in India. Input costs, such as seed, fertilisers, pesticides, irrigation, and labour, were derived from the Commission for Agricultural Costs and Prices (CACP, 2023). Information about the benefits of adopting YMS was obtained from academic case studies, such as Kumar et al. (2020). This was further supported by reports from ICAR and Agritech India, which documented trials and economic outcomes of GPS-enabled yield mapping systems. Market prices of potatoes in India were collected from a combination of platforms, including AgMarket (2025), KissanDeals (2025), and CommodityOnline (2025), with a focus on the six central potato-producing states in India: Uttar Pradesh, Bihar, Madhya Pradesh, West Bengal, Gujarat, and Punjab.

4.3 Economic Evaluation Framework

Return On Investment (ROI), Cost Benefit Ratio (CBR), and Payback Period (PP). These financial metrics were used in the analysis to find out the economic viability of the yield monitoring system in potato farming, comparing New Zealand and India. For the analysis, several assumptions are made for both countries, as shown in Table 3.

In New Zealand, YMS adoption is primarily driven by individual farmers, mainly due to the large average landholdings per farmer. Adoption also happens through Grower cooperatives or service contractors. The adoption through cooperatives and contractors enables farmers to distribute the high initial investment in YMS equipment across multiple users (Caradus & Clark, 2021; Potatoes New Zealand, 2024).

India shows a dual adoption structure. While smallholder individual farmers with an average of 2 hectares may invest in subsidised variants of YMS, significant adoption potential is observed through collective adoption models involving custom hiring centres (CHCs) and farmer producer organisations (FPOs), which manage around 100 hectares (Mehtha et al., 2021).

In this study, the capital cost of a yield monitoring system (YMS) in New Zealand is assumed to be NZD 20,000, representing the estimated cost of a fully integrated package including sensors, GPS units, data logging equipment, wiring harnesses, software access, and installation services. The exact market prices of complete YMS units are not publicly available, as major suppliers such as Trimble, John Deere, and AG Leader provide pricing only through authorised dealers. However, publicly accessible listings for partial YMS components from FarmTRX (2025) indicate that basic yield monitor kits range from NZD 3,000 to 6,000, excluding GPS receivers, moisture sensors, installation, and software. Since full-system deployments typically require multiple modules and integration services, industry consultation ranges reported in precision agriculture forums and supplier catalogues commonly fall between NZD 10,000 and 25,000. Therefore, NZD 20,000 is adopted as a realistic modelling assumption representing a mid-level integrated system, and screenshots of supplier listings are included in the Appendix as supporting evidence.

In India, this study assumes a capital cost of INR 800,000 (≈ NZD 16,000) for a complete yield monitoring system (YMS) integrated with GPS-enabled harvesting machinery. As with New Zealand, the exact prices of full YMS packages are not publicly available, as Indian suppliers typically disclose pricing only through dealer networks or institutional quotations. Publicly accessible manufacturer platforms such as AgriExpo (2025) list YMS components and precision agriculture tools but do not provide comprehensive system pricing, indicating that market transparency is limited for high-technology equipment.

Available online listings for individual components—such as GNSS receivers, display consoles, moisture sensors, and data loggers—show prices ranging from INR 40,000 to over INR 300,000 per unit, depending on configuration. Integrated institutional deployments, such as those procured under government-supported Custom Hiring Centres (CHCs) and Farmer Producer Organisations (FPOs), generally require multiple modules, software licences, installation, calibration, and training. These additional services substantially increase total system cost, and extension records and technical brochures commonly cite operational ranges between INR 600,000 and INR 1,200,000 for complete precision-agriculture monitoring systems.

Given this variability, INR 800,000 is adopted as a reasonable midpoint assumption that reflects the typical investment required for an institutional-grade YMS installation rather than a minimal hardware-only setup. This value supports consistent economic modelling across adoption scenarios, and screenshots of publicly available component-level listings are included in the Appendix to demonstrate the non-disclosure of full system prices and to illustrate the cost range of individual YMS elements.

Both capital ownership and service-based access models are evaluated in this study to reflect real-world adoption scenarios in both countries.

	New Zealand	India
YMS cost	NZD 20000 (FarmTrax, 2025)	INR 800,000 (NZD 16000) (tradeindia, 2025)
YMS service cost	NZD 200/ha (MPI, 2023)	INR 2000/ha (ICAR-NAARM, 2021)
Yields increase	18 % (Mahilum et al.,(2022)	9% (Mehta et al., 2021)
Input cost reduction	15 % (Mahilum et al., 2022)	7% (Mehta et al., 2021)
Discount rate	6% (Boardman et al.,2018)	8% (Boardman et al.,2018)
Farm size	67 hectares (Curran-Cournane & Rush, 2021)	2 hectares (Agriculture census of India, 2021)
Model of adoption	Primarily Individual farmers; some adoption through cooperatives or contractors (Caradus & Clark, 2021; Potatoes New Zealand, 2024)	Individual farmer and collective models via CHC or FPO owned (Mehta et al., 2021)

Table 3: Assumptions Made on YMS

Region	Annual Yield per Hectare	Cost of cultivation per hectare	Price range per tonne
Manawatu	57	5000	550
canterbury	58	5000	550
Pukekohe	47	5000	550

Table 4: The average yield per hectare and potato prices per tonne

Source: Potatoes New Zealand; Tupu.nz

state	Seed cost (INR/ha)	Labour cost (INR/ha)	Fertiliser cost (INR/ha)	Irrigation cost (INR/ha)	Plant protection (INR/ha)	Total cost (INR/ha)
Uttar Pradesh	15,481	22,477	7,920	7,257	610	53,745
West Bengal	27,878	25,000	24,995	4,754	3000	85,567
Bihar	27,586	11,015	6,260	4,526	2800	52,187
Gujarat	22,626	19,149	INR 8,248	INR 6,837	INR 3,660	60,520
Madhya Pradesh	22,626	15,850	8,700	6,475	3,450	57,101
Punjab	33,167	14,337	8,250	7,905	2,400	66,059

Table 5: India Potato Cultivation State-wise input costs

Source: adapted from desagri.gov.in(2025)

State	Annual Yield per hectare	Potato price per ton
Uttar Pradesh	20	INR 12000
West Bengal	22	INR 19000
Bihar	25	INR 11000
Gujarat	30	INR 12700
Madhya Pradesh	24	INR 11500
Punjab	34	INR 16000

Table 6: State-wise yield per hectare and potato price per tonnes.

Source: adapted from desagri.gov.in (2025); commodityOnline (2025); KisanDeals (2025); CEIC (2025)

4.3.1 Return On Investment

Return on Investment (ROI) is a financial metric used to calculate the profitability of an investment to its cost. In this study, ROI is used to evaluate the economic return from adopting yield monitoring systems (YMS) in potato farming by comparing the financial benefits from yield improvements and input cost savings with the cost of the YMS technology.

ROI = [(Yield Gain + Input Savings) - Cost of YMS Per Hectare] / Cost of YMS Per Hectare × 100

Yield gain is the increase in yield resulting from improved farm management enabled by spatial data collected through YMS. (Basso & Antle,2020)

Input savings refer to the reduction in production costs resulting from the use of inputs such as fertilisers, seeds, irrigation, pesticides, and labour costs (Pierpaoli et al., 2013; Finger et al., 2019).

This formula shows the net benefit (monetary gains minus costs) of adopting YMS as a proportion of the total investment. A positive ROI indicates that the adoption is financially viable, while a negative ROI suggests losses (Shockley et al., 2012; Mahilum et al., 2022; Lowenberg-DeBoer & Erickson, 2019).

4.3.2 Cost-Benefit Ratio (CBR)

The cost-benefit ratio is used to compare the total discounted benefits of an investment to its costs, helping assess whether a project or technology adoption is economically justified. A CBR value greater than 1 suggests that the investment gives positive net benefits, while a value less than 1 suggests a net loss (Boardman et al., 2018)

CBR = Present Value of Total Benefits ÷ Total Investment Cost of YMS Per Hectare

For constant annual benefits, future benefits must be discounted to their present value because money received in the future is worth less than money today. The present Value (PV) is calculated using the formula for the present value of an ordinary annuity.

$$\text{present value} = \sum_{t=1}^{n} Annual\ benefits \div (1+r)^{t}$$

$$present\ value\ of\ total\ benifits\ = Annual\ Benefits\ \times \frac{1-(1+r)^{-n}}{r}$$

Where,

Annual benefits = Revenue from Yield Gains + Input Cost Savings

r = Discount rate

n = Number of years in the analysis period

4.3.3 Payback period (pp)

The payback period is used to determine the length of time required for the benefits generated by an investment to recover its initial cost. It is a widely applied tool in farm management and agricultural technology evaluation to assess the investment recovery period (Kay et al., 2016).

PP = cost of YMS Per Hectare ÷ Annual net benefit of YMS Per Hectare

Where

The Cost of YMS is the capital investment or the service fee per hectare, according to the model of adoption.

4.4 limitations

The methodology in this study provides a structured evaluation for the economic viability of yield monitoring systems (YMS) in potato farming; several limitations must be acknowledged that may affect the precision, generalisability, and applicability of the findings.

This study is based entirely on secondary data sources, including government publications, institutional reports, and peer-reviewed academic literature. These sources are widely used in agricultural research, but they do not fully capture the field-level differentiation in farming practices, soil conditions, market volatility, and technology performance (Makridakis et al., 2018; FAO, 2019). The lack of primary data collection, such as interviews, surveys, or field trials, limits the ability to incorporate honest feedback from farmers or region-specific challenges linked to YMS.

The analysis depends on the set of standard assumptions regarding yield increase, input cost savings, farm size, and investment costs, these assumptions were derived from previous studies and national level averages, they do not fully account for variability across farming ecosystems, social and economic status or institutional support systems (Mondal & Basu, 2009; Finger et al., 2019). In India, the responsiveness to input and benefits from technology adoption differ significantly based on landholding size, access to services such as education and extension, digital literacy, irrigation infrastructure, and supply and cold chain infrastructure (Kumar et al., 2020; Mehta et al., 2021). Modern YMS solutions have lower entry prices; the chosen estimates include integrated systems, such as sensors, GPS receivers, data loggers, software, calibration support, and training. These values remain useful for comparing economic modelling but may not represent all possible real-world procurement scenarios in either country.

This study used a fixed five-year time horizon and constant discount rates for both countries' YMS economic evaluation, which may not reflect the real-world differences and fluctuations in costs and returns. Agricultural markets are very volatile, and input and output prices change significantly due to external factors such as climate events, trade disruptions, or government policy changes (Boardman et al., 2018; Kay et al., 2016)

Another limitation is the simplification of adoption models. While the study distinguishes between individual and collective (CHC or FPO) adoption models, implementation in reality may involve both arrangements, such as leasing equipment, contract services, or community-based machinery rings (Barmes et al., 2019; Caradus & Clark, 2021).

This study focuses on economic indicators, namely ROI, CBR, and PP, without considering environmental or sustainability factors. Precision agriculture, such as YMS, reduces nutrient runoff, improves water usage efficiency, and lowers greenhouse gas emissions, all of which are critical to long-term agricultural sustainability (Basso & Antle, 2020; Schimmelpfenning, 2016). The study only assumes an initial capital investment for YMS adoption in the individual farmer adoption model and service costs for YMS adoption in the CHC or FPOs adoption model, without accounting for depreciation, maintenance, or upgrades. In reality, high upfront costs and a lack of technical knowledge constrain adoption (Pierpaoli et al., 2013; Kutter et al., 2011). The learning period required to use YMS tools and interpret special yield data effectively is not factored into the cost structure.

The results presented in this study are indicative rather than prescriptive. They give a comparative economic perspective based on available secondary data, but must be contextualised within broader agronomic, institutional and economic frameworks.

Chapter 5: Results

5.1 New Zealand – Individual Farmer Adoption Model

This section presents the economic evaluation of Yield monitoring systems (YMS) for Individual farmer adoption in New Zealand across three major potato-growing regions: Manawatu, Canterbury, and Pukekohe. ROI, CBR, and PP were calculated separately for each region using input costs, yields per hectare, and the assumptions made in Chapter 4. The calculations for ROI, CBR, and PP are shown in detail in the appendix section.

5.1.1 Return on Investment (ROI)

ROI = [(Yield Gain + Input Savings) - Cost of YMS Per Hectare] ÷ Cost of YMS Per Hectare × 100

Region	Yield Increase (t/ha)	Input savings (NZD/ha)	Total benefits (NZD/ha)	Cost of YMS/ha (NZD/ha)	ROI (%)
Manawatu	10.26	750	6,393	298	2,042
Canterbury	10.44	750	6,492	298	2,075
Pukekohe	8.46	750	5,403	298	1710

Table 7: Summary of ROI by region – New Zealand Individual Farmer adoption of YMS

5.1.2 Cost-Benefit Ratio (CBR)

CBR = Present Value of Total Benefits ÷ Total Investment Cost of YMS Per Hectare

The present value of total benefits is calculated using the annuity formula (Boardman et al., 2018):

$$present\ value\ of\ total\ benifits\ = Annual\ Benefits\ \times \frac{1-(1+r)^{-n}}{r}$$

Where :

Annual benefits = Revenue from Yield Gains + Input Cost Savings

r = discount rate = 6%

n = 5 years

Region	**Annual benefit (NZD/ha)**	**Cost of YMS per Hectare (NZD)**	**PV of total benefits (NZD/ha)**	**CBR**
Manawatu	6,393	298	26,930	90
Canterbury	6,492	298	27,346	92
Pukekohe	5,403	298	22,759	76

Table 8: Summary of CBR by region, New Zealand individual farmer adoption model

5.1.3 Payback period (PP)

The payback period shows the number of years needed to recover the investment in YMS through annual net benefits:

PP = cost of YMS Per Hectare ÷ Annual net benefit of YMS Per Hectare

Region	Payback Period (Years)
Manawatu	0.05
Canterbury	0.05
Pukekohe	0.06

Table 9: Summary of Payback Period by Region – New Zealand Individual Farmer Adoption Model.

5.2 India – individual farmer adoption model

This section presents the economic analysis of YMS for the Individual farmer adoption model in India. ROI, CBR, and pp were calculated using the assumptions made in Chapter 4 for six Indian states: Uttar Pradesh, West Bengal, Bihar, Gujarat, Madhya Pradesh, and Punjab.

5.2.1 Return on Investment (ROI)

ROI = [(Yield Gain + Input Savings) - Cost of YMS Per Hectare] ÷ Cost of YMS Per Hectare × 100

states	Yield increase (t/ha)	Input savings (INR/ha)	Total benefits(INR/ha)	Cost of YMS/ha (INR/ha)	ROI(%)
Uttar Pradesh	1.8	3,762.15	25,363.15	400,000	− 94
West Bengal	1.98	5,989.69	43,609.69	400,000	− 89
Bihar	2.25	3,653.09	28,403.09	400,000	− 93
Gujarat	2.7	4,236.40	38,837.07	400,000	− 90
Madhya Pradesh	2.16	3,997.07	28,837.07	400,000	− 93
Punjab	3.06	4,624.13	53,584.13	400,000	− 87

Table 10: Summary of ROI by state – India Individual farmer adoption model

5.2.2 Cost-Benefit Ratio (CBR)

CBR = Present Value of Total Benefits ÷ Total Investment Cost of YMS Per Hectare

The present value of total benefits is calculated using the annuity formula (Boardman et al., 2018):

$$present\ value\ of\ total\ benifits\ = Annual\ Benefits\ \times \frac{1-(1+r)^{-n}}{r}$$

Where :

Annual benefits = Revenue from Yield Gains + Input Cost Savings

r = discount rate = 8%

n = 5 years

States	Annual Benefits(INR/ha)	Cost of YMS per hectare(INR)	PV of total benefits (INR/ha)	CBR
Uttar Pradesh	25,363	400,000	1,01,268	0.25
West Bengal	43,610	400,000	1,74,130	0.44
Bihar	28,403	400,000	1,13,405	0.28
Gujarat	38,526	400,000	1,53,824	0.38
Madhya Pradesh	28,837	400,000	1,15,138	0.29
Punjab	53,584	400,000	2,13,946	0.53

Table 11: Summary of CBR state-wise – India individual farmer adoption model

5.2.3 Payback period (PP)

The payback period shows the number of years needed to recover the investment in YMS through annual net benefits:

PP = cost of YMS Per Hectare ÷ Annual net benefit of YMS Per Hectare

Region	Payback Period (Years)
Uttar Pradesh	15.77
West Bengal	9.17
Bihar	14.08
Gujarat	10.38
Madhya Pradesh	13.87
Punjab	7.46

Table 12: Summary of Payback Period State-wise – India Individual Farmer Adoption Model.

5.3 New Zealand Cooperative or Service-Based Adoption Model of YMS

This section presents the economic evaluation of YMS for cooperative or service-based adoption in New Zealand across three major potato-growing regions: Manawatu, Canterbury, and Pukekohe. ROI, CBR, and PP were calculated separately for each region using input costs, yields per hectare, and assumptions made in Chapter 4.

5.3.1 Return on Investment (ROI)

ROI = [(Yield Gain + Input Savings) - Cost of YMS Per Hectare] ÷ Cost of YMS Per Hectare × 100

Region	Yield Increase (t/ha)	Input savings (NZD/ha)	Total benefits (NZD/ha)	YMS service cost /ha (NZD/ha)	ROI (%)
Manawatu	10.26	750	6,393	200	3,096
Canterbury	10.44	750	6,492	200	3,146
Pukekohe	8.46	750	5,403	200	2,601

Table 13: Summary of ROI by region – New Zealand Cooperative or Service-Based Adoption Model

5.3.2 Cost-Benefit Ratio (CBR)

CBR = Present Value of Total Benefits ÷ Total Investment Cost of YMS Per Hectare

The present value of total benefits is calculated using the annuity formula (Boardman et al., 2018):

$$present\ value\ of\ total\ ben\,ifits\ = Annual\ Benifits\ \times \frac{1-(1+r)^{-n}}{r}$$

Where :

Annual benefits = Revenue from Yield Gains + Input Cost Savings

r = discount rate = 6%

n = 5 years

Region	Annual benefit (NZD/ha)	YMS service cost per Hectare (NZD)	PV of total benefits (NZD/ha)	CBR
Manawatu	6,393	200	26,930	135
Canterbury	6,492	200	27,347	137
Pukekohe	5,403	200	22,759	114

Table 14: Summary of CBR by region - New Zealand Cooperative or Service-Based Adoption Model

5.3.3 Payback period (PP)

The payback period shows the number of years needed to recover the investment in YMS through annual net benefits:

PP = cost of YMS Per Hectare ÷ Annual net benefit of YMS Per Hectare

Region	Payback Period (Years)
Manawatu	0.03
Canterbury	0.03
Pukekohe	0.04

Table 15: Summary of Payback Period by Region – New Zealand Cooperative or Service-Based Adoption Model

5.4 India – Custom hiring centres (CHCs) or Farmer Producer Organisation (FPOs) YMS adoption model

This section presents the economic analysis of YMS for the CHCs or FPOs adoption model in India. ROI, CBR, and pp were calculated using the assumptions made in Chapter 4 for six Indian states: Uttar Pradesh, West Bengal, Bihar, Gujarat, Madhya Pradesh, and Punjab.

5.4.1 Return on Investment (ROI)

ROI = [(Yield Gain + Input Savings) - Cost of YMS Per Hectare] ÷ Cost of YMS Per Hectare × 100

states	Yield increase (t/ha)	Input savings (INR/ha)	Total benefits(INR/ha)	Cost of YMS/ha (INR/ha)	ROI(%)
Uttar Pradesh	1.8	3,762	25,363	2,000	1,169
West Bengal	1.98	5,990	43,610	2,000	2,081
Bihar	2.25	3,653	28,403	2,000	1,320
Gujarat	2.7	4,236	38,837	2,000	1,826
Madhya Pradesh	2.16	3,997	28,837	2,000	1,342
Punjab	3.06	4,624	53,584	2,000	2,579

Table 16: Summary of ROI by state – India Custom hiring centres (CHCs) or Farmer Producer Organisation (FPOs) YMS adoption model

5.4.2 Cost-Benefit Ratio (CBR)

CBR = Present Value of Total Benefits ÷ Total Investment Cost of YMS Per Hectare

The present value of total benefits is calculated using the annuity formula (Boardman et al., 2018):

$$present\ value\ of\ total\ benifits\ = Annual\ Benefits\ \times \frac{1-(1+r)^{-n}}{r}$$

Where :

Annual benefits = Revenue from Yield Gains + Input Cost Savings

r = discount rate = 8%

n = 5 years

States	Annual Benefits(INR/ha)	YMS service cost per hectare(INR)	PV of total benefits (INR/ha)	CBR
Uttar Pradesh	25,363	2,000	101,268	50.6
West Bengal	43,610	2,000	174,130	87.06
Bihar	28,403	2,000	113,405	56.70
Gujarat	38,526	2,000	153,824	76.91
Madhya Pradesh	28,837	2,000	115,138	57.65
Punjab	53,584	2,000	213,946	106.97

Table 17: Summary of CBR state-wise – India Custom hiring centres (CHCs) or Farmer Producer Organisation (FPOs) YMS adoption model.

5.4.3 Payback period (PP)

The payback period shows the number of years needed to recover the investment in YMS through annual net benefits:

PP = cost of YMS Per Hectare ÷ Annual net benefit of YMS Per Hectare

Region	Payback Period (Years)
Uttar Pradesh	0.07
West Bengal	0.04
Bihar	0.07
Gujarat	0.05
Madhya Pradesh	0.06
Punjab	0.03

Table 18: Summary of Payback Period State-wise – India Custom hiring centres (CHCs) or Farmer Producer Organisation (FPOs) YMS adoption model

5.5 conclusion

The economic viability of YMS in both New Zealand and the Indian potato farming sector showed significant regional and adoption model-based variation economically.

In New Zealand, the individual farmer adoption model and cooperative/service-based adoption models showed strong economic indicators in all three regions, Manawatu, Canterbury, and Pukekohe. The Return on Investment (ROI) ranged from 1,700% to 3,200%, and the Cost-Benefit Ratios (CBR) exceeded 50. The Payback period (PP) remained under 0.1 years, confirming rapid cost recovery and high profitability. Outcomes from the economic analysis suggest that, according to the assumed variables, such as input costs and the cost of YMS in Chapter 4, YMS is highly viable under both individual farmer ownership and service-based adoption models in New Zealand.

The economic viability of YMS in the six central potato farming states in India varied significantly between adoption models, depending on the assumptions made. Under the individual farmer model, the high capital cost per hectare (INR 4,00,000) resulted in negative ROI values, low CBR values (below 0.5), and extended payback periods (7 to 15 years), making individual farmer adoption in India economically non-viable in all six central potato-producing states.

When adopted through Custom Hiring Centres (CHCs) or Farmer Producer Organisations (FPOs), with a reduced service cost of INR 2,000 per hectare, the model proved highly valuable. ROI values ranged from 1,168% to 2,579%, and CBRs were all above 50%. Payback periods dropped to well below one year.

Thus, addressing the research objectives:

(a) YMS is **not economically viable** under the individual ownership model for Indian farmers, due to high equipment costs and small landholdings.

(b) YMS can be effectively adopted in India through **CHCs or FPOs**, enabling broader access to precision agriculture technologies without the financial burden of direct ownership.

These findings from the economic analysis form the basis for further discussion in Chapter 6. The implications, challenges, and recommendations for scalable adoption in India will be discussed further in the next chapter

Chapter 6 Discussion

6.1 Introduction

This chapter provides an analysis of the results shown in Chapter 5. The primary objective is to analyse the economic viability of yield monitoring systems (YMS) in potato farming within two different agricultural scenarios: developed and developing countries, specifically New Zealand and India. This analysis integrates findings from existing literature, policy, and reports from government bodies. This discussion also aims to identify factors influencing the economic viability of YMS in both countries and provide relevant recommendations for their effective implementation.

Two core questions guided the research:

a) Are the Yield Monitoring Systems used in New Zealand potato farming economically viable in the Indian potato farming sector?
b) If not, how can the yield monitoring systems be adopted in the Indian potato farming sector?

The study employed economic metrics, including Return on Investment (ROI), Cost-Benefit Ratio (CBR), and Payback Period (PP), which are commonly used to evaluate the financial aspects of agricultural technologies (Shockley et al., 2012; Lowenberg-DeBoer & Erickson, 2019). The discussion is organised into several key sections. It summarises the significant findings of the results chapter. It interprets those findings about each country's agricultural characteristics, including regional or state-level variations. Explores how collective models, such as Farmer Producer Organisations (FPOs) and Custom Hiring Centres (CHCs), enhance adoption in India. A cross-country comparative discussion, outlining the differences that explain the viability gap. The chapter evaluates whether the findings align with or diverge from the existing literature, thereby contributing to the broader discourse on the adoption of precision agriculture in both developed and developing countries. The research questions are addressed, followed by implications for farmers and policymakers, a discussion of study limitations, and suggestions for future research directions.

6.2 Summary of Key Findings

This section presents a summary of key economic findings from Chapter 5, using ROI, CBR, and PP as indicators to evaluate the financial viability of YMS in potato farming across New Zealand and India. The analysis compares both the individual adoption model and the service-based/ cooperative models.

In New Zealand, the individual and service-based adoption models showed highly favourable results. In the individual farmer adoption model (Table 20), ROI ranged from 1,710 % in Pukekohe to 2,075 % in Canterbury. The CBR followed a similar trend, with values ranging from 70 to 92. Payback periods were also notably short, ranging from 0.05 years (Canterbury) to 0.06 years (Pukekohe).

The cooperative/service-based adoption model in New Zealand (Table 22) yielded even more impressive results. The ROI increased to 3,092 % in Manawatu, 3,146% in Canterbury, and 2,601% in Pukekohe, demonstrating the effect of scale and shared machinery on profitability. CBR values exceeded 100 in all regions, with a minimum of 114 in Pukekohe. Payback Periods decreased to between 0.03 and 0.04 years. These numbers indicate that collective or contract-led models facilitate effective capital utilisation and higher returns, mainly due to New Zealand's commercial farming system.

The situation in India revealed a clear distinction between the individual and CHC/FPO (service-based) models. In the individual adoption model (Table 22), the results were financially unviable in all six studied states. The ROI was negative across all states, ranging from -86.6 in Punjab to -93.66 in Uttar Pradesh, indicating that the cost of investment outweighed the gains. CBR ranged from 0.25 (Uttar Pradesh) to 0.53 (Punjab), which is below the viable threshold of 1.0; therefore, the technology generated less than the amount invested. The payback period exceeded the viable investment years, with Uttar Pradesh showing 15.77 years, Bihar 14.08 years, and the most favourable case (Punjab) requiring 7.46 years to recover costs.

When the YMS adoption model is implemented through Custom Hiring Centres (CHCs) or Farmer Producer Organisations (FPOs) (Table 23), the economic indicators change significantly. The ROI values turned positive, with CBRs improving, ranging from the lowest at 50.6 (Uttar Pradesh) to the highest at 106.97 (Punjab). Payback periods also shortened considerably, ranging from 0.07 years in Bihar and Uttar Pradesh to as low as 0.03 years in

Punjab. These improvements are attributed to cost-sharing mechanisms and reduced financial risk taken by individual farmers.

These results indicate that YMS is economically viable under both models in New Zealand. In India, the individual adoption model is not financially sustainable under current conditions, but CHC/FPO-based models offer a scalable and profitable alternative.

Region	Return on Investment (ROI) (%)	Cost-Benefit Ratio (CBR)	Payback Period (PP)(years)
Manawatu	2,042	90	0.05
Canterbury	2,075	92	0.05
Pukekohe	1,710	76	0.06

Table 19: Summary of Results – New Zealand individual farmer adoption model

Region	Return on Investment (ROI) (%)	Cost-Benefit Ratio (CBR)	Payback Period (PP)(years)
Manawatu	3,096	135	0.03
Canterbury	3,146	137	0.03
Pukekohe	2,601	114	0.04

Table 20: Summary of Results - New Zealand Cooperative or Service-Based Adoption Model

State	Return on Investment (ROI) (%)	Cost-Benefit Ratio (CBR)	Payback period (PP)(years)
Uttar Pradesh	- 94	0.25	15.77
West Bengal	- 89	0.44	9.17
Bihar	- 93	0.28	14.08
Gujarat	- 90	0.38	10.38
Madhya Pradesh	- 93	0.29	13.87
Punjab	- 87	0.53	7.46

Table 21: Summary of Results – India Individual Farmer Adoption Model.

State	Return on Investment (ROI)	Cost-Benefit Ratio (CBR)	Payback period (PP)
Uttar Pradesh	1,169	50.6	0.07
West Bengal	2,080	87.06	0.04
Bihar	1,320	56.70	0.07
Gujarat	1,826	76.91	0.05
Madhya Pradesh	1,342	57.65	0.06
Punjab	2,579	107	0.03

Table 22: Summary of results – India custom hiring centres (CHCs) / Farmer Producer Organisation adoption model.

6.3 Economic Viability of Yield Monitoring Systems in New Zealand

In both the individual farmer adoption model and the service-based adoption model, economic indicators exceeded investment benchmarks. In the individual adoption model, the ROI ranged from 2,042% in Manawatu to 1,710% in Pukekohe, while the CBR ranged from 90 to 76. Payback periods were short, with all three regions recovering the full investment in less than 0.05 years. In the contractor or service-based adoption model, the outcomes from the analysis are even better. ROI values are 3,096% in Manawatu, 3,146% in Canterbury, and 2,601% in Pukekohe.

Several factors contribute to YMS's strong economic performance in New Zealand. New Zealand farms are generally larger than Indian farms; in regions such as Canterbury and Pukekohe, commercial farms predominate. This scale enables the reduction of fixed YMS costs at high production volumes, thereby increasing ROI and reducing PP. New Zealand potato growers already operate advanced machinery such as tractors, harvesters, and planters that are compatible with YMS add-ons. The lack of additional capital machinery reduced investment stress on the farmers (Yule, 1999; Lowenberg-DeBoer & Erickson, 2019).

New Zealand's developed extension services and technical consultants ensure effective adoption and troubleshooting of precision technologies. Support from contractors and agronomic service providers benefits data integration and efficiency. Farmers are relying on precision data for variable rate application, crop forecasting, and benchmarking. YMS connects directly to digital tools, making adoption of YMS more attractive and economically sound (Eastwood et al., 2019).

This was further emphasised in the literature on precision agriculture adoption in developed agricultural systems. Mahium et al. (2022) stated that countries with ICT infrastructure, access to a skilled advisory network, and cost-sharing mechanisms exhibit profitability in the adoption of yield monitoring systems. A study conducted by Shockley et al. (2012) showed that large farms and cooperative models enhance the financial performance of technologies like YMS.

6.4 Economic Viability of Yield Monitoring Systems in India

The viability of YMS in Indian potato farming is dependent on the model of adoption, according to the analysis. The two adoption models explored in this study are the individual farmer adoption model and the service-based adoption model, such as CHCs and FPOs. The data in Table 22 shows that the individual farmer adoption model of YMS is economically not viable across all six states: Uttar Pradesh, West Bengal, Bihar, Gujarat, Madhya Pradesh, and Punjab. The ROI is negative in the individual adoption model, ranging from –86% in Punjab to 93.66% in Uttar Pradesh. CBR ranged between 0.25 and 0.53, indicating that financial benefits from using YMS do not justify the capital investment. Payback period ranged from 7.46 to 15.77 years.

This lack of viability is due to several factors. Most Indian potato farmers cultivate less than 2 hectares of Land (Agricultural Census, 2021). A small farm area limits the scale that adequately justifies YMS economics. The farm gate prices in India are very volatile and do not reflect the cost of production. According to Commodity Online (2025), potato prices ranged from INR 10,000 to INR 20,000 per ton in the financial year 2024-2025. Indian farmers lack advisory services related to precision technologies, let alone YMS, which require calibration tools and a reliable service ecosystem to operate efficiently (Jat et al., 2020). The effective use of YMS depends on the farmer's knowledge to interpret the Geo-referenced yield maps and make agronomic decisions in the absence of proper advisory services. According to Rao et al. (2017), the lack of digital literacy among Indian farmers in rural India is a significant barrier to the adoption of YMS.

These issues, along with the economic analysis, suggest that the Individual adoption model of YMS in India is not a realistic option for most Indian potato farmers, based on the assumptions made in Chapter 4 and the economic analysis presented in Chapter 5. According to the Literature by Bongiovanni et al. (2004) and Kutter et al. (2011), high-tech precision agriculture technologies often fail due to a misalignment with farm-specific approaches in their implementation.

In contrast, the CHC/FPO-based adoption models (Table 23) yield highly encouraging and positive outcomes. The ROI ranged from 1,169% in Uttar Pradesh to 2,579% in Punjab, and CBR values were consistently above 50, with the highest at 107% (Punjab). The payback period dropped to under 0.07 years in all cases, showing rapid capital recovery and profitability for smallholder farmers.

This difference in financial viability is due to the fee-for-service basis in the CHCs and FPOs' adoption model, which allows farmers to reduce the per-hectare cost of operation and increase equipment utilisation rates (Kumar et al., 2023). Organised service centres employ trained personnel to manage, calibrate, and maintain precision tools, addressing the knowledge and technical support gap that most farmers face. FPOs bring land under one umbrella, allowing economies of scale without altering ownership structure, which makes YMS easy to implement and follow data-driven farming practices (Singh & Kumar, 2022). When operated through CHCs or FPOs, YMS produce more reliable data that farmers can use to make informed decisions, such as nutrient application, harvesting time, and improving yields and profits (Hedley, 2015). According to Aubert et al. (2012) and Meena et al. (2021), cooperative models facilitate the adoption of precision technologies by reducing costs and enhancing knowledge transfer.

6.5 Implications and Answers to Research Questions

The results of the economic analysis and findings of this study have implications for the adoption and scalability of yield monitoring systems in Indian potato farming. This section addresses the two research questions posed at the beginning of this thesis:

A) Are the yield monitoring systems used in New Zealand's potato farming sector economically viable in India's potato farming sector?

The answer, based on the economic analysis conducted in Chapter 5 and according to the assumptions made in Chapter 4, implies that yield monitoring systems used in New Zealand potato farming under the individual farmer adoption model, which is widely used in New Zealand, are economically unviable in India across all the states studied. The primary issue is scale, as over 86% of Indian farmers operate on less than 2 hectares of land, making the per-acre cost of YMS too high for the farmer (Sharma, 2024; Vasavi, 2025). Gaps such as the lack of mechanisation, digital literacy, general literacy, extension services, and technical advisory services limit the ability of Indian potato farmers to fully utilise YMS features, including yield maps and special analytics (Jat et al., 2020; Rao et al., 2017). Thus, direct transfer of New Zealand’s individual YMS adoption model to the Indian potato farming sector is not economically viable without adaptation.

B) If not, how can the yield monitoring systems be adopted in the Indian potato farming sector?

YMS can be adopted economically in India across all states, according to the assumptions made in Chapter 4 and the economic analysis in Chapter 5, through collective service-based models such as Farmer Producer Organisations (FPOs) and Custom Hiring Centres (CHCs). The CHC/FPO models show strong viability across all six states studied. The ROI, CBR, and PP values strongly suggest that it is economically viable.

The results from the economic analysis of service-based YMS adoption in Indian potato farming align with the literature, which highlights the adoption of precision agriculture through collective cooperatives in developing countries (Aubert et al., 2012; Meena et al., 2021). The scale of economic reduction reduces the per-acre cost of YMS, CHCs, and FPOs, enabling knowledge sharing, access to trained personnel, and capital investment (Singh & Kumar, 2022). These findings suggest that for YMS to be adopted in India, policy should support collective delivery schemes and build institutional infrastructure around them.

6.6 conclusion

This study, based on the assumptions made in Chapter 4 and the economic analysis presented in Chapter 5, has found that context-specific strategies are crucial for promoting the adoption of technology in agriculture. For the economies of developing countries, such as India, the success of yield monitoring systems (YMS) relies not only on profitability but also on institutional support for developing shared infrastructure and a service delivery model. This chapter directly addresses the research questions, while New Zealand's YMS model is not directly transplantable to India, the technology can be viable through adapted adoption model pathways.

Chapter 7: Conclusion and Recommendation

7.1 Summary of Key Findings

The analysis found a contrast between the two countries in terms of YMS viability. In New Zealand, YMS adoption yielded exceptionally high ROI, exceeding 1,700% in individual models and surpassing 2,600% in contractor-based models. The payback periods were also remarkably short, ranging from 0.06 to 0.03 years. These results confirm the maturity of New Zealand's agricultural infrastructure and its readiness to integrate advanced technologies (Ministry for Primary Industries, 2022).

In India, the individual farmer adoption model proved economically unviable. The ROI values were negative, and the payback periods extended from 7 to 15 years, indicating substantial financial risks. However, when YMS adoption was modelled through Farmer Producer Organisations (FPOs) and Custom Hiring Centres (CHCs), the results shifted dramatically. ROI exceeded 1,000% in most states, and payback periods were reduced to less than 0.07 years. This suggests that cooperative or shared ownership models are crucial to the success of precision agriculture in smallholder-dominated economies, such as India (Bethi & Deshmukh, 2023; Singh & Meena, 2019).

These findings directly address the research question: Yield Monitoring Systems, although not economically viable under individual ownership in India, can become highly viable through shared service delivery models. This suggests that the technology itself is not the constraint—rather, it is the mode of implementation.

7.2 policy suggestions and recommendations

Yield monitoring systems are financially unviable for individual potato farmers in India under the current conditions. Service-based models, such as Farmer Producer Organisations and custom hiring centres, provide a scalable and economical pathway for YMS adoption. For New Zealand, where individual and contractor-based adoption models show strong returns, the focus should be on further digital integration and data analytics. For India, the successful implementation of YMS requires policy support, institutional reforms, and targeted investment.

Given that the YMS is not viable for individual farmer adoption in the Indian smallholder system, the Indian government should invest in CHCs and FPOs as a delivery model for YMS.

This approach enables YMS services to be provided on a shared-use basis, thereby reducing per-farmer capital burdens and enhancing accessibility (Singh & Kumar, 2022; Kumar et al., 2023). Capital subsidies, matching grants, and specific low-interest loans for machinery acquisition are examples of incentive models that will promote uptake. As a result, small farmers will benefit from advanced technologies without incurring unaffordable debt (Meena et al., 2021).

YMS tools and compatible harvesters should be integrated into existing machinery and digital agriculture schemes, such as the Sub-Mission on Agriculture Mechanisation (SMAM) and the Digital Agriculture Mission (2021-2025) (Government of India, 2022). Equipment eligible for financial assistance should include YMS sensors, GPS monitors, and data processing software, particularly when used in CHCs and FPOs.

According to Eastwood et al. (2019), the economic success of YMS in New Zealand was supported by access to trained advisors, extension services, and the support of agritech consultants. India must address the absence of these systems in rural areas. Investments should be made in training agriculture extension officers, agronomists, and developing a national training curriculum on precision agriculture and yield monitoring systems through Krishi Vigyan Kendras (KVKs) and FPO managers to enable them to apply and effectively interpret yield data. Collaboration with agricultural universities and private agri-tech startups should be encouraged to build this ecosystem (Jat et al., 2020).

The private sector can play a vital role in financing, developing, deploying and maintaining YMS tools through lease-to-own models, pay-per-use apps, and subscription-based platforms. Private-public partnerships (PPPs) should be designed to allow private players to manage YMS infrastructure within CHCs or provide bundled advisory services, data analysis, and yield prediction solutions (Aubert et al., 2012).

State-level differences in ROI, CBR, and PP, as shown in the analysis, suggest that policies must be localised. Punjab and West Bengal demonstrated higher economic feasibility for YMS under CHCs/FPO models; these states can serve as pilot regions for scaling the rollout. Uttar Pradesh and Bihar require higher capital support and risk mitigation before viable adoption is possible. Region-specific policies that tailor crop price trends, farm size distribution, and existing infrastructure will increase adoption success and reduce the failure rate (Rao et al., 2017).

7.3 limitations of the study

The economic models in this research were developed based on secondary data sources, including academic literature, government reports, commodity market data, and industry publications. These sources vary in their methodology and time frame. The yield data, cost structure, and technology prices were derived from a range of years and regions, which may introduce inconsistency and limit the direct comparability across countries and regions. Indian data is sourced from state-level government reports, academic literature and price aggregators, including commodity Online and Kisandeals. New Zealand data is sourced from Potatoes New Zealand reports, published case studies, and academic literature.

The study utilises data from selected regions in both countries; these regions, in New Zealand and states in India, are chosen for their relevance to potato farming. They do not fully represent the full diversity of agroclimatic zones, farming practices, or market access conditions in either country. The findings cannot be generalised across all potato-growing regions in India or New Zealand.

The economic indicators used, such as ROI, CBR, and PP, were calculated based on the assumptions outlined in Chapter 4. Assumptions include input costs, output returns, machinery lifespan, depreciation rate, and yield improvement percentage due to YMS. Real-world variability in crop yield, input prices, machine utilisation rates, and whether risk can significantly influence economic outcomes. As a result, models offer theoretical insights, but they do not fully capture the on-ground economics.

The study was conducted purely on an economic basis and does not incorporate behavioural, social, or psychological factors influencing YMS adoption. Factors such as Indian farmers' risk perception, cultural resistance to technology, lack of trust in digital systems, and variation in digital literacy were not considered in this analysis but are known to affect technology adoption (Aubert et al., 2012; Eastwood et al., 2019).

Yield improvements attributed to YMS were applied uniformly within each region or state in the models. In practice, yield responses to precision technologies can vary significantly based on soil type, rainfall, crop variety, and pest pressures. The study does not include a sensitivity analysis to evaluate the effects of these variables.

The study is based on secondary data; there was no direct field validation or survey among farmers to confirm either the cost figures or experiential feedback on YMS tools. Incorporating farmer voices and real case implementations could have strengthened the practical value and grounded the economic analysis in user realities.

7.4 Future Research

Future studies should consider conducting longitudinal field experiments with actual farmers across multiple agro-climatic zones in India and New Zealand. This would allow for real-time monitoring of YMS's impact on productivity, cost savings, and environmental sustainability.

Future research should explore hybrid economic models that incorporate not only ROI and CBR but also environmental cost savings and social return on investment (SROI) metrics. There is also scope to examine how farmers’ behavioural factors, such as risk aversion and perceptions of technology, influence adoption decisions.

In India, further research could assess the long-term sustainability of FPO/CHC-based service models, including their governance, transparency, and financial independence. In New Zealand, studies could investigate the role of predictive analytics and artificial intelligence in further optimising YMS outcomes.

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Appendices

Appendix 1: Results calculations

New Zealand – Individual Farmer Adoption Model

Return on Investment (ROI)

ROI = [(Yield Gain + Input Savings) - Cost of YMS Per Hectare] ÷ Cost of YMS Per Hectare × 100

Manawatu

Farm size: 67 ha

Annual yield per hectare: 57/ha

Potato price: NZD 550/t

Yield increase (18%): 10.26 t/ha

Input cost savings (15%): 15% of 5000 = NZD 750/ha

Revenue from yield increase: 10.26 t/ha × 550 = NZD 5,643/ha

Total benefits per hectare: 5,643 + 750 = NZD 6,393/ha

Cost of YMS: NZD 20,000

Cost of YMS per Hectare: 20,000 ÷ 67 = NZD 298.51

ROI calculation :

ROI = [6,393 – 298.51] ÷ 298.51 × 100 = 2,041.65 %

Canterbury

Farm size : 67 ha

Annual yield: 58 t/ha

potato price: NZD 550/t

Yield increase (18%): 10.44 t /ha

Input cost savings (15%): 15% of NZD 5000 = NZD 750/ ha

Revenue from yield increase: 10.44 × 550 = NZD 5,743/ha

Total benefits/ha : 5,643 + 750 = NZD 6,492

Cost of YMS: 20,000

Cost of YMS per ha: 20,000 ÷ 67 = NZD 298.51

ROI calculation :

ROI = [6,492– 298.51] ÷ 298.51 × 100 = 2,075 %

Pukekohe

Farm size : 67 ha

Annual yield per hectare = 47 t/ha

Potato price: NZD 550/t

Yield increase (18%): 8.46 t/ha

Input cost savings (15%): 15 % of NZD 5000 = NZD 750/ ha

Revenue from yield increase: 8.46 × 550 = NZD 4,653/ha

Total benefits/ha : 24,653 + 750 = NZD 5,403

Cost of YMS per hectare: 20,000 ÷ 67 = NZD 298.51

ROI calculation **:**

ROI = [5,403 – 298.51] ÷ 298.51 × 100 = 1,710%

Cost-Benefit Ratio (CBR)

CBR = Present Value of Total Benefits ÷ Total Investment Cost of YMS Per Hectare

$$present\ value\ of\ total\ benifits\ = Annual\ Benefits\ \times \frac{1-(1+r)^{-n}}{r}$$

Where :

Annual benefits = Revenue from Yield Gains + Input Cost Savings

r = discount rate = 6%

n = 5 years

Manawatu

Annual benefits: NZD 6,393/ ha

Cosy of YMS per hectare: NZD 298.51

Present value of benefits :

$$6{,}393 \times \frac{1-(1+0.06)^{-5}}{0.06} = NZD\ 26{,}929.64$$

CBR = 26,929.64 ÷ 298.51 = 90.21

Canterbury

Annual benefits: NZD 6,492/ha

Cosy of YMS per hectare: NZD 298.51

Present value of benefits :

$$6{,}492 \times \frac{1-(1+0.06)^{-5}}{0.06} = NZD\ 27{,}346.67$$

CBR = 27,346.67 ÷ 298.51 = 91.61

Pukekohe

Annual benefits: NZD 5,403/ha

Cost of YMS per hectare: NZD 298.51

Present value of benefits :

$$5{,}403 \times \frac{1-(1+0.06)^{-5}}{0.06} = NZD\ 22{,}759.40$$

CBR = 22,759.40 ÷298.51 = 76.24

Payback period (PP)

PP = cost of YMS Per Hectare ÷ Annual net benefit of YMS Per Hectare

Manawatu

Cost of YMS per hectare = NZD 298.51

Annual net net benefit of YMS = NZD 6,393

So,

PP = 298.51 ÷ 6,393 = 0.05 years

Canterbury

Cost of YMS per hectare = NZD 298.51

Annual net benefit of YMS = NZD 6,492

So,

PP = 298.51 ÷ 6,492 = 0.05 years

Pukekohe

Cost of YMS per hectare = NZD 298.51

Annual net benefits of YMS = NZD 5,403

So,

PP = 298.51 ÷ 5,403 = 0.06 years

India – individual farmer adoption model

Return on Investment (ROI)

ROI = [(Yield Gain + Input Savings) - Cost of YMS Per Hectare] ÷ Cost of YMS Per Hectare × 100

Uttar Pradesh

Farm size : 2 ha

Annual yield per hectare: 20 t/ha

Potato price per ton: INR 12000

Yield increase (9%): 1.8 t/ha

Input cost saving(7%): 7% of INR 53,745 = INR 3,762

Revenue from Yield Increase: INR 21,600

Total benefits per hectare: INR 25,363

Cost of YMS: INR 800,000

Cost of YMS per hectare: INR 800,000 ÷ 2= INR 400,000

ROI calculation :

ROI = [25,363.15 - 400,00] ÷ 400,000 × 100 = − 94 %

West Bengal

Farm size : 2 ha

Annual yield per hectare: 22 t/ha

Potato price per ton: INR 19000

Yield increase (9%): 1.98 t/ha

Input cost saving(7%): 7% of INR 85,567 = INR 5,989

Revenue from Yield Increase: 37,620

Total benefits per hectare: INR 43,609

Cost of YMS: INR 800,000

Cost of YMS per hectare: INR 800,000 ÷ 2= INR 400,000

ROI calculation :

ROI = [43,609.69 - 400,000] ÷ 400,000 × 100 = − 89%

Bihar

Farm size : 2 ha

Annual yield per hectare: 25 t/ha

Potato price per ton: INR11000

Yield increase (9%): 2.25

Input cost saving(7%): 7% of INR 52,187= INR 3,653

Revenue from Yield Increase: INR 24,750

Total benefits per hectare: INR 3,653.09 + INR 24,750 = INR 28,403

Cost of YMS: INR 800,000

Cost of YMS per hectare: 400,000

ROI calculation :

ROI = [28,403.09 - 400,00] ÷ 400,000 × 100 = − 93 %

Gujarat

Farm size : 2 ha

Annual yield per hectare: 30 t/ha

Potato price per ton: INR 12700

Yield increase (9%): 2.7

Input cost saving(7%): 7% of INR 60,520 = INR 4,236

Revenue from Yield Increase: INR 34,290

Total benefits per hectare: INR 4,236.40 + INR 34,290 = INR 38,526

Cost of YMS: INR 800,000

Cost of YMS per hectare: 400,000

ROI calculation :

ROI = [38,526.40 - 400,000] ÷ 400,000 × 100 = − 90%

Madhya Pradesh

Farm size : 2 ha

Annual yield per hectare: 24 t/ha

Potato price per ton: INR 11500

Yield increase (9%): 2.16 t/ha

Input cost saving(7%): 7% of INR 57,101 = INR 3,997

Revenue from Yield Increase: INR 24,840

Total benefits per hectare: INR 3,997.07 + INR 24,840 = INR 28,837

Cost of YMS: INR 800,000

Cost of YMS per hectare: INR 400,000

ROI calculation :

ROI = [28,837.07 - 400,000] ÷ 400,000 × 100 = − 93 %

Punjab

Farm size : 2 ha

Annual yield per hectare: 34 t/ha

Potato price per ton: INR 16000

Yield increase (9%): 3.06 t/ha

Input cost saving(7%): 7% of INR 66,059 = INR 4,624

Revenue from Yield Increase: INR 48,960

Total benefits per hectare: INR + INR = 53,584

Cost of YMS: INR 800,000

Cost of YMS per hectare: 400,000

ROI calculation :

ROI = [53,584.13 - 400,000] ÷ 400,000 × 100 = − 87 %

Cost-Benefit Ratio (CBR)

CBR = Present Value of Total Benefits ÷ Total Investment Cost of YMS Per Hectare

$$present\ value\ of\ total\ benifits\ = Annual\ Benefits\ \times \frac{1-(1+r)^{-n}}{r}$$

Where :

Annual benefits = Revenue from Yield Gains + Input Cost Savings r = discount rate = 8%

n = 5 years

Uttar Pradesh

Annual benefits: INR 25,363

Cosy of YMS per hectare: INR 400,000

Present value of benefits :

$$25363.15\ \times \frac{1-(1+0.08)^{-5}}{0.08} = INR\ 101{,}268$$

CBR = 101,268 ÷ 400,000 = 0.25

West Bengal

Annual benefits: INR 43,610

Cosy of YMS per hectare: INR 400,000

Present value of benefits :

$$43{,}609.69 \times \frac{1-(1+0.08)^{-5}}{0.08} = INR\ 174{,}130$$

CBR = 174,129.85 ÷ 400,000 = 0.44

Bihar

Annual benefits: INR 28,403

Cosy of YMS per hectare: INR 400,000

Present value of benefits :

$$28{,}403.09 \times \frac{1-(1+0.08)^{-5}}{0.08} = INR\ 113{,}405$$

CBR = 113,405 ÷ 400,000 = 0.28

Gujarat

Annual benefits: INR 38,526

Cosy of YMS per hectare: INR 400,000

Present value of benefits :

$$38{,}526.40 \times \frac{1-(1+0.08)^{-5}}{0.08} = INR\ 153{,}824$$

CBR =153,824 ÷ 400,000 = 0.38

Madhya Pradesh

Annual benefits: INR 28,837

Cosy of YMS per hectare: INR 400,000

Present value of benefits :

$$28{,}837.07 \times \frac{1-(1+0.08)^{-5}}{0.08} = INR\ 115{,}138$$

CBR = 115,138 ÷ 400,000 = 0.29

Punjab

Annual benefits: INR 53,584

Cosy of YMS per hectare: INR 400,000

Present value of benefits :

$$53{,}584 \times \frac{1-(1+0.08)^{-5}}{0.08} = INR\ 213{,}946$$

CBR = 213,946 ÷ 400,000 = 0.53

Payback period (PP)

PP = cost of YMS Per Hectare ÷ Annual net benefit of YMS Per Hectare

Uttar Pradesh

Cost of YMS per hectare = INR 400,000

Annual net benefit of YMS = INR 25,363

So,

PP = 400,000 ÷ 25.363 = 15.77 years

West Bengal

Cost of YMS per hectare =INR 400,000

Annual net benefit of YMS = INR 43,610

So,

PP = 400,000 ÷ 43,610 = 9.17 years

Bihar

Cost of YMS per hectare = INR 400,000

Annual net benefits of YMS = INR 28,403

So,

PP = 400,000 ÷ 28,403 = 14.08 years

Gujarat

Cost of YMS per hectare = INR 400,000

Annual net benefit of YMS = INR 38,526.40

So,

PP = 400,000 ÷38,526.40 = 10.38 years

Madhya Pradesh

Cost of YMS per hectare =INR 400,000

Annual net benefit of YMS = INR 28,837

So,

PP = 400,000 ÷ 28,837. = 13.87 years

Punjab

Cost of YMS per hectare = INR 400,000

Annual net benefits of YMS = INR 53,584

So,

PP = 400,000 ÷ 53,584.13 = 7.46 years

New Zealand Cooperative or Service-Based Adoption Model of YMS

Return on Investment (ROI)

ROI = [(Yield Gain + Input Savings) - Cost of YMS Per Hectare] ÷ Cost of YMS Per Hectare × 100

Manawatu

Farm size: 67 ha

annual yield per hectare: 57/ha

Potato price: NZD 550/t

Yield increase (18%): 10.26 t/ha

Input cost savings (15%): 15% of 5000 = NZD 750/ha

Revenue from yield increase: 10.26 t/ha × 550 = NZD 5,643/ha

Total benefits per hectare : NZD 5,643 + NZD 750 = NZD 6,393/ha

YMS service cost per Hectare: NZD 200/ha

ROI calculation :

ROI = [6,393 - 200] ÷ 200 × 100 = 3,096 %

Canterbury

Farm size : 67 ha

Annual yield: 58 t/ha

potato price: NZD 550/t

Yield increase (18%): 10.44 t /ha

Input cost savings (15%): 15% of NZD 5000 = NZD 750/ ha

Revenue from yield increase: 10.44 × 550 = NZD 5,742/ha

Total benefits/ha : 5,742 + 750 = NZD 6,492/ha

YMS service cost per hectare: NZD 200

ROI calculation :

ROI = [6,492 - 200] ÷ 200 × 100 = 3,142 %

Pukekohe

Farm size : 67 ha

Annual yield per hectare = 47 t/ha

Potato price: NZD 550/t

Yield increase (18%): 8.46 t/ha

Input cost savings (15%): 15 % of NZD 5000 = NZD 750/ ha

Revenue from yield increase: 8.46 × 350 = NZD 4,653/ha

Total benefits/ha : NZD 4,653 + NZD 750 = NZD 5,403/ha

YMS service cost per hectare: NZD 200

ROI calculation **:**

ROI = [5,403- 200] ÷ 200 × 100 = 2,601 %

Cost-Benefit Ratio (CBR)

CBR = Present Value of Total Benefits ÷ Total Investment Cost of YMS Per Hectare

$$present\ value\ of\ total\ benifits\ = Annual\ Benefits\ \times \frac{1-(1+r)^{-n}}{r}$$

Where :

Annual benefits = Revenue from Yield Gains + Input Cost Savings

r = discount rate = 6%

n = 5 years

Manawatu

Annual benefits: NZD 6,393

YMS service cost per hectare: NZD 200

Present value of benefits :

$$6{,}393 \times \frac{1-(1+0.06)^{-5}}{0.06} = NZD\ 26{,}929.64$$

CBR = 26,929.64 ÷ 200 = 134.65

Canterbury

Annual benefits: NZD 6,492

YMS service cost per hectare: NZD 200

Present value of benefits :

$$6{,}492 \times \frac{1-(1+0.06)^{-5}}{0.06} = NZD\ 27{,}346.67$$

CBR = 27,346.67 ÷ 200 = 136.73

Pukekohe

Annual benefits: NZD 5,403

YMS service cost per hectare: NZD 200

Present value of benefits :

$$5{,}403 \times \frac{1-(1+0.06)^{-5}}{0.06} = NZD\ 22{,}759.40$$

CBR = 22,759.40 ÷ 200 = 113.80

Payback period (PP)

PP = cost of YMS Per Hectare ÷ Annual net benefit of YMS Per Hectare

Manawatu

YMS service cost per hectare = NZD 200

Annual net net benefit of YMS = NZD 6,393

So,

PP = 200 ÷ 6,393 = 0.03 years

Canterbury

YMS service cost per hectare = NZD 200

Annual net benefit of YMS = NZD 6,492

So,

PP = 200 ÷ 6,492 = 0.03 years

Pukekohe

YMS service cost per hectare = NZD 200

Annual net benefits of YMS = NZD 5,403

So,

PP = 200 ÷ 5,403 = 0.04 years

India – Custom hiring centres (CHCs) or Farmer Producer Organisation (FPOs) YMS adoption model

Return on Investment (ROI)

ROI = [(Yield Gain + Input Savings) - Cost of YMS Per Hectare] ÷ Cost of YMS Per Hectare × 100

Uttar Pradesh

Farm size : 2 ha

Annual yield per hectare: 20 t/ha

Potato price per ton: INR 12000

Yield increase (9%): 1.8 t/ha

Input cost saving(7%): 7% of INR 53,745 = INR 3,762

Revenue from Yield Increase: INR 21,600

Total benefits per hectare: INR 25,363

YMS service cost per hectare: INR 2,000

ROI calculation :

ROI = [25,363.15 - 2000] ÷ 2,000 × 100 = 1,168%

West Bengal

Farm size : 2 ha

Annual yield per hectare: 22 t/ha

Potato price per ton: INR 19000

Yield increase (9%): 1.98 t/ha

Input cost saving(7%): 7% of INR 85,567 = INR 5,990

Revenue from Yield Increase: 37,620

Total benefits per hectare: INR 43,610

YMS service cost per hectare: INR 2,000

ROI calculation :

ROI = [43,610 - 2,000] ÷ 2,000 × 100 = 2,081 %

Bihar

Farm size: 2 ha

Annual yield per hectare: 25 t/ha

Potato price per ton: INR11000

Yield increase (9%): 2.25

Input cost saving(7%): 7% of INR 52,187= INR 3,653

Revenue from Yield Increase: INR 24,750

Total benefits per hectare: INR 3,653 + INR 24,750 = INR 28,403

YMS service cost per hectare: INR 2,000

ROI calculation :

ROI = [28,403 - 2,000] ÷ 2,000 × 100 = 1,320%

Gujarat

Farm size : 2 ha

Annual yield per hectare: 30 t/ha

Potato price per ton: INR 12700

Yield increase (9%): 2.7

Input cost saving(7%): 7% of INR 60,520 = INR 4,236

Revenue from Yield Increase: INR 34,290

Total benefits per hectare: INR 4,236.40 + INR 34,290 = INR 38,526

YMS service cost per hectare: INR 2,000

ROI calculation:

ROI = [38,526 - 2,000] ÷ 2,000 × 100 = 1,826 %

Madhya Pradesh

Farm size : 2 ha

Annual yield per hectare: 24 t/ha

Potato price per ton: INR 11500

Yield increase (9%): 2.16 t/ha

Input cost saving(7%): 7% of INR 57,101 = INR 3,997.07

Revenue from Yield Increase: INR 24,840

Total benefits per hectare: INR 3,997.07 + INR 24,840 = INR 28,837.07

YMS service cost per hectare: INR 2,000

ROI calculation :

ROI = [28,837 - 2,000] ÷ 2,000 × 100 = 1,342 %

Punjab

Farm size : 2 ha

Annual yield per hectare: 34 t/ha

Potato price per ton: INR 16000

Yield increase (9%): 3.06 t/ha

Input cost saving(7%): 7% of INR 66,059 = INR 4,624

Revenue from Yield Increase: INR 48,960

Total benefits per hectare: INR + INR = 53,584

YMS service cost per hectare: INR 2,000

ROI calculation :

ROI = [53,584 - 2,000] ÷ 2,000 × 100 = 2,579%

Cost-Benefit Ratio (CBR)

CBR = Present Value of Total Benefits ÷ Total Investment Cost of YMS Per Hectare

$$present\ value\ of\ total\ benifits\ = Annual\ Benefits\ \times \frac{1-(1+r)^{-n}}{r}$$

Where :

Annual benefits = Revenue from Yield Gains + Input Cost Savings

r = discount rate = 8%

n = 5 years

Uttar Pradesh

Annual benefits: INR 25,363.15

YMS service cost per hectare: INR 2,000

Present value of benefits :

$$25363.15 \times \frac{1-(1+0.08)^{-5}}{0.08} = INR\ 1{,}01{,}268$$

CBR = 1,01,268 ÷ 2,000 = 50.6

West Bengal

Annual benefits: INR 43,610

YMS service cost per hectare: INR 2,000

Present value of benefits :

$$43{,}609.69 \times \frac{1-(1+0.08)^{-5}}{0.08} = INR\ 1{,}74{,}130$$

CBR = 174,130 ÷ 2,000 = 87.06

Bihar

Annual benefits: INR 28,403

YMS service cost per hectare: INR 2,0000

Present value of benefits :

$$28{,}403 \times \frac{1-(1+0.08)^{-5}}{0.08} = INR\ 113{,}405$$

CBR = 113,405 ÷ 2,000 = 56.70

Gujarat

Annual benefits: INR 38,526

YMS service cost per hectare: INR 2,000

Present value of benefits :

$$38{,}526 \times \frac{1-(1+0.08)^{-5}}{0.08} = INR\ 153{,}824$$

CBR =153,824.40 ÷ 2,000 = 76.91

Madhya Pradesh

Annual benefits: INR 28,837

YMS service cost per hectare: INR 2,000

Present value of benefits :

$$28{,}837 \times \frac{1-(1+0.08)^{-5}}{0.08} = INR\ 115{,}138$$

CBR = 115,138 ÷ 2,000 = 57.65

Punjab

Annual benefits: INR 53,584

YMS service cost per hectare: INR 2,000

Present value of benefits :

$$53{,}584.13 \times \frac{1-(1+0.08)^{-5}}{0.08} = INR\ 213{,}946$$

CBR = 213,945.89 ÷ 2,000 = 106.97

Payback period (PP)

PP = cost of YMS Per Hectare ÷ Annual net benefit of YMS Per Hectare

Uttar Pradesh

YMS service cost per hectare = INR 2,000

Annual net benefit of YMS = INR 25,363

So,

PP = 2,000 ÷ 25,363 = 0.07 years

West Bengal

YMS service cost per hectare = 2,000

Annual net benefit of YMS = INR 43,609

So,

PP = 2,000 ÷ 43,609 = 0.04 years

Bihar

YMS service cost per hectare = INR 2,000

Annual net benefits of YMS = INR 28,403

So,

PP = 2,000 ÷ 28,403 = 0.07 years

Gujarat

YMS service cost per hectare = INR 2,000

Annual net net benefit of YMS = INR 38,526

So,

PP = 2,000 ÷38,526 = 0.05 years

Madhya Pradesh

YMS service cost per hectare =INR 2,000

Annual net benefit of YMS = INR 28,837

So,

PP = 2,000 ÷ 28,837.07 = 0.06 years

Punjab

YMS service cost per hectare = INR 2,000

Annual net benefits of YMS = INR 53,584

So,

PP = 2,000 ÷ 53,584 = 0.03 years

Appendix 2: Assumptions Source

	2024
Estimated hectares planted	10,358
Farmgate value ($000)	$226,367
Total Export volume (tonnes)	75,399
Total Export value ($000)	$134,608
Total Supermarket Volume (tonnes)	57,647
Total Supermarket Value ($000)	$478,434
Export:Import Ratio- volume	2.32
CPI increase for Table Potatoes	-23.9%
CPI increase for Frozen Fries	-3.0%
CPI increase for Crosps	-0.7%

International Day of Potato – 30 May 2025

Second year celebrating the International Day of Potato with the theme 'Harvesting diversity, feeding hope'.

5,000 potato varieties

Third most available food crop globally

8,000 years of potatoes and going strong!

2/3 of the world population consume potatoes

159 countries grow potatoes

Social Media Followers

- X: 2,600
- LinkedIn: 1,800
- Facebook: 1,600
- Instagram: 1,600

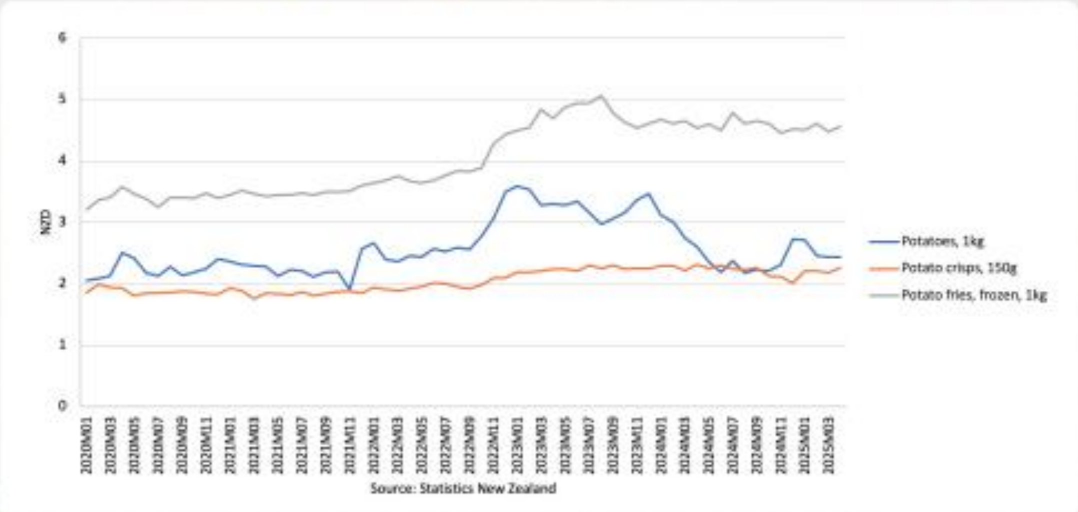
Supermarket Retails Sales

	2018	2019	2020	2021	2022	2023	2024	% Change
Volume (000 kg)								
Frozen Potatoes	26,343	19,280	22,815	22,867	23,389	24,712	25,062	1.4
Fresh Potatoes	-	23,506	21,916	20,539	19,549	20,605	18,297	-11.2
Crisps	11,967	12,910	14,012	14,264	13,792	14,096	14,287	1.3
Volume ($000)								
Frozen Potatoes	75,176	78,300	97,495	102,111	111,493	137,548	138,495	0.7
Fresh Potatoes	0	61,230	60,537	56,985	62,088	72,958	57,182	-21.6
Crisps Units	177,575	192,527	215,828	226,780	242,157	281,014	282,757	0.6
Consumer Price Index								
Calendar Year Average								
Potatoes 1kg	1.92	1.83	2.23	2.23	2.66	3.30	2.51	-23.9
Potato Fries, Frozen 1kg	3.25	3.23	3.40	3.48	3.85	4.75	4.60	-3.0
Potato Crisps 150g	1.90	1.88	1.88	1.85	1.98	2.24	2.22	-0.7

Area Planted (Year Ending June)

	2018	2019	2020	2021	2022	2023	2024	% Change
Seed	1,160	1,117	1075	908	697	961	962	0.1%
Brushed/Table/ Processed	8,579	8,911	9,242	9,993	7,727	8,305	9,396	13.1%
Total (ha) planted	9,739	10,028	10,317	10,901	8,424	9,266	10,358	11.8%
VALUE $000								
Levy income - Annual report $000	$1,368	$1,573	$1,555	$1,519	$1,703	$2,118	$1,850	-12.7%
Farmgate value - $000	$167,379	$192,461	$190,200	$185,861	$208,391	$259,158	$226,366	-12.7%
$/HECTARE								
	$17,186	$19,192	$18,436	$17,050	$24,738	$27,969	$21,854	-21.9%

Food Price Index Weighted Average Prices for New Zealand (Monthly)



Imports

Import Quantity (tonnes)

	2018	2019	2020	2021	2022	2023	2024	% Change
Frozen Fries	18,804	18,269	17,905	21,024	19,766	28,823	25,882	**-10.20%**
Potato Starch	3,007	2,224	2,765	3,943	2,603	2,323	2,792	**20.20%**
Crisps	1,068	1,634	2,122	2,097	1,991	2,020	2,076	**2.81%**
Frozen not-fried	319	337	253	185	190	133	503	**276.90%**
Fresh Potatoes	0	-	11	-	14	9	2	**-82.20%**
Seed Potatoes (Fresh)	-	-	-	-	-	-	-	-
Other	1,263	1,494	1,348	817	1,334	1,632	1,218	**-25.37%**
Total	**24,460**	**23,958**	**24,405**	**28,066**	**25,898**	**34,940**	**32,472**	**-7.06%**

Import Value ($/kg)

	2018	2019	2020	2021	2022	2023	2024	% Change
Frozen Fries	$1.84	$1.89	$2.02	$2.01	$2.30	$2.72	$2.82	**3.49%**
Potato Starch	$1.34	$1.67	$1.55	$1.55	$1.85	$2.48	$2.08	**-16.08%**
Crisps	$8.16	$9.84	$8.95	$10.77	$12.80	$15.86	$14.43	**-9.04%**
Frozen not-fried	$1.64	$1.83	$2.08	$1.74	$2.24	$2.18	$2.69	**23.48%**
Fresh Potatoes	$1.50	-	$1.19	-	$2.82	$2.29	$6.11	**166.72%**
Seed Potatoes (Fresh)	-	-	-	-	-	-	-	-
Other	$2.35	$2.63	$2.67	$2.51	$3.37	$4.58	$4.42	**-3.48%**
Total	**$2.08**	**$2.46**	**$2.60**	**$2.61**	**$3.12**	**$3.55**	**$3.56**	**0.12%**

Export/Import Ratio

Imports vs Exports

	2018	2019	2020	2021	2022	2023	2024	% Change
Volume	4.23	4.49	3.71	2.92	3.25	2.36	2.32	**5.74%**
Value	2.64	2.23	1.76	1.42	1.47	1.09	1.17	**6.81%**

Financial information

Operational costs

Operational costs for a season of growing potatoes depends on the variety you're growing, and whether you own your own machinery or are using contractors.

Spraying, fertilising and cultivating the land is typically around $2,200 per hectare. Seed potatoes average around $2,500 per hectare, and the average cost for hiring a contractor to plant is around $150 per hectare. This means there's a total cost of around $5,000 per hectare to establish and grow the crop.

The cost of harvest depends on whether or not you'll be hiring contractors to provide the harvester, and the arrangement you have in place for packing. If you're using a local packhouse, get in touch with them to discuss costs.

→ **Search for funding opportunities**

Grower returns

The income from your crop is determined by your yield and the price you're paid per tonne.

The yield depends on the variety grown and the growing conditions during the season. The average crop size has increased steadily over the last 20 years and now sits at an average of 64 tonne per hectare.

There are more than 50 varieties of potato grown commercially in New Zealand, so talk to your seed merchant about the best varieties for your region and the yield you should reasonably expect.

The price you're paid for your crop is either set down in your contract (if you have a contract with a processor), or set by the market at the time you harvest your crop. In the 3 years to 2017 the average price for open market potatoes varied between $400 and $700 per tonne, depending on:

- the varieties available
- the quantity coming to the market, and
- demand from consumers.

There's a slight premium for early season potatoes, with at least $500-$600 per tonne expected.

Potatoes store well in the ground, so you have some flexibility on when to bring the crop to market if you miss the early season. Base your harvest date on the availability of equipment and labour, as well as discussions with your wholesaler about what the market's doing.

Based on an average yield of 64 tonne and a market price of $400-$700 per tonne, the average gross revenue per hectare is in the range of $25,600 to $44,800.

YIELD MONITOR PRO

From: USD$3,150.00

The Yield Monitor Pro is the flagship Yield Monitor from FarmTRX, featuring free space-based corrections (PPP HAS) with no set up or configuration required. Build out the ideal harvest monitoring package featuring the Yield Monitor Pro by selecting from the available add-ons below:

Header Height Sensor for Yield Monitor Pro

Add the Header Height Sensor to deliver real-time header height values to the yield monitor. The Header Height Sensor improves in-field area accuracy and gives operator cut height during harvest.

☐ Add for USD$400.00

Moisture Sensor

Add the universal combine grain moisture sensor.

☐ Add for USD$1,000.00

Soil Moisture Sensor Industrial

Price: 3000.00 INR / Unit G

(3000.00 INR + 0% GST)

1 Pack Contains : 1

Minimum Pack Size : 2

In Stock

- 2 + BUY NOW

Product Specifications

Material	ABS
Product Type	Soil
Application	Indu
Color	Blac

Gnss Receiver Usage: Automotive

Price: 750000.00 INR / Unit Get Latest Price

(750000.00 INR + 0% GST)

1 Pack Contains : 1

Minimum Pack Size : 1

In Stock