Identification of Technical Practices for Climate-Smart Agriculture (CSA) in Indonesia: A Case Study in the Sukabumi Regency, West Java

Output 4 – Analyse Market Potential and Cost-Benefit of the Fully Integrated System

Final Report on the Market Potential Analysis for the Deployment of the Fully Integrated System

D4.1.1

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1 Introduction

Indonesian agriculture, a significant contributor to GDP through exports and domestic trade, is vital for rural livelihoods and national food security, producing staples like rice, corn, and soybeans. While known for its diverse commodities and traditional practices, the sector faces challenges from climate change and a growing emphasis on sustainable methods, reflecting an increasing environmental consciousness.

This report aims to deliver a comprehensive analysis and strategic recommendations to foster an environment conducive to the adoption of integrated technology in Indonesian agriculture. It includes a market potential analysis, emphasizing institutional reform, financing access, capacity development, and the incorporation of Climate-Smart Agriculture (CSA) practices, to offer strategic insights to policymakers and stakeholders, establish a framework for financing, create a capacity development plan, augment climate-related research, and bolster the implementation of CSA practices with integrated technology.

The fully integrated technology for soil monitoring system and automated irrigation with fertilization (Figure 1.1), focusing on enhancing agriculture through smart systems. Key components include field sensors for soil and environmental monitoring, a Field Controller/Remote Terminal Unit (RTU) for data processing and command execution, and various actuators for irrigation and fertilizer distribution. The system employs a central computer for data analysis and command issuance, and an Internet connection for seamless communication. It also features a user interface for real-time field monitoring and system control. This integrated approach aims to optimize water and nutrient delivery based on real-time field conditions, promoting efficient and sustainable agricultural practices.

Figure 1.1 Schematics of the proposed integrated system.

The integration of smart irrigation and fertilization systems has significantly advanced agriculture. Technologies like precision agriculture, data analysis, automated actuators, and remote monitoring have transformed crop management, enhancing efficiency, productivity, and sustainability. Precision agriculture employs advanced sensors for accurate water and fertilizer application, while data analysis optimizes resource use. Automated actuators deliver real-time, precise inputs, and remote monitoring allows for field management from anywhere. User-friendly interfaces make these technologies accessible to all farmers.

These advancements address major global challenges such as food security for a growing population, sustainable farming practices, climate change adaptation, and economic growth. They are contributing significantly to the needs of increase in agricultural productivity. Efficient use of resources and minimized environmental impact are key benefits, while adapting to climate change through responsive farming practices.

Economic advantages for farmers include cost reductions and increased profits, enhancing national agricultural competitiveness. These technologies also tackle water scarcity and soil degradation, optimizing water use and promoting soil health. The resultant of higher yields and resource conservation will improve income and also contribute to food security and rural community development and improving living standards.

In an era of increasing globalization and climate change, smart agriculture has become a key to enhancing efficiency and environmental resilience. These technologies, including soil monitoring systems and automated irrigation with fertigation, can significantly improve productivity and sustainability in agriculture. This document aims to investigate and analyze various aspects necessary for creating an environment conducive to the implementation of these technologies in Indonesia.

Chapter III will discuss the current state of agricultural technology in Indonesia, identify key market segments, demand and future market projections. Emphasis will be placed on understanding the specific market dynamics of Indonesia and the potential for adopting integrated agricultural technologies. Chapter IV will explore existing institutional frameworks and policies in the agricultural sector, providing recommendations for policy reforms that can facilitate the adoption of integrated technologies. Case studies of successful institutional reforms will be presented as examples. Chapter V will examine the current financial landscape and the barriers faced by farmers and technology providers in accessing financing. Detailed discussions of innovative financing models that can support technology adoption will be provided. Chapter VI will assess the current knowledge and skill levels among Indonesian farmers regarding integrated technologies and outline strategies for capacity building and skill development. Awareness campaigns and educational programs will be detailed as efforts to enhance technology adoption. Chapter VII will focus on the importance of climate-related data in agricultural technology, review the current state of climate-related research in Indonesian agriculture, and propose ways to enhance research and improve data quality. Chapter VII will discuss the role of integrated technologies in achieving CSA objectives, analyze how technology can enhance resilience and sustainability in farming, and present case studies of successful CSA implementations using integrated technologies. The final Chapter VIII will summarize key findings from each chapter, provide recommendations for stakeholders, and discuss the future outlook for integrated agricultural technologies in Indonesia.

2 Potential of Global Warming Potential Reduction of The Integrated Technology

In this chapter, an analysis is conducted on the carbon emissions associated with two distinct irrigation and fertilization practices on a farm spanning 1 hectare, which is cultivated with chili peppers. The analysis is framed within the broader context of sustainable agriculture's role in mitigating the impacts of climate change, with accuracy and relevance ensured by adopting the Global Warming Potential (GWP) values.

2.1 Case Overview

Central to this study is the examination of a chili pepper farm, which operates under two different irrigation and fertilization regimes:

Case 1 : conventional Irrigation and Fertilization: Traditional methods of watering and fertilizing are employed here, and the irrigation process is noted to have an efficiency rate of 60%. Here the electric pump is used for delivery of irrigation water from reservoir to the field.

Case 2 : Automatic Drip Irrigation with Fertigation: In this method, water and nutrients are delivered directly to the plants' root zones through an automated drip irrigation system integrated with fertigation, achieving a higher efficiency rate of 90%, and fertiliser application efficiency is 80% higher than conventional. This case is the representative of the fully integrated system of soil monitoring and automatic irrigaiton with fertiliser application. Here pump, soienoid valves, sensor and controller are used for automation of drip irrigation/fertigation network, and so the energy use is associated with these equipments. The pump used in this case can be lowered in power and working time, as leww water will be delivered by drip system.

2.2 Assumptions and Data Considerations

Several key assumptions and data points are taken into account for the purpose of this analysis:

- A reference evapotranspiration rate of 5 mm per day is assumed, reflecting the water requirement of the crops.
- It is presupposed that the farm operates under a dry season condition, receiving no rainfall to meet the water needs of the crops.
- The cultivation of a single crop of chili peppers on a one hectare land, is considered.
- The use of chemical fertilizers, focusing on nitrogen (N) as the primary nutrient, is the exclusive method of fertilization examined.
- The energy source for irrigation is derived from the local electric grid, with specific consumption rates associated with each method of irrigation and 0.8 Kg CO_2 / kWh emission factor.

- The Global Warming Potential (GWP) of nitrous oxide (N_2O) is regarded to be 265 times that of carbon dioxide (CO_2).

This analysis not only explores the direct emissions from the application of fertilizers and the use of energy for irrigation but also accounts for the efficiency of water usage and its indirect impact on carbon emissions. By evaluating these practices through the perspective of greenhouse gas emissions, insights are aimed to be provided into optimizing agricultural practices for productivity as well as environmental sustainability.

2.3 Water Use and Carbon Emission Analysis

1. Water Use

The daily water requirement based on a reference evapotranspiration of 5 mm for a 1-hectare area is 50 m³. We'll calculate the annual water requirement and adjust for the efficiencies of the irrigation systems.

- Conventional Irrigation: 60% efficiency implies more water is used to meet the crop's needs due to losses. To deliver 50 m³/day effectively, 50 m³ / 0.6 = 83.33 m³/day are actually used.
- Drip Irrigation: 90% efficiency means less water is wasted. To effectively deliver 50 m³/day, 50 m³ / 0.9 = 55.56 m³/day are actually used.

2. Carbon Emission Analysis

Conventional Irrigation and Fertilization

- Nitrogen Fertilizer Use: 160 kg N/ha
- Energy Use for water pump:

  4.4 kWh/day for 365 days = 1,606 kWh/year

- Fertilizer-Induced N_2O Emissions:

  160 kg x 0.01 x 265 = 424 kg CO_2-eq/year

- Energy-Related CO_2 Emissions:

  1,606 kWh x 0.8 kg CO_2/kWh = 1,284.8 kg CO_2/year

Drip Irrigation with Fertigasi

- Improved Fertilizer Efficiency: 128 kg N/ha (due to 20% reduction)
- Energy Use for pump, valves, sensor and controller:

  1.5 kWh/day for 365 days = 547.5 kWh/year

- Fertilizer-Induced N_2O Emissions:

  128 kg x 0.01 x 265 = 339.2 kg CO_2-eq/year

- Energy-Related CO_2 Emissions:

  547.5 kWh x 0.8 kg CO_2/kWh = 438 kg CO_2/year

Total annual GHG emissions and water use combining N_2O from fertilizer use and CO_2 from energy use:

- Conventional Irrigation and Fertilization:
    - Total GHG Emissions:

      424 kg CO_2-eq + 1,284.8 kg CO_2 = 1,708.8 kg CO_2-eq/year

    - Annual Water Use:

      83.33 m^3/day x 365 = 30,415.45 m^3/year

- Automatic drip Irrigation/Fertigation:
    - Total GHG Emissions:

      339.2 kg CO_2-eq + 438 kg CO_2 = 777.2 kg CO_2-eq/year

    - Annual Water Use:

      55.56 m^3/day x 365 = 20,279.4 m^3/year

This analysis demonstrates that adopting Automatic drip Irrigation/Fertigation will reduce the total greenhouse gas emissions associated with cultivating chili peppers on a 1-ha farm and also result in substantial water savings. By improving the efficiency of water and fertilizer use and reducing energy consumption, these agricultural practices contribute positively to sustainability and climate change mitigation efforts. In this cases, case 2 with fully integrated system can potentially reduce carbon emissions more thatn 50% lower than conventional system in case 1. This is however will depends of the conditions of the real case at the field, for instance, type of crop and cropping, wet/dry season, water reseources infrastructure etc.

3 Market Potential of The Integrated Technology in Indonesia

3.1 Current State of Agricultural Technology in Indonesia

As a tropical country, Indonesia has advantages and disadvantages in terms of agricultural development. Indonesia has large agricultural lands but faces d with varied climatic conditions including, social and cultural problems. Indonesia has a fertile agricultural areas of around approximately 33.8 Million million Ha hectares (*Statistik Lahan Pertanian* 2015-2019, Center for Agriculture Data and Information System, Secretariat General, –Ministry of Agriculture, 2020), including Including 11.7 billion hectares of fallow land as of 2019, due to water supply or financial problems. The Secretary General of the Ministry of Public Works and Housing (Pekerjaan Umum dan Perumahan Rakyat / PUPR), Mohammad Zainal Fatah, revealed that Indonesia currently has an irrigation areas (DI) covering an area of 9.1 Millon hectares, including 1.2 Million hectares of premium irrigation area in 2024 (Sejauh Ini, Indonesia Punya Daerah Irigasi Seluas 9,1 Juta Hektar, n.d.; Selesaikan 61 Bendungan Hingga 2024, Kementerian PUPR Optimalkan Potensi Irigasi Premium Seluas 1,2 Juta Hektare, n.d.). Agricultural land in Indonesia has a tendency to decline due to land conversion into non-agricultural areas. This conversion rate in 2020 is estimated to reach 100,000 hect thousand Hares per year (*Alih Fungsi Lahan Pertanian Tembus 100 Ribu Hektare per Tahun | Republika Online*, t.t.).

The role of agriculture in GDP is stillremains important, around 13.3% in 2021, and has an increasing trend even though in 2020 the role of the agricultural sector reached 13.8% (Sabarella et. al., 2022). Indonesia is a producer of various tropical foods, having high potential for development. Considering that the number of agricultural businesses on land of less than 0.5 hectares reached 17.5 million (62%) compared to the number of businesses on land of more than 2 Ha hectares of 7% (*Jumlah Usaha Pertanian Perorangan Pengguna Lahan Pertanian Menurut Wilayah dan Luas Lahan Pertanian yang Dikuasai, di INDONESIA - Dataset - Sensus Pertanian 2023 - Badan Pusat Statistik*, t.t.), the type of agricultural development has become more complex. Along with this, the low level of education of agricultural business actors, complex and insecure tenure arrangements, low access to appropriate technologies, infrastructure, financial services, and markets also need to be taken into consideration in determining the type of agricultural development.

Irrigation technology in Indonesia has evolved over time and is tailored to the products demanded by both local and regional markets. Irrigation is built based on five (5) irrigation pillars, namely: (i) water availability; (ii) infrastructure; (iii) irrigation management; (iv) irrigation institutions; and (v) human doers. The five elements must be mutually correlated, related and interrelated so that it can be said that irrigation is a system. Gravity-based surface irrigation is the longest applied irrigation technology, even starting in the era of the ancient kingdom in Indonesia. Water is carried from the source to the land through open channels either by lining or through pipes with low heads. The water source comes from reservoirs (rivers) or springs and groundwater. In conditions where gravity systems are not possible, pumps are used to raise water to the field. When water resources are limited, some farmers in a Water User Farmer Association (Perkumpulan Petani Pemakai Air/P3A) apply water-saving irrigation, such as sprinkler irrigation or drip irrigation, either based on local wisdom or imported technology. P3A is an institution in the field of irrigation that is protected and fostered based on the 2007 Public Works (PU) Regulation.

In lineTogether with the Ministry of Public Works, which builds irrigation network facilities and infrastructure for agriculture, the Department of Agriculture is responsible for developing agriculture into an independent, developed, and prosperous sector by increasing food security and agricultural competitiveness. The collaboration of these two ministries has resulted in the development of agricultural technology that characterizes Indonesia, namely appropriate technology for small-scale farmers, while productive and technology-intensive agriculture is developed for corporate circles.

Some farmer groups or joint farmer groups have successfully transformed into cooperatives and implemented productive technology to produce high-value agricultural products, as seen in areas like Cipanas, Cianjur, and Sukabumi. These cooperatives employ greenhouse systems, drip irrigation, and automatic control to produce high-value products as their main business and involve farmers as landowners to maintain crops or produce products with specific specifications. Of course, Although the quality of these farmers' produce varies, but it can still meet market demand after undergoing a sorting process.

3.1.1 Current State of Agricultural Technology in Sukaraja District, the Regency of Sukabumi

The majority of Sukabumi's farmers engage in traditional farming methods; this includes manual labor for planting, irrigating, and harvesting. While traditional methods dominate, there is's an increasing interest in modern technologies among the farming community (Rachmawati, 2021), particularly the younger, more educated demographic . A segment of Sukabumi's farmers, especially in Sukaraja, are open to and enthusiastic about integrating new technologies into their farming practices to enhance productivity and sustainability. Although, there are barriers to widespread adoption, including limited access to technology, financial constraints, and a need for more education and training on modern farming methods.

Generally, the Sukaraja District in the Sukabumi regency is not water-stressed, but certain periods during the year, particularly in extended dry seasons, pose challenges for water availability. Farmers often rely on water sourced from distant areas through pipes, and while rice fields with technical irrigation systems face fewer issues, other crops might be more vulnerable during dry spells.

In addition to staples like rice, there is's a trend toward cultivating high-value crops such as flowers, which require more precise agricultural practices. Farmers in Sukaraja cultivate a diverse range of crops, from chili, tomatoes, and onions to other horticultural products, each with its specific needs and challenges.

Young generation of farmers in Sukaraja, who are more educated and tech-savvy, are more likely to adopt and benefit from modern agricultural technologies. They can be crucial in driving the adoption of new technologies, serving as early adopters and influencers within their communities. Technologies that allow for precise soil monitoring and efficient irrigation are particularly relevant in Sukaraja, where a mix of crops is cultivated, and water management is crucial.

To predict the farmer's adoption of agricultural technology, we need to see the gender composition or capacity to contribute to the economy in this district. One measurement is based on The Gender Empowerment Index (GEI) which describes women's contribution to economics and politics and comprises three (3) indicators, namely women in the workforce, women in decision-making power, and women representatives in Parliament. Based on GEI, Sukabumi District is 57.45 and 61.52

for 2021 and 2022. The score shows that women in this district have moderate contributions to public work through their income, structural position in the formal organization, and political power. It can be seen from the number of women farmers in Sukaraja Subdistrict in agriculture sectors that are significantly lower than men which is 605 women (10%) from the total number of farmers households is 6129 people (BPS Kabupaten Sukabumi, 2023). It means that women involved in agriculture practices should be determined by the technological implementation because they can work in public.

Agricultural technology is not always easy to be accepted by many social groups in the farmer's community. There are 13.12 million farmers who use modern agricultural technology and digital (BPS, 2023a) Regarding the usage of this technology and digital based on farmer's age, farmers who are more than 39 years old are 80,24% and less than 19 years old are 0,04% (BPS, 2023a) while farmers who are between 19-39 years old are 21,93% (BPS, 2023b). The number of technologies in Sukaraja Village has increased to 5 both for 2020 and stabilized in 2021 from 0 in 2019 (BPS Kabupaten Sukabumi, 2023). There is a potential number of farmers to adopt agricultural technology in the future, both for men and women.

Even though women's involvement in agriculture exists, their adoption of agricultural technology is lower than men's (Aduwo et. al., 2019). The case in Sukaraja shows no similar condition because women farmers In Sukaraja still can adopt agricultural technology since women farmers can gain benefits from it. However, they have a risk of being marginalized in the future from the application of irrigation technology. Women farmers in chili commodity from the laborer class (*buruh tani in Bahasa Indonesia*) in Sukaraja spray manually with other four people for 1 ha twice daily in the furrow irrigation with a lot of moving the water by using watering pots. They are vulnerable to being marginalized when the owner tries to use the sprinkler irrigation method when the effect is decreasing the women's work twice a day. Women who are involved in paddy commodities also practice turning off the irrigation pipe by sprinkling. After that, they can do another activity, including non-farm activity, namely managing their grocery store.

These women's capacities need to be determined since in the routine productive activities in the land there are gender inequality issues in gender relations in agriculture, namely stereotype and subordination. The stereotype existence of a stereotype that leads women to be more involved in "*ligh not heavy"*activity than men. Women from the same farmer's group can be laborers in these activities that work from morning to noon with a revenue of IDR. 50.000. It is lower than men who paid more for this because they also provided the cigarettes and lunch from the farmers who owned the business (contractor). In other hand, women farmers who are laborers even can has more productive time than men/husband going to their farm since men usually have non-farm activity outside the village. The claim for this subordination issue is that women are involved in several times where the plant is in large areas, so they still can have monthly stable revenue.

3.2 Key Market Segments for Integrated Technology

The agricultural extension programme coordinated by the Ministry of Agriculture has successfully increased the capacity of farmers in the agricultural production system in some areas of Indonesia (Rasyid, 2015). While some farmers in certain areas may be hesitant to adopt new practices from the extension program, others find them valuable. Conversely, some farmers rely heavily on government assistance due to factors like limited access to resources or market inefficiencie. Areas that are satellite cities adjacent to large urban areas, such as the national capital, provincial capitals, and other business centers, are regions with high success rates as the subrubs can play role in food supply for the urban area (*Can Urban Agriculture Provide Enough Food for Big Cities?*, n.d.; de Bruin et al., 2021). The open-minded, market-savvy, and innovative nature of the community is an important element in the success of these capacity enhancement programmes.

Agricultural areas specializing in food crops and horticulture with strong institutions, whether Water User Associations (P3A) or farmer groups, have great potential to adoapt the proposed integrated technology. These regions usually plan for year-round planting, implement intensification programmes, and produce high-value exotic products where demand is always present but fluctuated. The farmers are accustomed to using agricultural technology related to water provision and agricultural production and are aware that price fluctuations can provide opportunities for profit. These price fluctuations are related to off-season demand or when supply is limited. Factors such as high labour costs and limited water quantity during times of high demand for products with specific specifications increase the potential for the use of this integrated technology.

Key market segments for integrated agricultural technologies can be the different groups that could significantly benefit from, or influence the adoption of, soil monitoring, automatic irrigation, and fertigation technologies:.

- **Smallholder Farmers**:
  - Smallholder fFarmers often manage a few acres of areas., These farmers typically rely on traditional farming practices and have limited access to capital and technology. They require affordable, scalable technology solutions and face barriers such as lack of knowledge, financial constraints, and access to markets.
- **High-Value Crop Producers**:
  - High-vValue cCrop pProducers contribute substantially to the local and national economy by producing crops that command higher market prices. Precision agriculture technologies are crucial for them to maintain the high quality and yield of their crops.
- **Water-Stressed Regions**:
  - Areas where water scarcity significantly impacts agricultural productivity and sustainability. Technologies that optimize water use and improve irrigation efficiency are critical for these regions.
- **Young and Progressive Farmers**:
  - This segment includes the younger demographic, more educated and open to adopting new technologies. Encouraging this group involves demonstrating the economic and operational benefits of integrated technologies.

- **Government and NGO Projects:**
  - Initiatives that aim to improve agricultural productivity and sustainability through technology. Potential of expanding projects to include more integrated technological solutions and cover more areas.
- **Research and Education**:
  - Research institutions often explore new agricultural technologies and their applications. There are opportunities for collaboration between the agricultural sector, technology providers, and academic institutions to foster innovation and adoption.

In Sukaraja District, the Regency of Sukabumi, agriculture is primarily on a small scaled, with farmers cultivating both staple crops and high-value economic plants like flowers. Besides growing chilis, tomatoes, onions, and other horticultural products, they also cultivate rice and secondary crops (*palawija*). Generally, the area is not prone to water scarcity, but there are periods of water shortage during extended droughts. For some lands, water is sourced from quite a distance through pipes. But for rice fields with technical irrigation, drought is not a significant issue.

During a visit toin Sukaraja there was a young and relatively well-educated farmer. The young farmer show enthusiasm for new technologies that can enhance agricultural production performance. , and hopefully there are more enthusiast farmers. The introduction and training of new technologies are areas where donor support can significantly aid. With their openness to innovation, there i's a good opportunity to introduce the integrated technologies that not only improve production but also serve as a basis for ongoing research and development.

Implementing integrated technology can be an excellent tool for monitoring and furthering agricultural research and development in Sukaraja. With a population ready to embrace new methodologies and the presence of water during critical times, integrated soil monitoring and automatic irrigation with fertigation could significantly boost the efficiency and productivity of small-scale farming in this region. The combination of a favorable demographic, technological openness, and the specific agricultural profile of Sukaraja makes it an ideal candidate for the successful adoption of integrated agricultural technologies.

3.3 Demand and Future Market

The demand analysis for integrated technology for Climate-Smart Agriculture (CSA) is based on population size, the number of foreign workers, the economic level, and the population's perception of high-quality products and green technology. Each of these components correlates positively with the demand for integrated technology for CSA. This means that as the population increases, the demand for integrated technology will also increase due to the rising need for food. Similarly, as the number of foreign workers in a region increases, the demand for specific products associated with their country of origin also grows. Although it is easier to import, this market potential can be met by integrated technology, at a certain level. In a high economic condition, public perception can change, especially regarding idealism, such as about quality food or environmentally friendly technology. Ultimately, a high economic level encourages society to adopt this integrated technology related to CSA.

Many countries all over the world have planned to accept climate smart agriculture (CSA) approach, which combines set of technologies and practices, to make improvements in agriculture (Hussain et al., 2022). Components related to CSA-related technology are expected to increase in the future. Thus, the demand for integrated technology will increase also in the future. The Indonesia's population in Indonesia in 2050 is expected towill reach 328.9 million people or around 22% growth based on the results of the 2020 Population Census (SP2020) which was 269.6 million people (*BPS: Penduduk Indonesia Diproyeksi Capai 328,93 Juta pada 2050*, t.t.). More specifically, Jakarta's population growth, which is an attraction for the growth of agricultural businesses in the surrounding area, is 2% per year (*BPS Provinsi DKI Jakarta*, t.t.). The number of foreign workers in Indonesia also increases by around 11.7% per year (Figure 3.1) (*Tenaga Kerja Asing dan Pertumbuhan Ekonomi Nasional*, t.t.). However, the growth of foreign workers fluctuates every year, and in 2022 will reach 26% (*Jumlah Tenaga Kerja Asing di Indonesia Melejit 26,36% pada 2022*, t.t.).

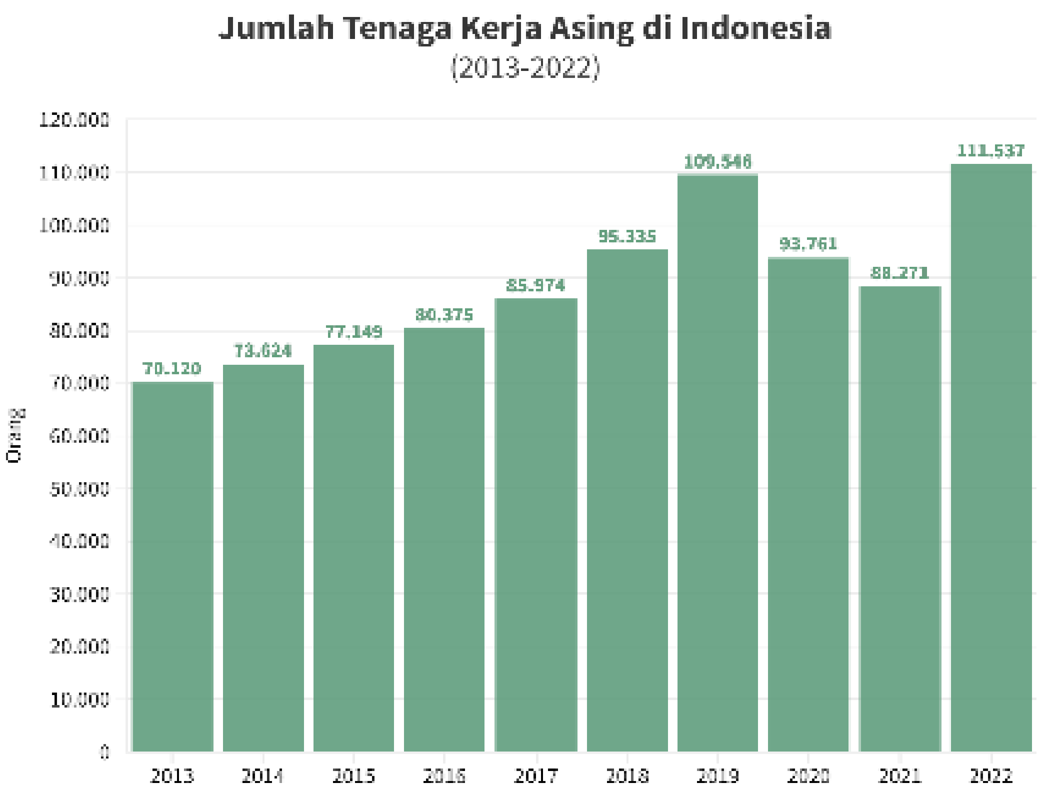


Figure 3.1 Foreign workers in Indonesia (2013-2022)

The Indonesian economy in 2024 is projected to continue to slow down. This allows the government to correct economic growth midway, which is currently projected at 5.2% growth. (*Proyeksi Perekonomian Indonesia 2024*, t.t.). Despite this, public perception is estimated to still experience a positive trend towards demand for integrated technology related to CSA. Understanding the concept of green, halal and healthy, shows a significance value of 0.00 < 0.05 and an R^2 value of 0.295, which means religiosity and perceived product quality contribute 29.5% to purchasing decisions (Azizah, 2023). Economic growth also has a significant influence on halal and healthy lifestyles in society, especially on the development of organic agriculture. In the application of organic farming there is a prohibition on the use of synthetic inputs such as synthetic fertilizers and pesticides, veterinary medicines, genetically modified seeds and breeds, preservatives, additives and irradiation. Healthy and highly nutritious food can be produced on organic farming so that it is useful for fulfilling daily needs. On the other hand, plants that are managed using organic farming principles will have a high need for integrated technology to ensure productivity (*Meningkatkan Minat dan Pemahaman pada Pertanian Organik*, t.t.).

On the other side, there are potential obstacles to the widespread adoption of integrated technology related to CSA, such as cost levels, technology, infrastructure limitations, knowledge gaps, climate and environmental changes, and government policies. In general, these obstacles can be controlled by government policy, either directly or by reducing their impact. However, specifically for climate and environmental change, this requires broad community participation because it is the main parameter of this integrated technology planning.

4 Institutional Reforms for Technology Adoption

Agricultural institutions are norms or customs that are structured and patterned and practiced continuously to meet the needs of community members who are closely related to the livelihood of agricultural fields in rural areas. In the life of the farming community, the position and function of farmer institutions are part of social institutions that facilitate social interaction or social interplay in a community. Farmer institutions also have a strategic point (entry point) in driving the agribusiness system in rural areas In doing the business, if the farmer farms individually, then he can be on the weak side because individual farmers will manage a farm with a small and scattered arable area and low capital ownership. Therefore, strengthening institutions through farmer groups should be a priority for the government. This is because group participation can make farmers stronger, both in terms of their organizational capacity and access to capital. The institutional development of farmers in rural areas was set up born to meet the social needs of their communities. It is not linear, but tends to be the individual needs of its members, in the form of: physical needs, security needs, social relationship needs, recognition, and recognition development. Including organizations, and sets of rules and laws require adjustment so that opportunities for every citizen to act as a subject in the development at the core of the movement can grow in all areas of his life.

In addition, it must also pay attention to the elements of the order in the village, both in the form of soft elements such as humans with their value systems, institutions, and technostructures, as well as those in the form of hard elements such as the natural environment and resources, a dynamic identity that always adapts or grows and develops. Empowerment means preparing rural communities to strengthen themselves and their groups in various ways, ranging from institutional, leadership, socio-economic, and political matters using their own cultural bases (Taylor & Mackenzie, 1992). Farm institutions have the potential to increase productivity and increase the income and welfare of farm.

4.1 Existing Institutional Frameworks and Policies in Agriculture.

In the agricultural system, it is also known as supply chain institution, which is a management relationship or work system that is systematic and mutually supportive among several supply chain partnership institutions of a commodity. The institutional component of supply chain partnerships includes actors from all supply chains, applicable mechanisms, patterns of interaction between actors, and their impact on the business development of a commodity as well as for improving the welfare of 9 actors in the supply chain. The institutional form of agricultural supply chains consists of two patterns, namely general trade patterns and partnership patterns. The bond between farmers and traders is generally a subscription bond, without a binding agreement contract between the two and relying only on trust. Farmers and traders on this pattern often bond capital loans. Meanwhile, the agricultural supply chain partnership pattern is a working relationship between several supply chain actors who use the mechanism of agreements or written contracts within a certain period of time. In the contract an agreement is made that will be the rights and obligations of the parties involved (Marimin & Maghfiroh, 2010).

The government already has regulations regarding the development of farmer groups, namely the Regulation of the Minister of Agriculture of the Republic of Indonesia Number 67/PERMENTAN/SM.050/12/2016 concerning Farmer Institutional

Development. Based on the regulation, farmer empowerment is carried out through training and extension activities with a group approach. Extension activities through a group approach to encourage the formation of Farmer Institutions that are able to build synergy between farmers and between groups in an effort to achieve business efficiency.

Furthermore, in an effort to improve the ability of the Poktan (*of Kelompok Tani* or Farmers Group), coaching and assistance are carried out by Agricultural Extension Officers, by carrying out an assessment of the Poktan Capability Classification on an ongoing basis that is adjusted to its development conditions. The characteristics of the Poktan are non-formal Farmer Institutions with the following criteria:

- Poktan Features
  - knows each other, gets along and trusts each other among members;
  - hasve the same views and interests and purpose in striving for agriculture; And
  - hasve similarities in tradition and / or settlement, area / expanse of business, type of business, economic and social status, culture / culture, customs, language and ecology.

There are elements that become Farmer Group Association (Gabungan Kelompok Tani / GAPOKTAN), namely:

- the area of *usahatani* (farming operation or simply “farming”) which is a shared responsibility among the members;
- activities whose benefits can be felt by the majority of members;
- cadres who are able to mobilize farmers with leadership accepted by members;
- distribution of duties and responsibilities among members based on mutual agreement; and
- motivation from community leaders in supporting established programs.

This regulation also explains the functions of athe Poktan, namely:

- learning classes:
  - Poktan is a teaching and learning forum for members to improve knowledge, skills and attitudes in order to grow and develop into independent farming through the use and access to information and technology resources so as to increase productivity, income and a better life;
- cooperation vehicle:
  - Poktan is a place to strengthen cooperation, both among fellow farmers in the Poktan and between groups as well as with other parties, so that it is expected that farmers will be more efficient and able to face threats, challenges, obstacles and be more profitable; and
- Production production Unit:

- The farming of each member of the Poktan as a whole is a business unit that can be developed to achieve business economies of scale, by maintaining quantity, quality and continuity.

Farmer institutions are developed to meet the business feasibility of economies of scale and business efficiency, so that they function as business units providing production facilities and infrastructure, farming/production units, processing business units, marketing business units and microfinance business units (savings and loans).

At the development stage, Farmer Groups (Poktan) can join to become more economically scalable and business efficient through the merger of farmer groups, or Gapoktan institutions (Joint Farmer Groups). The Association can provide information, technology, and capital services to its members and establish cooperation through business partnerships with other parties. The merger of Poktan into Gapoktan is expected to make the Farmer Institution strong and independent and competitive.

Farmers group consist of consist of men and women farmers. However the number of women as members can be less than 30% of the total farmers' group number and women also rare who become officials of farmers' groups (Kementerian Pertanian 2021). Farmers group officials frequently have more access and control than other members to use farmers group connectivity to gain more benefits from government aid. Women farmers usually have access to monthly meetings, but their aspirations related to their farm and group can depend on their husbands, who are also farmers' group members.

Women farmers unified in the women farmers group as a different entity from the farmers group. They dominantly do activities related to post-harvest processing or grow their house yard like vegetables like chili and tomatoes where the results can they consumed by themselves or sold to add to their household income. These groups could be a source for women to be empowered since many programs to increase household income through training and socialization are done through these women's groups (Afifah & Ilyas, 2021).

Every month, farmers and women farmers groups usually held a meeting where the extension also visited them to facilitate the planning activity for their groups. This meeting is beyond formal regulation, as suggested by the Minister of Agriculture of the Republic of Indonesia Number 67/PERMENTAN/SM.050/12/2016 concerning Farmer Institutional Development. Still, informally farmers' group also provide an arisan as a local activity, like a lottery club as a routine activity (Munggaran et. al., 2021). It can be beneficial for member and also organizations that it maintains their solidarity and strengthens their identity as farmers or economic exchange to help farmers who need the cash.

4.2 Recommendations for Facilitation of Technologically Adoption

Based on the function of the Farmer Group, where the farmer group is a forum for teaching and learning for members to improve knowledge, skills and attitudes in order to grow and develop into an independent Farmer through the use and access to sources of information and technology so as to increase productivity, income and a better life; and can strengthen cooperation in order to achieve efficiency to achieve business economies of scale, by maintaining quantity, quality and continuity.

Therefore, farmer groups are institutions that can be used to disseminate technology or introduce technology such as technology related to climate smart agriculture. For example, with precision technology, where this technology requires quality human resource skills. With the existence of farmer groups, farmers will be introduced through development, so that they are more effective in the introduction and adoption of technology.

The women, both in the farmers group or women farmers group, are potential human resources in these institutions to be influenced by information about agricultural technology. It is also supported by their capacity to operate digital device since they can using their mobile phone with social media and their availability time of women in productive time than men/husband going to their farms since their husbands usually have non-farm activities outside the village. However, the workshop meetings need to be based on women's allocation of time. So, the increasing capacity program from stakeholders to running the technology in gender mainstreaming can start from these social institutions. Even women over 39 years old can be motivated to learn new technological devices that will benefit them.

In adopting technology for farmer groups requires quite intensive assistance, this is because the technology to be introduced includes new technology for farmers, where farmers usually use conventional or traditional technology. Assistance is needed so that technology adoption activities do not wither before they develop. Some problems related to the adoption of technology from farmers and technology management are:

- Farmers are still reluctant to change technology and feel that they do not need new technology. Where farmers are not unwilling to change to more modern technology, it is's just that farmers are reluctant to learn again in using newer technology.
- Farmers do not understand correctly how alsintan works. Farmers are still afraid of various kinds of news that the use of modern alsintan will harm farmers.
- Agricultural extension workers are also not optimal in managing and understanding how alsintan works. Extension workers will better assist farmers in the cultivation process, still lacking in assistance in alsintan management.
- The high price of Agricultural machiner (*Pemanfaatan Alsintan Pascapanen Padi | Dinas Pertanian*, t.t.) .

Based on these problems, assistance is needed so that technology adoption can be carried out and applied sustainably. This Farmer Empowerment is based on the REGULATION OF THE MINISTER OF AGRICULTURE OF THE REPUBLIC OF INDONESIA NUMBER 67/PERMENTAN/SM.050/12/2016 CONCERNING FARMER INSTITUTIONAL DEVELOPMENT, carried out through training and extension activities with a group approach. Extension activities through a group approach to encourage the formation of Farmer Institutions that are able to build synergy between farmers and between groups in an effort to achieve business efficiency. Furthermore, in an effort to improve the ability of the Poktan, coaching and assistance are carried out by Agricultural Extension Officers, by carrying out an assessment of the Poktan Capability Classification on an ongoing basis that is adjusted to its development conditions. In addition, several research institutions, universities, NGOs or private parties provide assistance to farmers.

Smart farming also means agriculture that is Specific, Manageable, Adaptive, Remarkable, and Traceable. Specific in terms of the system, production technology, and products produced. Manageable means it can be applied and managed by farmers. Adaptive refers to the system and production technology at the location. Remarkable means capable of significantly increasing productivity, efficiency, and product quality. Traceable indicates that the activities can be easily tracked. In building smart farming, precision agriculture is an important component and a crucial initial step. Precision agriculture is a farming management system aimed at increasing productivity and resource use by enhancing outputs or reducing inputs and adverse environmental impacts by utilizing information technology. (Balafoutis et. al., 2017).

Precision agriculture is key to producing the best and maximum harvest results with the proper use of inputs in terms of quantity and timing, while also considering environmental sustainability. Based on the Masterplan for Precision Agriculture Development compiled by the Directorate General of The Directorate General of Agricultural Infrastructure and Facilities (Ditjen Prasarana dan Sarana Pertanian (PSP)), Ministry of Agriculture (2023), precision agriculture management implementation involves planning, execution, monitoring, and evaluation (Jamil et. al., 2023). Activities are carried out participatively and integratedly by involving all parties, namely:

- Technology providers (Himpunan Bank Milik Negara or Association of State-Owned Banks in Indonesia (HIMBARA), Kementerian Komunikasi dan Informatika or Ministry of Communication and Informatics (Kemenkominfo) , private).
- Providers of facilities and infrastructure (Ditjen PSP Kementan).
- Technical assistance (Ditjen PSP Kementan, other technical Ditjens).
- Human resource assistance (Human Resources Agency Kementan).
- Business financing (KUR, Commercial Credit, Social and Environmental Responsibility/TJSL (SOEs), Corporate Social Responsibility/CSR (Private), and Insurance (PT Jasindo)).
- Off Taker = PPI (*Perusahaan Perdagangan Indonesia*) and BUMN Pangan (Badan Usaha Milik Negara Pangan, State-Owned Enterprises for Food).

Precision agriculture management in one area is essentially run by farmer corporations. In other words, the farmer corporation becomes the center of management and decision-making for the implementation of precision agriculture in the development location. The formation and development of farmer corporations begin with the consolidation of agricultural business and human resources, as well as the development of farmer institutions and farmer economic institutions into farmer corporations.

The role of management run by farmer corporations involves compiling technical recommendations and planting plans that require precision mapping; farming activities require input price data and activity implementation; monitoring activities and early warning systems require data on weather, plant conditions, water availability, and HPT; and harvesting and transportation activities require processing units and transportation of raw products. In addition, farmer corporations also become communication and coordination centers with all stakeholders. Overall, the management of precision agriculture implementation in agricultural areas starts with initiation and cultivation activities. At this stage, the establishment of guidelines, diagnostic analysis, and business plans, budgeting, and socialization are carried out. Budgeting and socialization include the preparation of plans and the provision of government program assistance and budgets. Meanwhile, socialization is the activity of communicating development plans to the parties, including the determination of the implementing organization.

The process of forming farmer corporations through consolidation starts from farmers consolidated into a farmer group (Poktan), then Poktan is consolidated into a joint farmer group (Gapoktan) and then transformed into farmer corporations.

4.3 Case Studies of Successful Institutional Reforms in Similar Contexts

In 2021, the Ministry of Communication and Informatics (Kominfo), through the Director-General of Informatics Applications (Dirjen Aptika) and the Directorate of Digital Economy, facilitated farmers to go online in Sukabumi Regency, specifically in Selaawi Village, Sukaraja District. The Ministry of Kominfo, through Dirjen Aptika, facilitated the farmers with the Precision Agriculture program (*Pertanian Presisi Berbasis IoT Tingkatkan 30% Hasil Petani Sukabumi – Ditjen Aptika*, t.t.). This includes the Internet of Things (IoT)-based Precision Agriculture 4.0 program in collaboration with the startup PT Mitra Sejahtera Membangun Bangsa (MSMB). The Ministry facilitated farmers in Selaawi Village, Sukaraja District, Sukabumi Regency, with the Precision Agriculture program. Sukabumi, West Java, became the third city in the Movement Towards Agriculture 4.0, showcasing the RiTx Soil & Weather Sensor technology, enabling real-time monitoring of land conditions and expected to provide more measurable and precise agricultural data.

In Selaawi Village, Sukaraja District, Sukabumi Regency, precision agriculture adoption activities have already begun for rice commodities. This programme successfully increased agricultural yields by up to 30% Dry Harvest Grain (GKP), from 6.5 tons to 9 tons per hectare, through the use of devices and applications for agricultural monitoring. The equipment used includes soil and weather sensors, enabling farmers to obtain more precise information on fertilizer composition, planting and harvesting times, and pest predictions. Dirjen Aptika collaborated with the farmer group association (Gapoktan) and field agricultural extension officers (PPL). Approximately 56 farmers participated through Gapoktan Bibirintik.

Some challenges in the digitalization of the agricultural sector in Selaawi Village include the limited ability of the farmers and the outdated availability of devices (mobile phones). This is because most farmers belong to the older generation, while the younger generation prefers to work in factories. Additionally, the smartphones available are from 2015 with limited memory capacity, often causing the applications to hang and the pointers to jump around. After experiencing an increase in income, the farmers hope for the continuous digitalization of agriculture, with expanded program coverage and more benefits from digitalization.

This initiative involves collaboration between the Ministry of Agriculture (Kementan), the Ministry of Communication and Informatics (Kemenkominfo), PT Mitra Sejahtera Membangun Bangsa (PT MSMB), and Bank Negara Indonesia (BNI). The Sukabumi Government welcomed the implementation of both mechanization and digitalization technologies, which can help improve farmers' productivity. BNI acted as a financing institution for the farmers, providing them with affordable and easy access to financing, accompanied by guidance utilizing RiTx smart farming technology throughout the cultivation process through the People's Business Credit (KUR) program and BNI's Corporate Social Responsibility (CSR) for agricultural technology. BNI's CSR assistance included the RiTx Soil & Weather Sensor technology, useful for real-time monitoring of land conditions and expected to provide more measurable and precise agricultural data. This method is expected to help farmers increase efficiency and productivity.

As for the production output, the farmers' rice will be absorbed by BNI's partner offtaker. Consequently, it is hoped that in the future, farmers will become more productive, efficient, and effective, their produce will be more accessible to the market, and ultimately, they will become professional and high-quality farmers.

5 Access to Finance for Agricultural Technologies

According to (Mangunwijaya & Sailah, 2009), agriculture is defined as a subsystem within human life that focuses on producing plant and animal materials using natural resources optimally, with the dual goals of enhancing human well-being and preserving environmental sustainability. The core subjects of agricultural science, particularly in reproductive cultivation, encompass a range of activities that form the backbone of effective farming. These include preparing the land for cultivation, planting seeds for crop growth, and managing the overall cultivation process. Additionally, maintaining crops through various stages is crucial, as is harvesting the produce from cultivation and enhancing the quality of the harvested crops. Managing post-harvest processes and marketing the agricultural produce are also essential components that complete the cycle of agricultural production. Each of these activities plays a vital role in ensuring a successful and sustainable agricultural endeavor.

5.1 Current Financial Landscape for Agricultural Technology Investments

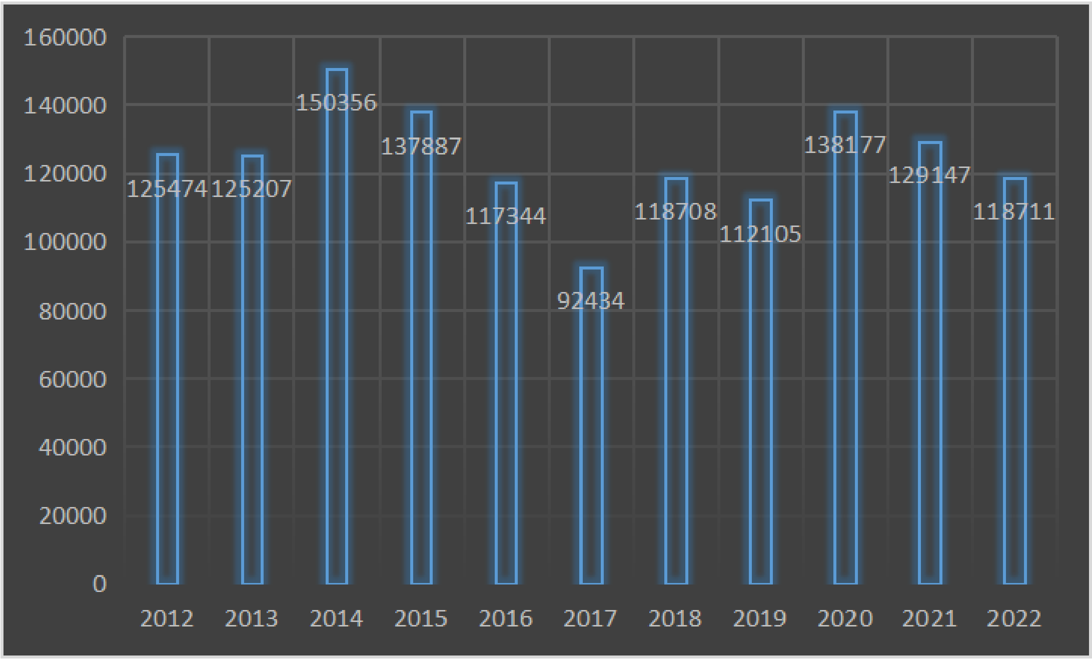
This section describes the difference in treatment in cultivation between conventional models and integrated agricultural technology models.   An example used as a case is for melons, where the use of integrated agricultural technology in Indonesia is also widely carried out in melon cultivation, which is also cultivated in Sukabumi. This is because melon is one of the profitable commodities and is widely consumed by the community in daily activities or in hotels., so the needs of melons.

The attraction to growing them melons is that the melon plants are short-lived (a plant takes a; Approximately within three (3) months toit can produceharvest), the price of fruit is relatively stable and of high economic value (Aminudin & Supardi, 2009). There are even melons that have a harvest period of only two (2) months, namely golden melons, where with a land area of 2,800 square metersm^2, it can produce about 11 tons. Where one golden melon weighs about 1.5 kilograms to 2.5 kilograms with a price per kilo of IDR 10 thousand at the farmer level (*Petani Lamongan Ini Sukses Raup Cuan Berkat Melon Golden*, t.t.).

Melon plants (*Cucumis melo* L.) are agricultural commodities with high economic value. The most widely grown melons in Indonesia are green melons, honey melons, orange melons, and yellow melons. Melon is a fruit that is included in the type of pumpkin – Labuan or cucurbitaceae. Unlike green melons which have a softer and more juicy flesh texture, yellow melons have a harder and drier texture. In the process of planting yellow melons require more special attention and also more care, so this is what makes the quality of yellow melons more awake.

Data in 2020 shows melon production in Indonesia reached 138,177 tonnes (*Badan Pusat Statistika*, 2020), but declined to 129,147 tons in 2021 (*Badan Pusat Statistika*, 2021) Furthermore, in 2022 it decreased again to 118,117 tons or decreased by 8.08% (Figure 5.1). This condition is one of them because melon harvests in some regions are disrupted by high rain intensity.

Meanwhile, East Java is one of the provinces that is famous as the largest melon producer in the country. Several areas that are melon centers in this province, including Tuban Regency, Ngawi Regency, Banyuwangi Regency, and Sumenep Regency.Melon plants have high domestic and international market potential with domestic consumption levels ranging from 0.42-0.52 kg / capita per year (Andarani, 2020).



Source: *BPS Indonesia* from Various Years

Figure 5.1 Indonesian melon production (2012 - 2022)

Melon cultivation is now not only done conventionally on open land, but can be done by implementing smart farming systems. One of them is hydroponic melon cultivation in the greenhouse. This is because conventional melon cultivation has several problems, such as using large land or land, the process of preparing planting material requires tillage, plowing the land or irrigation takes a long time. In addition, conventional melon cultivation requires planting rotation time because it affects weather or climate changes. Conventionally grown melons are not able to be exposed to rain continuously, where melon plants are very sensitive to high rainfall. Conventional melon plants require control of attacks from pests and diseases due to the season (Ritschel *et al*., 2004).

Melon cultivation by conventional methods is usually carried out at the end of the rainy season (close to dry season). This is because melons planted in the rainy season will result in bland fruit. Melon plants are not able to be exposed to continuous rainwater. This is what makes some melon farmers start using greenhouses in cultivating melons.

The following are the advantages and disadvantages of the melon melon hydroponic system in the greenhouse (*Kelebihan dan Kekurangan Budidaya Melon Sistem Hidroponik di Greenhouse - Hortikultura sariagri.id*, t.t.).

Advantages of the melon of the hydroponic system in the greenhouse:

- The substrate does not use soil or basic fertilizers. Growing melons hydroponically in a greenhouse does not require soil media so. This facilitates the planting preparation process because there is no need for tillage anymore.
- Can grow melons all year round. Hydroponic melon cultivation in the greenhouse can be done throughout the year without planting rotation because it is not

affected by weather changes. In contrast to conventional melon cultivation in open land which is generally the ideal time for planting at the end of the rainy season.

- Melon production is healthier. Hydroponic melon plants in the greenhouse do not require chemical pesticides in controlling pest and disease attacks, but can use a fumigation system to prevent pest and disease attacks on melon plants.
- Measurable nutrition and labor efficiency. When growing melons with a hydroponic system, automation becomes mandatory. Temperature, humidity of the room can be controlled automatically. The fertilization system can be automated so that there is no need to use human labor in fertilizing.

Meanwhile, for the disadvantages of melon cultivation, the hydroponic system in the greenhouse is:

- The investment cost at the beginning is greater. Higher initial investment costs are used for greenhouse manufacturing, cut and fill system assembly and automation systems.
- Pollination of plants need human help. The hydroponic system with greenhouses causes access to pollinating insects to be limited so that the melon pollination process must be assisted by human roles.
- However, this is not a big problem because it can be overcome by keeping pollinating bees in the greenhouse to help pollinate melon plants.

After knowing the advantages and disadvantages of conventional and hydroponics, the next is to compare the financial analysis between the two. Financial analysis of melon farming in Banjarbaru City (Nafisah et. al., 2020) taken as the case for conventional methods while for hydroponics or integrated farming, using financial analysis of melon cultivation in greenhouses in Denpasar City (BULAN et. al., 2022).

Based on the results of the study (Nafisah et.al., 2020) It can be known that the cost of production facilities in the implementation of melon farming in one planting season in Banjarbaru City has an average of IDR 7,062,624.00 per farm or IDR 18,585,850.00 per hectare. The largest cost of production facilities incurred is for the cost of purchasing fertilizers due to meeting the nutrients needed by melon plants. The most widely used fertilizer is pet-organic from chicken manure. For inorganic fertilizers SP-36, NPK Phonska, NPK Yaramila and TSP are not as widely used as organic fertilizers. Lime is also quite widely used to reduce acid levels in the soil, because the soil in Banjarbaru City is quite acidic. In the melon production process, not only using equipment but also using equipment to help the production process, including mulch, *ajir* (stake) and rope.

Melon farming land at the research site are all land with an estimated rental price of land used that applies to the research site, which is per wholesale (USD 6.50). So, the average cost of land loaned is IDR 1,316,667.00 per farm (USD 85.58) or IDR 3,558,559.00 per hectare (USD 231.30) per hectare.

The Unit of Man-Day of Labor (HOK) is used to measure the cost of labor within the family with a standard working time of 8 hours per day according to the work standards in the research area and according to the prevailing wage rate.

The cost of labor outside the family is measured in units of Man-Day of Labor (HOK) with a standard working time of 8 hours per day according to the work standards in the research area and according to the prevailing wage rate.

Table 5.1 Table 5.2 Average direct costs of melon farming per growing season period (4 months)

No	Component	Cost per Average	Cost per Hectare
	Income		
A	Explicit Costs		
1	**Cost of Production Facilities**	**7.062.624**	**18.858.850**
	Seeds	541.667	1.425.439
	Pupuk	**3.973.916**	**10.457.675**
	-Pet organic	1.237.250	3.255.921
	-SP36	690.000	1.815.789
	-NPK Phonska	458.333	1.206.140
	-NPK Yaramila	780.000	2.052.632
	-TSP	455.000	1.197.368
	-Kapur	353.333	929.825
	Cost of Medicines	**2.372.041**	**6.242.212**
	Insecticide		
	-Prevathon	452.083	1.189.693
	-Stadium	250.000	657.895
	-Metha	200.000	526.316
	Fungisida		
	-Antracol	945.000	2.486.842
	-Acrobat	213.500	561.842
	-Ziflo	311.458	819.624
	Tractor Rent	175.000	460.526
2	**Equipment Cost**	**172.164**	**453.062**
	Mulch Plastic (roll)	80.750	212.500
	Ajir (pcs)	86.518	227.679
	Plastic rope (m)	4.896	12.884
3	**Labor Cost**	**753.125**	**1.981.908**
	Land Processing	243.750	641.447
	Planting	43.750	115.132
	Plant Care	265.625	699.013
	Harvest	200.000	526.316

No	Component	Cost per Average	Cost per Hectare
4	**Depreciation Cost**	63.848	168.021
5	**Implicit Costs**	3.755.787	9.883.651
	Land	1.316.667	3.464.912
	Labour (HOK)	2.253.125	5.929.276
	Interest costs on farmer capital	185.999	489.462
	Income	34.937.500	91.940.789
	Production	5.375 kg	14.527 kg
	Price	IDR 6,500	IDR 6,500
	Total Cost	11.807.549	31.345.492
	RCR	2,95	2,93
No	**Component**	**Cost per Average**	**Cost per Hectare**
	Income		
A	Explicit Costs		
1	**Cost of Production Facilities**	**7.062.624**	**18.858.850**
	Seeds	541.667	1.425.439
	Pupuk	**3.973.916**	**10.457.675**
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	-Antracol	945.000	2.486.842
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	Tractor Rent	175.000	460.526
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	Mulch Plastic (roll)	80.750	212.500
	Ajir (pcs)	86.518	227.679

No	Component	Cost per Average	Cost per Hectare
	Plastic rope (m)	4.896	12.884
3	**Labor Cost**	**753.125**	**1.981.908**
	Land Processing	243.750	641.447
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	Land	1.316.667	3.464.912
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	Interest costs on farmer capital	185.999	489.462
	Income	34.937.500	91.940.789
	Production	5.375 kg	14.527 kg
	Price	IDR 6,500	IDR 6,500
	Total Cost	11.807.549	31.345.492
	RCR	2,95	2,93

Source: (Nafisah et.al., 2020)

In this study, the capital for melon farming comes from the owner's equity. The interest cost of the owner's equity is included in the implicit cost component, where the interest rate is based on the People's Business Credit (KUR) system from BRI bank at 7% per year, effective since December 31, 2018. Thus, for a single planting season period of 4 months, it amounts to 2.31%.

The total cost calculation is obtained from the sum of explicit and implicit costs. Therefore, from the calculations made, it can be known that the total cost incurred by respondent farmers in undertaking melon farming is quite substantial, amounting to IDR 11,807,549.00 per farming unit or IDR 31,072,498.00 per hectare.

Production is the output obtained from the cultivated melon farming. Meanwhile, revenue is the physical quantity multiplied by the prevailing price at the farmer level. The average production of melon farming is 5,375 kg per farming unit or 14,527 kg per hectare with an average selling price of IDR 6,500.00 per kilogram. Thus, the revenue from melon farming is obtained at IDR 34,937,500.00 per farming unit or IDR 91,940,789.00 per hectare.

Income is obtained through the difference between total revenue and total explicit costs, so the income received is IDR 26,885,738.00 per farming unit or IDR 72,664,158.00 per hectare.

The obtained RCR (Return Cost Ratio) is 2.96 for a single planting season, which is from January to April 2019. Furthermore, for the integrated agricultural model, which is based on research conducted by Bulan et al (2022) (BULAN et.al., 2022) the fee structure, receipts and benefits can be seen in this section.

The investment cost used in this study is the average of the respondent farmers' investment cost, which is IDR. 96,552,333. This is considering that in the

Experimental Garden, there is no investment cost for greenhouses commonly operated by farmers. The scale of the greenhouse used is 20 m x 21 m with a total of 800 planting points.

Table 5.3 Investment in Greenhouse Melon Cultivation

No	Information	Age Economists (Yr)	Unit	Unit Price (IDR)	Total Fee (IDR)
1	Greenhouse	10	1	96,552.,33	96,552,333
2	Hydroponic installation	7	4	4,650,000	18,600,000
3	Gunting	1	5	20,000	100,000
4	Air pump	2	1	330,000	330,000
5	Man	2	5	50,000	250,000
6	The balance of seedlings	2	15	40,000	600,000
				Total	116,392,333

Table 5.4 Greenhouse Melon Cultivation Investment

No	Description	Economic Life (Years)	Unit	Unit Price (IDRIDR)	Total Cost (IDRIDR)
1	Greenhouse	10	1	96,552,333	96,552,333
2	Hydroponic Installation	7	4	4,650,000	18,600,000
3	Scissors	1	5	20,000	100,000
4	Water Pump	2	1	330,000	330,000
5	Bucket	2	5	50,000	250,000
6	Seedling Tray	2	15	40,000	600,000
				Total116,392,333	116,392,333

Source: (BULAN et.al., 2022)

The operational costs consist of the procurement of seeds, A&B mix nutrients, planting media, multivitamins, electricity, and water. Considering that melons can be harvested 60-75 days after planting (four harvesting periods per year), the planting period within a year is assumed to be four (4) times. The total annual operational cost can be seen in Table 5.5.

Table 5.5 Operational costs for greenhouse melon cultivation

Year	Total Cost (IDR)
1	8,868,200
2	17,736,400
3	17,736,400
4	17,736,400
5	17,736,400
6	17,736,400
7	17,736,400
8	17,736,400
9	17,736,400
10	17,736,400

Sumber: (BULAN et.al., 2022)

In this greenhouse melon cultivation business, Alisa F1 and Madesta F1 seeds are used. The cultivation is assumed to manage 800 planting points with an average production of one kg per plant. The revenue from hydroponic farming occurs in the first year, and it is assumed that there are only two planting periods with the selling price of the melon being IDR 20,000/kg. In the first year, production begins, but the results obtained are not yet optimal. This is because, in the first year, the frequency of planting is done twice compared to the following years. Considering that in the first year, the investment process is still ongoing, this leads to a less than optimal production process.

Table 5.6 Revenue from Greenhouse Melon Cultivation

Year	Planting Frequency in 1 Year	Production (Kg)	Price/Kg	Revenue (IDR)
1	2	1,200	20,000	24,000,000
2	4	2,400	20,000	48,000,000
3	4	2,400	20,000	48,000,000
4	4	2,400	20,000	48,000,000
5	4	2,400	20,000	48,000,000
6	4	2,400	20,000	48,000,000
7	4	2,400	20,000	48,000,000
8	4	2,400	20,000	48,000,000
9	4	2,400	20,000	48,000,000
10	4	2,400	20,000	48,000,000

Source:(BULAN et.al., 2022)

The feasibility of greenhouse melon cultivation analyzed using financial analysis methods with investment criteria includes NPV (Net Present Value), Net B/C, PP

(Payback Period), and IRR (Internal Rate of Return) (Gresya, 2015). The interest rate used is 5.5%.

Table 5.7 Financial Feasibility Analysis of Greenhouse Melon Cultivation

Criteria	Value	Conclusion
NPV	93,239,925	Feasible
IRR	24%	Feasible
Net B/C	1.97	Feasible
Payback Period	4.9	Feasible

Source (BULAN et.al., 2022)

Table 5.6 shows the NPV for greenhouse melon cultivation at an interest rate of 5.5% is IDR. 93,239,925. An NPV>0 indicates that the net revenue from greenhouse melon cultivation is greater than the total cost incurred, suggesting that hydroponic melon cultivation is profitable and viable. Furthermore, the IRR value is 24%, higher than 5.5%, which means it's feasible.

The Net B/C calculation at a 5.5% interest rate is 1.97, making greenhouse melon cultivation feasible and worth developing since the Net B/C > 1, with an investment payback period of 4.9 years.

Comparing both, the analysis for conventional methods uses income or farm business analysis, whereas for integrated farming models, a 10-year feasibility analysis is used. This means that for conventional methods, returns or profits can be realized within just one year, while integrated farming requires waiting for up to 4.9 years.

This difference is due to the higher initial investment for the integrated farming model, which reaches IDR 116.39 million, with the highest costs being for greenhouse installation. Additionally, in one year, the conventional model is conducted once, while integrated farming or greenhouse can occur up to four times.

This analysis reveals that farmers have limited funds, even for conventional models, and still require third-party funding. Integrated farming models require even higher funds. Therefore, an institution is needed to support these activities, especially for integrated agriculture where greenhouses are used for melon commodities.

This is also evident in the previous chapter on institutions for rice commodities, where funding in that activity was done in collaboration using KUR funds from Bank BNI, and the technology received CSR support from Bank BNI.

Based on the strategic plan of the Ministry of Agriculture, the financing instruments that are the focus of agricultural business development are:

- Optimizing the People's Business Credit (KUR) Scheme:
  - The KUR scheme is a government-initiated credit program aimed at providing affordable loans to small and medium-sized enterprises, including farmers. Optimization efforts focus on making these loans more accessible and tailored to the needs of the agricultural sector, including lower interest rates, simplified application processes, and flexible repayment terms.
- Developing Agribusiness Microfinance Institutions (MFIs):

- Agribusiness MFIs are specialized financial institutions that provide targeted financial services and products to the agricultural sector. Development efforts aim to enhance their capacity to serve farmers effectively, offering products such as microloans, savings programs, and insurance, along with financial education and advisory services.

- Facilitation of Agricultural Insurance programme:
  - The Agricultural Insurance program is designed to protect farmers from the financial risks of adverse events like natural disasters, crop failures, or market volatility. The facilitation of this program involves making insurance more accessible and affordable through subsidies, expanding coverage, and streamlining the claims process, thereby mitigating the risks associated with farming and encouraging greater investment in agricultural development.

5.2 Barriers to Financial Access

Finance is one of the capital factors in farming. Capital includes both capital in the form of money (geld capital), and in the form of goods (sac capital), such as machinery, goods, and so on (Riyanto, 2010). Agricultural capital in the micro sense is a factor of capital production that is channeled, managed, and controlled in an agribusiness company or a simple farm. Agricultural capital can be in the form of currency, checkable deposit or in the form of goods used in production activities in agriculture. Capital can be obtained from:

- Own capital –. Is capital obtained from self-reliance business or profits that are retained and reused.

- External capital –. It is capital from external parties, either in the form of institutions or individuals (investors).

External capital consists of:

- Bank financial institutions: A bank is an institution that acts as a financial intermediary between those who have funds and those who need funds, as well as an institution that functions to facilitate payment traffic. The main function of banking in general is to collect funds from the public.

- Non-bank financial institutions: This institution was established in 1973 based on the Decree of the Minister of Finance No. Kep. 38 / MK / I / 1972 which issued that these institutions can conduct the following businesses
  - raise funds by issuing a temporary letter
  - providing medium-term credit
  - holding temporary capital participation
  - act as an intermediary of an Indonesian company and a government legal entity;
  - act as an intermediary in obtaining participants or campaigns
  - as an intermediary to obtain experts and provide advice according to expertise
  - conduct other business in finance.

- Other financial institutions: . This institution consists of institutions outside the previously mentioned financial institutions whose activities are included in the activities of financing institutions, consisting of: Consumer Finance Company, Credit Card Company, Factoring Company, Leasing Company, Securities Trading Company, Venture Company, Pawnshop companies, Insurance companies.

5.2.1 Obstacles for Farmers

Access to credit is the ability of individual and group farmers to obtain capital facilities and financial services from banks/financial institutions. A household has access to a particular source of credit if it can afford to borrow from that source of credit, although for various reasons it may choose not to borrow (Diagne & Zeller, 2001).

There are several reasons for farmers' access to financial institutions, namely:

- Most farmers do not have a certificate for their land, farmers who have narrow land do not have a certificate for their land, this makes it difficult for farmers to access formal financial institutions because they do not have collateral determined by the Bank as one of the loan conditions.
- Credit procedures in banking are very complicated This complicated procedure causes farmers to be reluctant to access formal financial institutions. This assumption is also caused by the lack of understanding and knowledge of farmers in accessing formal financial institutions and the lack of counseling on credit procedures from the bank to farmers which causes farmers to consider the difficulty of banking credit procedures
- Fear of not being able to pay installments. High interest rates cause farmers to feel afraid to access formal financial institutions. Currently, banks apply interest rate and principal payments per month, in contrast to previously only applied interest rate payments. This is very burdensome for farmers, therefore farmers are reluctant to access formal financial institutions for fear of not being able to pay installments.
- Most aquaculture farms have a production cycle that does not recognize a monthly system. Similarly, with derivative businesses. Meanwhile, the credit return method from financial institutions still uses a monthly installment system. This causes a difference in cash flow, between the farm business and the bank business.

5.2.2 Barriers for Technology Providers.

The classification of technology providers can be classified based on the assets owned, namely small, medium and large entrepreneurs. For large businesses, it is relatively easier to access credit from financial institutions (bank and non-bank). As for medium and small entrepreneurs, there are barriers in accessing financial products. The causes are:

- Require formal documents, such as payslips for employees. Meanwhile, for small and medium enterprises, it is very rare to issue payslips according to bank standards.
- Requires marketable collateral , such as BPKB, fixed asset certificates.
- There are age restrictions.

- The distance of the business place is far from the bank service office. Especially for the Eastern part of Indonesia.
- Perceptions from prospective customers, who are afraid of being denied credit by banks.
- Bank loans are usury, ghoror and maysir
- Financial institution staff are not friendly
- There are no bank unit ATMs close to the business location.

5.3 Innovative Financing Models to Support Technology Adoption

Indonesian agriculture is embracing technological advancements, and various financing models are playing a crucial role in supporting this adoption. Government initiatives like the Assistance Task Fund and Central Fund provide essential financial backing. Additionally, the private sector is contributing through Environmental Social Responsibility programs and direct investments. Furthermore, Financial Technology has emerged as a game-changer, offering alternative funding options such as peer-to-peer lending and e-wallets. Notably, NGOs are actively involved in providing support and building resilience within the agricultural sector. This diverse landscape of resources empowers farmers and technology providers, ultimately propelling the adoption of agricultural technologies and driving the sector's development.

5.3.1 Government

The government has various financial instruments to support business. Judging Taking from the aspect of financial administration, there are instrumentsthe instruments are:

- The Assistance Task Fund (TP) is in the Province, is the Head of the Office in charge of Agriculture at the Provincial Level and the implementation of activities is in the District / City is the Head of the Office in charge of Agriculture at the District / City Level responsible in their respective work areas.
- The Deconcentration Fund (DK) located in the Province is the Head of the Office in charge of Agriculture at the Provincial Level and responsible in their respective work areas.
- Central Fund (Center) is in the Directorate General of Agricultural Infrastructure and Facilities is the Director

The General of Agricultural Infrastructure and Facilities and the Implementation of activities are in the Directorate and Secretariat of the Scope of the Directorate General of Agricultural Infrastructure and Facilities. This instrument is in the form of assistance (grants) from the government to farmer groups in the form of:

- Money Transfer
  - The principle of government assistance in the form of money through a money transfer mechanism to the beneficiary's account which is then spent by the beneficiary in accordance with the Proposed Activity Plan (RUK) which has received approval from the Commitment Making Officer (PPK).

- Disbursement of government aid funds provided in the form of money to beneficiaries is carried out through a Direct (LS) mechanism from the State Treasury account to the beneficiary's account. The designations are:
  - Operating Fund
  - Facilities and infrastructure assistance
  - Rehabilitation or construction of buildings

- Transfer of goods
  - Government assistance in the form of goods/services is carried out through the mechanism of procurement of goods and/or services. In order to procure goods and/or services, KDP enters into agreements/contracts for the provision of goods and/or services with third parties/providers of goods and/or services. The distribution of Government Assistance in the form of goods and/or services is carried out based on the Decree of providing assistance determined by the KDP and authorized by the KPA.

5.3.2 Enterprises

In addition to the government, private businesses also have an obligation to provide financial access to agricultural technologists. Instruments that can be used are:

- Environmental Social Responsibility (TJSL). Law No. 40 of 2007, requires companies to set aside their profits to help the business of the community. Currently, several local governments (PEMDA) have issued Regional Regulations (PERDA) challenging the management of TJSL. With the goal, these funds can be used optimally for regional progress. The agency responsible for this funding is the Department of Industry and Trade Cooperatives, or its equivalent. In some areas there are differences in nomenclature.

- Madani Investment (PNM). PT PNM is a government-owned company that aims to help the business world. PT PNM does not only provide financial assistance, but provides assistance to entrepreneurs, so that business activities can be more advanced.

5.3.3 Financial Technology Innovation

Financial Technology (FinTech) itself was developed due to the demands of changing people''s lifestyles that are dominated by technology-based use. With the presence of FinTech, problems faced by the community such as buying and selling transactions, not having time to go to banks / ATMs to transfer funds, and others can be minimized.

There are three (3) rules regulations governing FinTech business, which are as follows:

- Bank Indonesia Circular Letter No. 18/22/DKSP concerning the Implementation of Digital Financial Services.

- Bank Indonesia Regulation No. 18/17/PBI/2016 regulates all matters related to Electronic Money.

- Bank Indonesia Regulation No. 18/40/PBI/2016 stipulates the implementation of payment transaction processing.

The types of fintech in Indonesia are:

- Peer to peer landing service:.
  - This type provides borrowing funds for business capital or meeting needs. FinTech is usually used to help business people to obtain capital quickly.
- E-Wallet:.
  - The most common FinTech today, namely digital wallets that play a role in providing electronic money storage for users. The goal is to make it easier for users to disburse funds for transactions in marketplaces, merchant apps, and the like. Examples such as Dana, OVO.
- Crowdfunding:.
  - This type of FinTech brings together parties who need funds and donors with guaranteed transactions safely and easily. Crowdfunding is not only used to collect donations / donations, but also can find investors and business people.
- Payment gateway:.
  - Payment gateway is a FinTech system that authorizes payments through online transactions. An example is PayPall.
- Investment:.
  - In addition to digital wallets, there are instruments for investment migrating through online applications so that investors can easily invest their capital, due to the rapid changes in the era in the field of technology. An example is Seedling, Miraculous.
- Digital bank:.
  - The last and rising type of fintech lately is a digital bank, which is a bank whose transactions are 100% done digitally, from account registration to asset management. An example is Allo Bank.

5.3.4 Non-Governmental Oorganizations Related to Agriculture

- IFAD (International Fund for Agribussiness Development):.
  - IFAD is an international financial institution and specialized agency of the United Nations based in Rome, the food and agriculture hub of the United Nations. Since 1978, it has provided grants and low-interest loans totaling US$23.2 billion.
  - IFAD invests in rural communities, to improve food security, improve family nutrition, and increase incomes. they. IFAD helps communities build resilience, grow businesses, and take control of their own development.
- Rikolto:.
  - Rikolto in Indonesia began in Flores around 1960 under the name Florescommittee, founded by a Belgian missionary, Father Rene Daem. Then in 1973, Father Rene Daem changed it to "Vereniging Zonder Winstoogmerk" or VZW, which is equivalent to Foundation. Rikolto Indonesia operates in 25 regencies and 4 cities in 8 provinces in Indonesia (Jambi, West Java, Central Java, East Java, Bali, West Sulawesi, South Sulawesi, East Nusa Tenggara).

Rikolto is currently focused on achieving sustainable sources of coffee, cocoa, rice and cinnamon where the private sector includes smallholders in Java, Sulawesi, Flores and Sumatra in the agricultural value chain. Sustainable rice production with good quality benefits smallholders and consumers

- Alliance of Indonesian Organizations (AOI):.
  - AOI aims to strengthen and advance the movement of organic agriculture and fair trade in Indonesia. In particular, in empowering smallholders through strengthening institutional capacity and production quality management to be able to access better markets. With this support, small farmers will be more sovereign and able to have a better life.
  - The Indonesian Organic Alliance has 122 members in various regions in Indonesia and partners with various institutions in IndonesiaProposed Design of The Integrated System.

6 Capacity Building and Awareness Enhancement

6.1 Assessment of Current Knowledge Levels and Skills Regarding Integrated Technologies

In Sukaraja, a sub-region of Sukabumi, the agricultural practices are at a crucial juncture of transformation. While traditional methods still prevail, there's a growing interest among farmers, especially the younger generation, to incorporate modern technologies into their farming practices. The majority of irrigation and fertilization processes are carried out manually. This traditional approach, while deeply ingrained in the local farming practices, poses limitations in terms of efficiency and productivity. Limited exposure and experience with modern irrigation techniques are significant barriers that farmers in this region face.

Some progressive farmers in have begun experimenting with sprinkler systems, marking a shift towards modern irrigation methods. This indicates a willingness among the farming community to explore and adopt more efficient practices. Younger farmers in Sukaraja display a notable interest in updating farming technology. Their openness to new methods and technologies represents a potential turning point in the region's agricultural development. This demographic is pivotal in driving innovation and modernization in farming practices.

Micro-irrigation systems, such as drip and sprinkler systems, are particularly well-suited for horticulture and floriculture in Sukaraja. These systems can provide more precise water and nutrient delivery, enhancing crop yield and quality, which is crucial for these specialized agricultural sectors. Farmers in Sukaraja, as in other parts of Indonesia, have varying levels of understanding and skills in modern agricultural technologies. While traditional practices dominate, there's a noticeable curiosity and eagerness to learn among many, especially the youth. The key areas for assessment include:

- Understanding of traditional versus modern irrigation and fertilization methods.
- Awareness of the benefits of technologies like sprinkler and drip irrigation systems.
- Openness to adopting new technologies and methods, particularly among younger farmers.
- Identifying the gaps in knowledge and skills that need to be addressed to facilitate the adoption of modern agricultural practices.

6.2 Strategies for Capacity Building and Skill Development

In the Sukaraja sub-region of Sukabumi, transitioning from manual to modern irrigation and fertilization practices presents both a challenge and an opportunity. To support this transition, focused strategies for capacity building and skill development are crucial. The followings describeHere's how these strategies could be enriched and tailored for the local context:

- **Training and Education Workshops:** The objective of these workshops is to educate farmers about the benefits and operational aspects of modern irrigation systems such as drip and sprinkler irrigation. The content of these workshops would cover the basics of setting up and maintaining micro-irrigation systems, understanding the water requirements for different crops, and learning the best practices for fertilizer application. The training is designed to start with the basics and gradually introduce more complex concepts, ensuring it's accessible and relevant to farmers' existing knowledge and skills. Women and men both in farmers' groups and women farmers' groups are equally invited to the training and workshops where the schedule is friendly for women. It needs to be determined since women usually have household chores, so the training and workshops should be delivered after they fulfill their needs.

- **On-field Demonstrations and Pilot Projects:** The goal here is to provide farmers with hands-on experience and showcase the practical benefits of modern irrigation and fertilization methods. This is achieved through collaboration with agricultural extension services and technology providers to set up demonstration plots. These plots not only demonstrate the use of micro-irrigation systems for horticulture and floriculture but also help farmers see the technology in action and understand its impact on crop yield and quality, thereby influencing their willingness to adopt new practices. This activity also invites men and women equally in order to gain a higher capacity to run the system.

- **Mentorship Programmes:** These programs aim to provide ongoing support and guidance to farmers as they transition to modern agricultural practices. By pairing experienced farmers who have successfully adopted modern irrigation and fertilization techniques with farmers who are new to these technologies, a supportive learning environment is created. This approach leverages the experience of successful adopters to provide relatable and practical advice, making the learning process more effective and encouraging for newcomers.

- **Financial Support and Incentives:** To alleviate the financial burden of adopting new technologies, various options are made available. This includes facilitating access to credit through schemes like the People's Business Credit (KUR), providing subsidies for purchasing micro-irrigation equipment, and offering tax incentives for adopting sustainable practices. Such financial support can be a significant motivator for farmers to invest in modern technologies. Women in farmers' groups or women farmers' groups can support the finances through arisan as a local activity, like a lottery club as a monthly activity informally.

- **Youth Engagement and Technology Integration:** Recognizing the interest of young farmers in technology, this strategy aims to leverage their enthusiasm to drive innovation and adoption. By creating programs and platforms specifically targeting young farmers, and offering training in both agricultural practices and technology use, such as smart farming applications and data management, a broader shift towards modern agriculture is encouraged.

- **Community-Based Learning Groups:** These groups foster a community-driven approach to learning and adopting new technologies. By establishing farmer groups where members can share experiences, discuss challenges, and support each other, a collective learning environment is cultivated. This approach is particularly effective in communities where manual practices are deeply ingrained and shifting to new methods requires a collective effort and reassurance.

By implementing these strategies, Sukaraja can gradually transform its agricultural practices, moving from manual to more efficient and sustainable methods. The success of these efforts will depend not only on the availability of resources and technology but also on the active participation and engagement of the farming community, with a particular focus on empowering the youth and leveraging local experiences and knowledge.

6.3 Awareness Campaigns and Education Programmes for Technology Adoption

To further enhance the adoption of modern irrigation and fertilization techniques in Sukaraja, Sukabumi, especially among farmers predominantly engaged in manual practices, effective awareness campaigns and educational programs are essential. These initiatives need to be tailored to the specific needs and context of the region.

- Awareness Campaigns
  - Focus on Micro Irrigation: Given the suitability of drip and sprinkler systems for horticulture and floriculture in Sukaraja, campaigns should emphasize the benefits of these micro-irrigation systems, including water conservation, improved crop yields, and quality.
  - Demonstrations and Success Stories: Utilize local demonstration plots to show the effectiveness of modern irrigation systems in action. Sharing success stories of farmers who have adopted these systems can serve as powerful testimonials to motivate others.
  - Involvement of Young Farmers: Engage young farmers, both men and women who have shown interest in updating farming technology, as champions and influencers in these campaigns. Their enthusiasm and openness to new technologies can inspire the wider farming community.
  - Women sharing season: Besides the technical benefits of the technology, women using the farmer's group or women farmers group also shared about the time-efficient fertigation activity by the technology. It will attract them to provide attention and a positive attitude that the technology can help them to plan other activities productive time or even leisure time. It is need to determined since there is a correlation that when women’s leisure time interrupted by their responsibility in productive activity so women’s well-being is potentially disrupt (Rowland et al., 2022)
- Education Programs
  - Training and Workshops: Conduct regular training sessions and workshops focused on the operation and maintenance of modern irrigation systems. These should be designed to cater to different skill levels, from beginners to more advanced users. It is publicly open both for women and men farmers.
  - Field Schools: Implement Field Schools as dynamic, hands-on learning environments where farmers can acquire practical skills in using modern irrigation and fertilization techniques. These schools can be particularly effective in bridging the gap between traditional practices and modern technologies.
  - Collaboration with Agricultural Experts: Partner with agricultural experts and institutions to provide up-to-date information and training on the latest agricultural technologies and practices. This collaboration can help in introducing innovative techniques that are relevant to the local agricultural conditions in Sukaraja.

- Community Engagement
    - Creating Local Networks: Establish local networks and forums where farmers can exchange knowledge, discuss challenges, and share experiences related to modern farming practices.
    - Incentives for Early Adopters: Offer incentives or recognition for farmers who take the lead in adopting and mastering new technologies. This can motivate others in the community to follow suit.
    - Engaging Local Leaders and Influencers: Involve local community leaders and influencers in promoting the adoption of modern agricultural practices. Their endorsement can have a significant impact on the acceptance and uptake of new technologies within the community.

The shift from manual to advanced irrigation and fertilization methods is pivotal for sustainable and productive farming. The engagement and education of the farming community, particularly the youth, are critical in this transformative journey. Recognizing the existing understanding and willingness among farmers, especially the youth, to adopt modern practices is crucial. Despite some progress, there's a significant need for broader education and skill development to move away from traditional manual methods.

Implementing training, mentorship programs, financial support, infrastructure development, and especially focusing on young farmers are essential strategies. These are designed not just to educate but to empower farmers both women and men with the knowledge and tools needed for informed decision-making and effective use of modern technologies. These are vital in demonstrating the practical benefits of technology adoption, offering hands-on experience, and fostering a supportive learning community. They act as bridges between traditional practices and the potential of advanced agriculture, making new methods accessible and understandable.

The successful transition hinges on a collective effort from government, private sectors, NGOs, and the farmers themselves. Through continued education, support, and community engagement, the farmers can anticipate a future marked by increased productivity, sustainability, and prosperity. This is not merely about adopting new technologies but about cultivating a new mindset and creating an environment conducive to continuous learning and innovation

7 Enhancing Research and Data on Climate Nexus

7.1 Importance of Climate-Related Data in Agricultural Technology

Climate-related data are crucial for the design and operational planning of agricultural technologies. Understanding variables like eEvapotranspiration (ETo) and rainfall patterns is vital for creating irrigation schedules that meet crop water requirements efficiently. Accurate measurement of Evapotranspiration (ETo) is crucial for creating precise irrigation schedules, leading to effective water conservation and enhanced crop productivity (Allen et.al., 1998). In cultivation in greenhouses, rainfall is negligible, but can be included when rain harvesting is used. Beyond that, rainfall data needs to be converted into effective rain data, i.e. the amount of rain that can be used for crops. The benefit of this approach are designs with smaller capacity and ease of operation based on time and amount of water application, although when it rains the irrigation efficiency decreases. CSA practice in technology helps to maintain high irrigation efficiency and water productivity.

Utilizing climate data for predictive analysis helps foresee potential weather-related risks, plant stress – yield relationships, and enables farmers to implement preemptive measures to protect crops and optimize resource allocation. Predictive models based on climate data significantly improve agricultural decision-making, leading to better crop selection, timing of planting, and efficient resource use, thus enhancing farm productivity and resilience. Climate prediction can be a valuable tool for farmers, offering the potential to increase food production and profit, or reduce risks. However, applying climate predictions effectively requires forecast skill and approaches to use the information in management. An interdisciplinary systems approach is crucial to relate knowledge from different disciplines, such as climate scenario analysis and simulation with credible models. Effective collaboration and communication among researchers, analysts, and decision-makers is also essential, as all stakeholders learn from the process. Importantly, understanding and communicating decision risks is key, as recognizing the limitations of forecasts and clearly communicating potential risks are crucial for successful implementation (Hammer et.al., 2001).

In Indonesia, and specifically in regions like Sukabumi, climate variability significantly impacts agricultural productivity. Issues such as the onset of the rainy season, unpredictable dry spells, and changing temperature patterns affect the traditional farming calendar. The agricultural sector faces significant challenges due to climate variability, which shifts the rainy season and introducing unpredictable dry season that affect crop yields and water resource management. Naylor et. Al (2001) demonstrates that quantitative predictions of ENSO's effects on rice harvests can provide an additional tool for managing food security in one of the world's most populous and important rice-producing countries (Naylor et.al., 2001).

To address these issues, it is's crucial to develop localized climate models and data collection initiatives that provide accurate, real-time information to farmers in Indonesia and specific areas like Sukabumi. This will enable them to make informed decisions, adapt to climate variability, and maintain sustainable agricultural practices. Developing localized climate models and enhancing data collection initiatives are essential for providing Sukabumi's farmers with accurate, real-time information, enabling them to make informed decisions and adapt to climate variability effectively.

Incorporating these localized climate insights and predictive models into agricultural planning will be crucial for regions like Sukabumi to mitigate the adverse effects of climate variability and sustain agricultural productivity. The suggested references provide a foundation for understanding the role of climate data in agricultural decision-making and the specific challenges faced in regions like Sukabumi, Indonesia.

7.2 Current State of Climate-Related Research in Agriculture

In Indonesia, climate-related research in agriculture is increasingly focused on understanding and mitigating the impacts of climate variability and change on farming practices. This is crucial for developing water-saving practices and other strategies to enhance agricultural sustainability. Indonesia has been exploring the effects of climate change on agricultural productivity, water resource availability, and the efficacy of various adaptation strategies. For instance, a start of rainy season (monsoon onset) prediction based on climate variability indices over Java island (Rohmawati et.al., 2014), which can provide information related to rainy season particularly if there is a delay in rainy season that can lead to the crop failure.

Despite ongoing studies, there remain gaps in localized research, particularly in understanding how specific regions like Sukabumi are affected by and can adapt to climate variability. While broad research has been conducted, there is a lack of in-depth, localized studies focusing on specific regions like Sukabumi, which are crucial for developing targeted adaptation strategies.

Research has also been directed towards water-saving practices, critical in areas where water resources are increasingly under stress due to climate change and other factors. Adopting water-saving practices such as micro-irrigation, rainwater harvesting, and mulching is essential for Indonesian agriculture to combat the challenges posed by climate change and ensure sustainable water use (Putra et.al., 2021; Saptomo et.al., 2013, 2022; Suhartono et.al., 2023; Sumarsono et.al., 2018). In Sukabumi and similar regions, integrating traditional knowledge with modern scientific understanding can lead to more effective water-saving strategies and climate adaptation practices. Integrating traditional agricultural knowledge with modern scientific research offers a potent approach for developing effective water-saving and climate adaptation strategies.

To enhance the effectiveness of climate-related research in Indonesian agriculture, particularly in water-saving practices and adaptation strategies, it is vital to focus on localized studies, integrate traditional and modern knowledge, and promote collaborative research efforts. The suggested references provide a solid foundation for understanding the current state of climate-related research in Indonesia and the specific needs and strategies relevant to regions like Sukabumi.

7.3 Proposals Recommendation for Increasing Research and Improving Data Quality

In the context of Indonesia, enhancing research and improving data quality related to agricultural technologies, especially those focusing on water conservation, is critical. The integration of water-saving agricultural technologies, such as efficient irrigation systems and soil moisture sensors, must be aligned with the broader objectives of climate nexus research. This alignment is crucial for addressing the unique climatic challenges faced by regions like Sukabumi. Aligning water-saving agricultural technologies with climate nexus research is essential for addressing the specific climatic challenges in regions like Sukabumi, enhancing resilience and sustainability in agriculture. There are sufficient land and water resources available to satisfy global food demands during the next 50 years, if agricultural water is managed more effectively (de Fraiture & Wichelns, 2010).

Effective utilization of climate data is vital for implementing CSA practices, which involves leveraging data for informed decision-making in water management, crop selection, and adaptation strategies. It can significantly improve water management, crop resilience, and overall agricultural sustainability in Indonesia, particularly in water-stressed areas. CSA differs from 'business-as-usual' approaches by emphasizing the capacity to implement flexible, context-specific solutions, supported by innovative policy and financing actions (Lipper et.al., 2014).

Focused research and data collection efforts are needed in Indonesian to understand local climate patterns, water availability, and soil conditions. This localized approach is key to developing effective, region-specific water-saving technologies. Localized research and targeted data collection in regions are crucial for developing and implementing effective water-saving technologies tailored to the specific needs and conditions of these areas

Fostering collaborations between government agencies, local universities, research institutions, and farming communities can accelerate the development and adoption of effective water-saving technologies. Collaborative research and development initiatives involving multiple stakeholders are essential for advancing water-saving agricultural technologies in Indonesia, with a special focus on regions like Sukabumi.

Example of the research is by systematically review and collect data from existing published researches on sustainable intensification, which is defined as a process or system where yields are increased without adverse environmental impact and converting more land for cultivation. Sustainable Intensification has the potential to positively impact yields and natural capital in both developing and industrialized countries, while also addressing the criticisms and outlining necessary policies for its wider adoption and contribution to greener economies

In summary, proposals for increasing research and improving data quality related to agricultural technologies in Indonesia should focus on aligning these technologies with climate nexus research, utilizing climate data in CSA applications, enhancing localized research, and fostering collaborative initiatives. These strategies are particularly relevant for addressing the water-related challenges in regions like Sukabumi. The suggested references provide a comprehensive overview of these areas, offering insights and guidance for future research and development

8 Climate-Smart Agriculture (CSA) and Technology Integration

8.1 Role of Integrated Technologies in Achieving CSA Objectives

Climate change can have an impact on the decline and stagnation of agricultural production that threatens food security and human survival. This situation requires us to reform agricultural systems by applying the Climate Smart Agriculture (CSA) approach: (1) increase agricultural productivity and income in a sustainable manner, (2) adapt and build resilience to climate change, and (3) reduce greenhouse gas emissions (Rouw, 2018).

The ability to understand and predict climate variability and change is the basis for the CSA approach. Changes in rainfall patterns and rising air temperatures cause agricultural production to decline significantly. The impact of climate change on agriculture shows that with every 1°C minimum temperature increase, rice yields decrease by between 10-25%.

On Sumba Island, smallholders often experience a decline in production due to uncertain climatic conditions and changes in rainfall patterns. In addition, farmers also often have difficulty in growing major crops such as corn in sufficient quantities as production shocks often lead to seed shortages for the next growing season. Access to alternative seeds is limited due to the lack of ability to pay for seeds in local markets which in many cases are not suitable for the local climate. NTT's uncertain climate has a major impact on local food systems, particularly seed availability and food security in general. Farmers often lose seeds due to crop failure, especially during the dry season (Lassa et.al., 2014).

At the global level, the agricultural sector contributes around 14% of total emissions, while at the national level the contribution of emissions is 12% (51.20 million tons of CO_2) of total emissions of 436.90 million tons of CO_2. If emissions from these three activities are taken into account, the contribution of the agricultural sector is only around 8%. Although the contribution of emissions from the agricultural sector is relatively small, the impact felt is very large. Extreme climate events in the form of floods and droughts cause plants that experience puso to become more widespread. Rising sea levels lead to shrinking paddy fields in coastal areas and crop damage due to salinity.

In addition, resilience and efficient use of resources are the main guiding principles for CSA (Torquebiau et.al., 2018). The ecosystem approach is the dominant aspect of CSA including agricultural practices that are key roles of CSA such as crop diversification, intercropping, rotation, cover crops, agroforestry, pest and disease control, plant-animal interactions, and agrobiodiversity utilization.

Such a large impact of climate change requires active efforts to anticipate it through mitigation and adaptation strategies. Mitigation technology aims to reduce greenhouse gas (GHG) emissions from agricultural land through the use of low-emission varieties and water and land management technologies (Doni et.al., 2022). Adaptation technologies that can be applied include adjusting planting times, using drought-resistant high-yielding varieties, soaking and salinity, and developing water management technology (Surmaini & Runtunuwu, 2010).

The digital farming system is part of modern agriculture used for qualitative and quantitative cultivation of various plant varieties to be planted in agricultural gardens or residential homes (Putri et.al., 2023). Agriculture in urban areas has different challenges from rural areas such as limited land, poor soil quality, and water shortages. Based on this, innovative solutions are needed to increase agricultural production equipped with Internet of Things (IoT) technology and other technologies including Arduino UNO, solar panels, soil moisture sensors, temperature sensors, and irrigation system automation.

Irrigation and fertigation technology systems are one of the technologies that have a major role in achieving Climate Smart Agriculture (CSA) goals by integrating efficient use of water and plant nutrients. Automated irrigation technology enables more efficient management of water delivery to plants, directly responding to soil moisture conditions and climate change. The application of irrigation and fertigation technology equipped with sensor networks enables optimal water use by responding directly to soil moisture conditions. Thus, farmers can reduce water wastage and ensure water delivery that is in accordance with plant needs (Torquebiau et.al., 2018).

Irrigation and fertigation systems bring innovation by combining water delivery and plant nutrients simultaneously. This not only increases the efficiency of fertilizer use but also helps plants get the right nutrients at the required time. By optimizing the use of water and nutrients, this technology directly supports increased plant productivity (Jabbar & Purnaningsih, 2022). Thus, farmers can provide the right nutrients at the right time, increase the efficiency of fertilizer use and reduce the risk of water pollution due to fertilizer runoff. In addition, farmers can also achieve better yields while reducing the use of inputs. This system allows farmers to adapt to rapid climate change.

Through automated monitoring and regulation, farmers can adjust irrigation and nutrient patterns according to changing climatic conditions (Suhartono et.al., 2023). Efficient irrigation and fertigation systems not only increase productivity but also contribute to the sustainability of water resources.

Irrigation and fertigation technologies help reduce the negative impact of agriculture on the environment. By using resources efficiently, they help reduce environmental footprint, such as increased greenhouse gas emissions. Real-time sensors and monitoring systems allow farmers to track soil and crop conditions in real time. It provides accurate information for quick and precise decision making. The application of this technology encourages innovation in agriculture. The development of intelligent sensors, monitoring algorithms, and automated control systems continues to improve the effectiveness and sustainability of irrigation and fertigation systems (Fajar et.al., 2018).

The application of these technologies supports more sustainable agricultural practices by minimizing waste and improving soil nutrient balance. Through the integration of irrigation and fertigation technologies, farmers can increase crop productivity and reduce carbon emissions and environmental impact. This practice is in line with the CSA concept which emphasizes adaptation to climate change, resource efficiency, and environmental sustainability. Thus, irrigation and fertigation technologies play an important role in shaping climate-smarter agriculture, improving food security, and caring for natural resources for future generations.

In the quest for scale, governments, agricultural organizations, and the private sector need to work together to drive adoption of these technologies. Supportive incentives and policies can accelerate the shift to climate-smarter agriculture. The application of irrigation and fertigation technologies helps farmers manage risks related to extreme weather and climate change. With real-time data, they can respond quickly to potential threats, such as droughts or floods.

The technology could also trigger the development of crop varieties better suited to irrigation and fertigation systems. These varieties can be designed to optimize yield and maximize the benefits of controlled nutrient feeding. The partnership between the agriculture industry and the technology industry is crucial. This can accelerate the development and deployment of more sophisticated and affordable irrigation and fertigation technologies. Raising awareness and educating farmers about the benefits and use of this technology is an important step. With a good understanding, farmers will be more motivated to adopt this technology.

In the context of sustainability, water and fertilizer management is not only concerned with current efficiency but also with long-term thinking. An integrated irrigation system helps maintain water availability for agriculture in the future by considering sustainability aspects. Irrigation and fertigation systems not only optimize crop production but also contribute to improved food security. With better and more stable yields, people can count on a reliable food supply. Involving farmers in the application of irrigation and fertigation technology is key to sustainability. Training and technical support ensure that they can manage these systems effectively, helping to create a more sustainable agricultural culture. Continuous evaluation and follow-up research are needed to understand the long-term impact of applying irrigation and fertigation technology. This helps improve systems, identify new challenges, and ensure the long-term sustainability of climate-smart agriculture.

8.2 Roles of Technology to Enhance Farming Resiliency and Sustainability

The integration of irrigation and fertigation technologies in CSA's agricultural practices supports the concept of sustainability by reducing excessive water and fertilizer use. This is consistent with CSA principles that emphasize sustainable management of natural resources to support climate-resilient agriculture. Thus, this technology not only increases productivity, but also supports the environmental and economic sustainability of farmers.

The use of irrigation and fertigation technologies also supports crop diversification, which is an important strategy in CSA. Farmers can more easily select and grow crops that are more resistant to climate change or crops that are suitable for local environmental conditions. This crop diversification can increase the diversity of agricultural yields, reduce the risk of crop failure, and provide economic resilience for farmers.

In addition, the adoption of this technology in agricultural practices opens up opportunities for the utilization of renewable energy resources. Irrigation using renewable energy resources, such as solar or hydrokinetic energy, can reduce the carbon footprint of the agricultural sector. This is in line with CSA principles that emphasize more environmentally friendly agricultural practices and contribute to climate change mitigation. By utilizing irrigation and fertigation technologies wisely, agriculture can become more adaptive, efficient, and sustainable. This not only creates a conducive environment for crop growth, but also improves the welfare of farmers and contributes positively to the sustainability of the food system as a whole. As an integral part of CSA, these technologies are key to achieving resilient and sustainable agriculture amid the growing challenges of climate change.

The application of irrigation and fertigation technology in the context of Climate Smart Agriculture (CSA) can also support the efficiency of agricultural land management. A well-controlled irrigation system can help farmers optimize land use, ensuring that every part of the land is used efficiently. This is especially important in dealing with limited land and increasing productivity per hectare, in line with CSA principles that prioritize sustainable use of resources.

Irrigation and fertigation technologies can also help reduce soil damage and erosion. Measurable water delivery and proper fertilization can prevent soil degradation, maintain soil fertility, and support the health of agricultural ecosystems. In this way, farmers can practice agriculture that is not only productive but also environmentally sustainable.

Furthermore, irrigation and fertigation technologies can improve the efficiency of energy use in agriculture. Automatically controlled irrigation systems with sensors can reduce energy consumption significantly compared to traditional irrigation methods. More efficient use of energy contributes to the reduction of the carbon footprint of the agricultural sector, supporting climate change mitigation efforts. From an economic perspective, the application of this technology can increase the competitiveness of farmers. Higher productivity and efficient use of resources can increase farmers' incomes and increase their economic resilience to market fluctuations and climate change. The integration of irrigation and fertigation technologies in Climate Smart Agriculture's agricultural practices provides holistic solutions to improve agricultural resilience and sustainability. By combining water, fertilizer, land, and energy use efficiencies, these technologies provide the foundation for agriculture that is responsive to the challenges of climate change while achieving economically, socially, and environmentally sustainable outcomes.

CSA's approach to adaptation and building resilience to climate change in East Java was carried out by Faza Akmal (2018) (Faza Akmal, 2018). The CSA models that can be done to improve resilience and sustainability in agriculture are :

- Water Management:
  - in practice water management in practice in the field is carried out by regulating the availability of water by irrigation, groundwater, watersheds (DAS) and from existing rainfall. Water management carried out will affect planting patterns for one year.
- Soil Management:
  - soil management or soil management carried out is by setting the dose of fertilizer. Where the use is adjusted to the condition of the soil and the needs of plants.
- Crop Management:
  - crop management or crop management itself, what is done in the field is by selecting and using superior seed varieties that are in accordance with existing planting conditions.
- Energy Management:
  - for energy management itself there is no practice applied in the current rice production system.
- Livestock Management:

- livestock management is livestock management, this is not done because it is not related to case studies.

- Forestry and Agroforestry:
  - : forestry and agroforestry is the practice of combining annuals, fruit crops, and livestock. This practice is not applied because the focus of this research is on rice plants.

- Fisheries and Aquaculture:
  - fisheries and aquaculture are related to fisheries. This practice is also not applied because of differences in objects with this study. Intermittent irrigation techniques can save irrigation water needs up to 31.88% and are also believed to increase rice productivity up to 22%.

Rouw (2018) (Rouw, 2018) stated that ecosystem perspective agriculture (ecological techno) can combine the production system of the circulation cycle of nutrients and biomass in one chain with a touch of advanced technology, will be able to lead to zero waste or zero waste agriculture. The bio-industrial agricultural system is a system that conforms to the CSA approach. Bio-industry model, namely: seeking more than one type of commodity that has a strong functional relationship on one unit of land that can reduce the use of external inputs / maximize the use of inputs in a system. With this model, business risk can be reduced; crop failure in one commodity can be covered by the harvest of another commodity; a drop in the price of one product can be helped by the good price of another product; More ensure the sustainability of farming, while at the same time being able to increase adaptation and mitigation to the impacts of climate change. Increasing agricultural productivity can be achieved with the input of technological innovations that are adaptive to climate change in the sense that they can increase productivity while avoiding the impact of environmental damage.

Mitigation and adaptation in agricultural solutions are targeted primarily at minimizing methane or nitrous oxide pollution or growing soil energy accumulation. Tolerance to temperature fluctuations and increased rainfall can help in ensuring higher production processes. It can do so by improving the ability of surface water to transport and distribute mineral elements from the soil. This goal can be achieved by increasing groundwater retention potential by channeling crop waste into arable soil or by introducing flexibility to crop rotation. New agricultural systems that combine bioenergy and agricultural production systems need to be built to understand the maximum potential of agriculture in the face of climate change (Masturi et.al., 2021).

8.3 Case Studies of Successful CSA Implementations Using Integrated Technologies

Atjo and Gani (2023) (Atjo & Gani, 2023) apply Climate Smart Agriculture (CSA) technology to make farmers in Nagekeo Regency, East Nusa Tenggara Province [NTT] smart to adapt to climate change, supported by modern agricultural technology through the Strategic Irrigation Modernization and Urgent Rehabilitation Project (SIMURP) Program from the Indonesian Ministry of Agriculture in Nagekeo Regency, NTT able to increase the productivity of corn planting covering an area of one hectare. CSA technology is the main key to increasing productivity in the face of climate change. The SiMURP program has taught farmers many things to do smart agriculture, including in responding to climate change. With modern agricultural technology and knowledge gained, it has succeeded in increasing production and productivity as well as the quality of produce and having a positive impact on the local economy that sales of agricultural products have increased in Nagekeo. The SIMURP program encourages and supports the use of vegetable pesticides, low-emission high-yielding rice varieties, water-saving irrigation techniques, balanced fertilization and the use of organic matter are expected to contribute to increasing production, productivity and IP of rice and non-rice.

Rouw (2018) (Rouw, 2018) applies the Bio-Industry model carried out by BPTP West Papua through the integration of cocoa and goat commodities in local communities in Oransbari, Manokwari. Here there is a cycle of matter (hara) that complements each other between integrated commodities, thus reducing external inputs. There is product diversification that can increase income, and the productivity of land resources is maintained.

Prastowo et al. (2023) (Prastowo et.al., 2023) apply smart irrigation in P4S Buana Lestari, Nganjuk Regency, East Java. The portable sprinkler irrigation system that has been developed has specifications: Impact Plactic Sprinkler head nozzle with a nozzle size of 4 mm, total stick riser height of 1.3 meters with a diameter of 3/4", elastic lateral pipe with a diameter of 2" and a length of 50 meters, a sub-main pipe (manifold) and a main pipe of 2". The pump used has a total head of 55 meters with a driving force of 5.5 HP, and a 2" suction hose. The type of sprinkler used is Impact Sprinkler Plastic Model Naan 427B GAG with specifications: operational pressure 2 – 4 bar with nozzle size 4 mm; sprinkler discharge 0.85 – 1.2 m /hour; and wet diameter 24 – 26 m.

Sirait et al. (2020) and Sirait et al. (2022) (Sirait et.al., 2020, 2022) designed and analyzed the efficiency of solar-powered automatic irrigation technology in the Cahaya Tani Farmer Group, North Tarakan District, Tarakan City. The developed system consists of pump components, sprinkler nozzles, piping networks, sensors and microcontrollers. Irrigation sprinklers operate based on soil moisture values for ON/OFF irrigation pumps. The efficiency of applying this technology is classified as good condition and is able to increase the productivity of irrigation water.

Lasa et al. (2014) (Lassa et.al., 2014) implemented the CSA approach also carried out on Sumba Island, NTT, namely through several innovations in the efficiency of water use and management in plants such as mulching, and agroforestry systems carried out by several farmers. Some technological innovations such as drip irrigation for agriculture (especially for cash crops), rainwater harvesting, identification (and re-introduction) of some drought-resistant crop varieties, establishing sustainable local seed systems, participatory breeding, livestock adaptation measures and improvement of existing agroforestry and knowledge management

Agroforestry practices are one option to increase food production. The Central Java Provincial Government and Wonogiri Regency Government are working together to develop a farmer agroforestry system in Tempursari Village, Wonogiri Regency. The program covers an area of 25 hectares. In this agroforestry program, the people of Tempursari Village plant food crops in rotation under forest plants. Plant types for this program include cassava, corn, elephant grass, and teak trees. Wana tani or agroforestry is a way of farming that has long been known in Indonesia. In this way, tree planting is carried out on the same plot with annuals or annuals. In simple agroforestry, trees are planted intercropped with one or more types of annuals or annuals. The types of trees planted are also very diverse, such as coconut, kaliandra, and teak. In complex farming, the types of plants that grow are more diverse and with more diverse plant heights, including grasses. The characteristic of complex peasant wana is its appearance that resembles an anniversary. The advantages possessed by this complex agroforestry are in a more diverse flora and fauna. Agroforestry practices are useful for preventing erosion, storing more rainwater, and protecting the plants underneath from direct exposure to sunlight. In addition, this practice can provide additional income for farmers, should other crops fail to harvest. Farmers can harvest fruit or honey from shade trees. Some trees can also be a source of nutritious feed, for example kaliandra (Sustainable Landscape Newsletter. Edition 3 December 2016 Light Version. Business watch Indonesia. https://www.sustainable-landscape.org/).

M Ariani et al. (2018) (Ariani et.al., 2018) conducted research on pilot plots of main irrigated rice fields in three districts in Central Java, namely Banjarnegara, Purbalingga and Banyumas Districts used to compare farmers' practices with CSA technology. The CSA technology used is a leaf color chart for N fertilization, rice field soil test equipment for basic fertilizer determination, organic matter improver and intermittent irrigation. CSA is able to reduce GHG emissions between 7-23% of global warming potential (GWP), crop productivity 0.7-0.9 t/ha, and increase economic returns between 42-129%. The application of CSA techniques by farmers and communities can overcome climate change as an adaptation and mitigation effort. However, there are obstacles that must be faced by farmers in implementing CSA techniques in the field.

Agussabti et al. (2022) (Agussabti et.al., 2022) using smart farming technology (SFT) for food commodities in Aceh Province, Indonesia, namely rice, corn, and potatoes, shows that both farmers and extension workers have a positive perception of the implementation of SFT. The perception of farmers and extension workers in Aceh regarding the potential implementation of SFT is positive. Farmers believe that SFT can: (1) reduce input costs, (2) provide better information for decision-making, (3) limit agricultural pollution, (4) increase productivity, and (5) increase farm incomes. But farmers also face obstacles in implementing SFT, such as high investment costs, lack of access to demonstrations, land areas that do not support technology, and their inability to operate equipment and interpret data.

Junainah et al. (2016) (Junainah et.al., 2016) stated that the urban farming program is effective as a model for poverty reduction in the Keputih Village Farmer Group, Sukolilo District, Surabaya City. Through the urban farming program, farmer groups are able to overcome the constraints of lack of water during the dry season by changing agricultural techniques that require less water, have high selling power and better quality vegetables.

Nugroho and Nuraini (2016) (Nugroho & Nuraini, 2016) conducted a scenario analysis of cropping patterns based on global climate index and rainfall in Banyumas Regency, Central Java, Indonesia. Based on water balance, climate, and planting pattern recommendations are:

- rice-corn/soybean-rice,
- rice-corn/soybean-corn/soybean, and
- corn/soybean-corn/soybean-corn/soybean/soybean.

Diverse studies demonstrate how Climate Smart Agriculture (CSA) and smart farming technologies effectively address climate challenges, increase productivity, and aid in sustainable farming. These approaches, ranging from strategic irrigation systems to agroforestry, highlight innovation in water management, crop diversification, and the integration of traditional and modern techniques, proving essential for enhancing agricultural resilience and sustainability

9 Conclusion

The integration of automated irrigation and fertilization with smart technology represents a significant advancement in modern agriculture. It addresses global challenges and offers numerous benefits, including increased productivity, sustainability, adaptability, economic benefits, and inclusivity. Therefore, it is essential to continue investing in and developing these technologies to ensure a sustainable future for agriculture and food production.

The market potential analysis for integrated technology in Indonesian agriculture, with a focus on Sukaraja, Sukabumi, underscores a significant opportunity for modernizing the sector. Despite the prevalence of small-scale farming and traditional practices, there is an emerging interest in adopting advanced irrigation and fertilization systems, particularly among the younger, more educated farming demographic. The challenges of climate variability, land conversion, and water scarcity during droughts necessitate the adoption of efficient and sustainable agricultural technologies. With agriculture being a substantial contributor to Indonesia's GDP, leveraging technology is not only imperative for increasing productivity but also for ensuring food security and economic stability in the face of a growing population. The report advocates for a strategic approach that integrates appropriate technologies, supports smallholder and high-value crop producers, and promotes sustainable practices through Climate-Smart Agriculture. As Indonesia progresses, it is clear that the adoption of integrated agricultural technologies is key to its agricultural evolution, economic growth, and environmental sustainability.

Institutional frameworks in Indonesian agriculture, primarily farmer groups (Poktan), are pivotal for technology dissemination and adoption. Policy reforms targeting these groups can catalyze technology integration, addressing challenges like reluctance to change and knowledge gaps. Collaboration with agricultural extension officers and leveraging farmer groups for training and support are key strategies. This approach ensures sustainable technology adoption, empowering farmers through group dynamics and improved access to information and resources.

The financial landscape in Indonesian agriculture is crucial for technology investment, yet farmers and technology providers face access barriers. Innovative financing models, such as government schemes, private sector contributions, and FinTech innovations, are vital. Government initiatives, private investments, and NGO involvement are essential to facilitate technology adoption, highlighting the need for collaborative efforts to support agricultural development through accessible financial resources.

Capacity building and awareness are essential for technology adoption in Indonesian agriculture. Strategies include training workshops, on-field demonstrations, mentorship programs, financial support, youth engagement, and community-based learning groups. These initiatives aim to bridge the gap between traditional and modern practices, focusing on educating and empowering farmers, especially the youth, to embrace technology for improved agricultural productivity and sustainability.

Emphasizing the importance of climate-related data, this chapter advocates for focused research and improved data quality in Indonesian agriculture. It calls for localized studies, integration of traditional knowledge with scientific research, and collaborative efforts to develop effective water-saving technologies and adaptation strategies. Enhancing research in climate variability and its impact on agriculture is vital for developing targeted solutions, ensuring sustainability and resilience in farming practices.

Integrated technologies play a crucial role in achieving CSA objectives by enhancing resilience and sustainability in Indonesian agriculture. Successful case studies demonstrate the effectiveness of CSA practices in diverse contexts, underscoring the potential of technology integration in improving productivity, adapting to climate change, and reducing environmental impacts. The adoption of CSA technologies, supported by collaborative efforts and policy initiatives, is key to sustainable agricultural development.

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