A STUDY OF FACTORS AFFECTING ADOPTION OF AUTOMATED PRECISION IRRIGATION MANAGEMENT SYSTEMS BY THE FARMERS IN PUNE DISTRICT

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February (2022)

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Dheeraj Singh
Research Student

Abstract

Water is more important to life on this planet than anything else. People can live in a healthy and balanced ecosystem with the correct amount and quality of water. When individuals get access to clean water, everything changes. When people have access to clean water, they are more likely to promote appropriate hygiene practices.

However, the world is currently confronting a water crisis. It's a problem because about 1 billion people lack access to adequate drinking water. It is going place all throughout the world, particularly in developing and disadvantaged countries. The majority of countries are currently experiencing severe water shortages.

To increase water supply in the face of rising demand due to growing population, water scarcity due to current practises, growing unpredictability, larger extremes caused by climate change, and fragmentation concerns, countries must invest in institutional development, information management, and (natural and man-made) infrastructure growth. However, developing such solutions can be costly and time-consuming.

Agriculture is both a cause and a consequence of water scarcity. Agriculture uses around 70% of all water, and in certain impoverished countries, up to 95%. Those who do not have access to water are unable to irrigate their crops, and as a result, are unable to feed the world's fast growing population. In an attempt to address this ever-increasing problem, many people have worked to develop more sustainable groundwater management methods and approaches.

Over the last few decades, groundwater has become a more important source of irrigation, accounting for around 40% of the world's irrigation area. As agricultural production becomes increasingly reliant on unsustainable groundwater use, we may run out of water in the future, posing a threat to crop supply.

In India, where 85 percent of farmers are impoverished and marginalised, and 60 percent of agriculture is dependent on monsoon fluctuations, climate change has a much more obvious impact. As a result, the importance of irrigation is highlighted. India's overall irrigation productivity is typically found to be low when compared to global levels due to the widespread use of traditional flood irrigation technologies. And it's at this point that the value of precision irrigation becomes clear.

A precision irrigation system is a cutting-edge irrigation system. Single droplets, continuous drops, streams, and other forms of water are often distributed in this system. Precision irrigation systems are gaining popularity because to their low cost and high water efficiency. Precision irrigation can increase yields while saving money on water, fertiliser, and labour.

One of the most efficient irrigation technologies is drip irrigation. In Drip Irrigation, emitters transmit water directly to the plant root, which is further into the soil. These emitters regulate and spread the pressure from the water source through valves, twisters, and convoluted or extended flow pathways, allowing just a small volume of water to flow through.

As a result of less soaking of soil surfaces and plant tops, weed and pest pressure may be reduced. The most major agricultural benefits of precision irrigation are that it saves water, reduces pest problems, reduces surface crusting, and coordinates irrigation and fertiliser application. Low pumping requirements, machines (which reduce labour costs), and scalability, in addition to these agricultural advantages, all help to reduce production costs.

India and Adoption of Precision Agriculture

The success or failure of precision agriculture in India would be determined in large part by how institutions and the government implement the programmes. Before policymakers can grasp the lock screen application of precision agriculture in the Indian setting, much research on the subject is required.

Precision agriculture can be looked at from three different angles: current, intermediate, and future. The present state will focus on soil management and raising precision agriculture awareness during the next five months using various mass media tactics.

The intermediate state will generate zones at random and conduct research to better understand precision agriculture and its results across the country, with a focus on studying computer-based data from various zones.

Coated State will focus on simulating farming circumstances utilising sensors and computer-based data, and then making decisions based on that information to provide a favourable farming outcome.

Need of Precision Farming for Indian Farmers

The most significant change in agriculture management this century has been the use of information and communication technologies (ICTs). Using an information technology-based farm management system, crop production methods are carried out at the precise location and time at the right site for optimal profitability, sustainability, and land resource protection.

Precision agriculture (PA) technologies have been developed by many researchers, but only a small number of farmers are adopting them to transform their entire farming system into one that is low-input, high-efficiency, and sustainable.

In order to implement precision farming, ICT inputs were accurately utilised to enhance average yields in comparison to traditional agriculture methods. The limited size of the farm area is a critical challenge in India for precision farming. Over 58 percent of the country's active farms are less than one acre in size (ha).

In Punjab, Rajasthan, Haryana, and Gujarat, nearly two-thirds of agricultural land is larger than four hectares. In both commercial and horticultural crops, PA has a larger potential in cooperative farms.

Thanks to the use of Information and Communication Technologies, sustainable PA is the most major improvement in farm management in the twenty-first century. Sustainability and the production of healthy food are at the heart of this latest technological development, which aspires to be profitable while improving productivity and lowering environmental expenses.

This study was done in the Pune district of Maharashtra, which is in India. According to this, the average annual rainfall in the district ranges from approximately 468 mm to 4659 mm on average. The minimum rainfall occurs in the eastern half of the district, in the vicinity of Daund (468 mm), Baramati (486 mm), and Jejuri (494 mm). In the western ghat, this increases as one travels westward and reaches a maximum around Khandala (4659 mm) in the west.

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List of Abbreviations

Abbreviation	Explanation
AIBP	Accelerated Irrigation Benefit Programme
APMC	Agricultural Produce and Marketing Committee
BCM	Billion Cubic Meters
CICR	Central Institute for Cotton Research
DAP	District Agricultural Plan
DCPC	Department of Chemicals and Petrochemicals
DI	Drip Irrigation
DoA	Department of Agriculture
DoH	Department of Horticulture
ECM	Executive Committee on Micro Irrigation
FAO	Food and Agricultural Organization
GGRCL	Gujarat Green Revolution Company Limited
GoI	Government of India
GNFC	Gujarat Narmada Valley Fertilizers and Chemicals Limited
GSWMA	Gujarat State Watershed Management Agency
HDPE	High Density Poly Ethylene
HMNH	Horticulture Mission for North Eastern and Himalayan States
ICAR	Indian Council for Agricultural Research
ICID	International Commission on Irrigation and Drainage
IDE	International Development Enterprises
IFFCO	Indian Farmers Fertilizer Cooperative Limited
INCID	Indian National Committee on Irrigation and Drainage
IWMI	International Water Management Institute
KRIBHCO	Krishak Bharti Cooperative Limited
LDPE	Low Density Poly Ethylene
MI	Micro Irrigation
MoA	Ministry of Agriculture
NABARD	National Bank for Agriculture and Rural Development
NABCONS	NABARD Consultancy Services
NADP	National Agriculture Development Plan
NCPA	National Committee on use of Plastics in Agriculture
NCPAH	National Committee on Plasticulture Applications in Horticulture
NDC	National Development Council
NER	Northeastern Region

NGO	Non-Governmental Organization
NHM	National Horticulture Mission
NMMI	National Mission on Micro Irrigation
OBC	Other Backward Classes
PFDC	Precision Farming Development Centers
PDC	Plasticulture Development Centres / Product Development Centers
RIDF	Rural Infrastructure Development Fund
RKVY	Rashtriya Krishi Vikas Yojana
SAP	State Agricultural Plan
SC	Scheduled Castes
SIMI	Smallholder Irrigation market Initiative
ST	Scheduled Tribes
SPC	State Planning Commission
TM	Technology Mission
UNEP	United Nations Environment Program
USA	United States of America
USSR	Union of Soviet Socialist Republics
WWDR	World Water Development Report

Chapter 1: Introduction

1.1 Introduction

Nothing is more vital to life on this planet than water. With the right quantity and right quality of water, people can live a healthy and balanced ecosystem. Everything changes when people have access to clean water. People are likely to encourage good hygienic practices when they have a source of clean water. But the world is experiencing a water crisis in current times. It's a crisis because approximately 1 billion people don't have access to safe drinking water. It is taking place all across the world, particularly in underdeveloped countries and developing nations. Most countries are currently putting tremendous strain on their water supplies.

Countries need to invest in institutional development, information management, and (natural and man-made) infrastructure growth to increase water supply in the face of rising demand due to growing population, water scarcity because of current practices, growing unpredictability, larger extremes caused by climate change, and fragmentation concerns. But to engineer such solutions may cost a great deal and is time taking.

Agriculture is both a contributor to water scarcity and a victim of it. Farming consumes about 70% of all water usage, and in certain poor nations, up to 95%. Those without water are unable to irrigate their crops and, as a result, are unable to feed the rapidly rising population. Many people have sought to develop more sustainable groundwater management methods and techniques in an attempt to solve this ever-growing challenge.

Groundwater has been an increasingly important source of irrigation over the last few decades, and it is now used in roughly 40% of the world's irrigation area. We may run out of water in the future as agricultural production becomes increasingly reliant on unsustainable groundwater use, posing a threat to future crop supply. Climate change has a considerably more visible influence in Indian agriculture, where 85% of farmers are poor and marginalized, and 60% of agriculture is dependent on monsoon vicissitudes. As a result, the role of irrigation comes into focus. Because of the widespread usage of traditional flood irrigation technology, India's overall irrigation productivity is frequently found to be rather low when compared to worldwide levels. And that's where the importance of precision-irrigation becomes apparent.

A precision irrigation system is a modern irrigation technology. Water is frequently distributed in this system in the form of single droplets, continuous drops, streams, and so on. Precision- irrigation systems are becoming increasingly popular because of their low cost and water efficiency. Precision irrigation can boost yields while lowering water, fertilization, and labor costs. The approach lowers water loss by transport, run-off, evapotranspiration, and absorption by providing water to the plant's root zone. Drip irrigation is one of the most effective irrigation systems. Emitters carry water straight to the plant root further into the soil in Drip Irrigation.

These emitters use valves, twisters, and complicated or extended flow routes to regulate and spread the pressure from the water source, allowing just a little volume of water to flow through. Weed and pest pressure may be reduced as a result of less soaking of soil surfaces and plant tops. The most important agricultural advantages of precision irrigation are that it saves water, pest problems are reduced, the amount of surface crusting is reduced, and irrigation and fertilizer application are managed jointly. In addition to these agricultural benefits, low pumping requirements, machines (which lower labor expenses), and scalability all minimize production costs. However, there is little evidence that precision irrigation has a positive impact on the economy. The Union government, seeing the importance and potential benefits of the precision- irrigation technique to double farmers' earnings while also ensuring agricultural sustainability and environmental integrity, created the Pradhan Mantri Krishi Sinchai Yojana. However, there is still a long way to go, and significant trials, training, and awareness campaigns are needed to bring the Indian farming community up to speed on precision irrigation procedures.

With the significant power limitations in India throughout the upcoming years, owing mostly to the water crisis, it will take another 100 years to give 'nationwide' precision-irrigation support. Pumps are typically left 24 hours a day, seven days a week by farmers. There have been cases where the mechanism has been automated so that pumping can resume as soon as the power is restored. Both power and groundwater resources are depleted as a result of such operations. There are also concerns regarding water conservation whilst the use of precision irrigation where the farmer may use up the extra saved water to grow another crop instead of preserving it for more beneficial uses.

The crop productivity increases but there is no increase in water conservation. Therefore, a systematic effort should be adopted to ascertain the situations under which precision- irrigation systems become the "safest innovation" in terms of acknowledging the positive advantages and the scope of agricultural water requirement reduction possible through such systems, is essential for assessing our capacity to address future water crisis at the national and regional level.

1.2 Irrigation

Irrigation is a method of providing water to crops in order to aid their growth. It also preserves crops, boosts yields, avoids soil compaction, and suppresses weed growth. India's net agricultural area is 142.0 million hectares, with a net irrigated area of 65.3 million hectares. Due to India's enormous geographical size, irregular rainfall distribution, differing water requirements of different crops farmed, and a tropical environment with high evaporation rates, increasing the gross irrigated area is critical.

Techniques of Irrigation

The following are the main types of irrigation:

Surface irrigation

To make the land wet and infiltrate the soil, water moves over and across the land via gravity flow.

Burrow, border strip, and basin irrigation are the three types of surface irrigation.

Localised irrigation

Is a system in which water is distributed through a piped network under low pressure. Water is applied as a tiny discharge to each plant or the region around it through the network, which is a pre-designed arrangement. This category includes drip irrigation, spray/micro-sprinkler irrigation, and bubbler irrigation**.**

Sprinkler Irrigation

Is a water distribution system that uses a piped network to distribute water at low pressure. Water is applied as a tiny discharge to each plant or the space around it through the network, which follows a pre-designed pattern. This category includes drip irrigation, micro-sprinkler irrigation, and bubbler irrigation.

Sub-irrigation

It's also known as seepage irrigation. It's employed in locations where the water table is high. It's a technique for artificially increasing the water table and moistening the soil below the root level of plants.

1.3 Components of Micro Irrigation Systems

Drip irrigation and sprinkler irrigation are the two main forms of micro irrigation systems.

The drip irrigation system is designed to irrigate the crop's root zone rather than the surface. The technology allows for the administration of small amounts of water on a regular basis, ensuring a constant supply of water throughout the day. In contrast to standard surface irrigation systems, which stress plants due to feast and famine cycles, such a system can neutralise the nutrients and level of water accessible to the crops, which is one of the primary reasons for its superior performance.

Sprinkler irrigation, on the other hand, is a type of water application that mimics natural rainfall. Water is sprayed on the crops and falls as smaller water drops through a series of pipes. Water is not applied directly to the soil or root zone in this technique.

A drip irrigation system consists of the following components: (but not limited to)

Controller/Timer: Watering cycle is controlled by a controller/timer, which directs when, how long, and how often the system operates.

Backflow Preventer: This device stops water from being syphoned back into the drinking supply.

Valves: These are used to turn the water on and off.

Filter: Prevents the system from being clogged with dirt and debris.

Pressure Regulator: lowers incoming water pressure to the system's ideal level.

Pipe: A pipe transports water throughout the system.

Micro-Tubing: transports water from the emitters to the plans via micro-tubing.

Emitters: provide water at a steady, gradual pace.

Flush Valve/Cap: located at the end of each irrigation line to flush out dirt and debris.

Sprinkler irrigation systems comprise the following components: (but not limited to)

Prime Mover/Pump Suction Pipe: The Prime Mover/Pump Suction Pipe is used to lift water from the source and push it through the distribution system at a high enough pressure.

Main Line: transports water from the pumping unit to various portions of the field.

Sub-Main: this pipe transports water from the main to the lateral lines.

Lateral Lines: The rising pipe transports water from the main line or sub lines to the sprinkler head. These are lightweight and have rapid connecting devices.

Sprinkler Head: This is a device that sprays water into the field. These can have a revolving, fixed, or perforated head.

Sprinkler Lead: There are three types of sprinklers based on their operating pressure: low operating pressure sprinklers, intermediate pressure sprinklers, and high operating pressure sprinklers.

1.4 The Global Water Management Crisis and Precision-Irrigation

Water scarcity is evident not only in the desert and drought-prone countries but also in locations with copious rainfall: Water scarcity refers to both the quantity and quality of available resources, as deteriorated water supplies become unavailable for more severe requirements.

With the growing unavailability of clean water, it goes out to conclude that water shortages will cause a shift in popular opinion of the worth of water, leading governments and businesses to consider clean water as a priceless resource rather than a commodity to be exploited.

Agriculture in water-scarce areas stresses sustainable water use, including conserving natural resources, environmental protection, suitability of technology, economic feasibility, and social implications of development challenges.

Approximately 11% of the world's terrain is currently used for crop cultivation (arable land and land under permanent crops). This area accounts for somewhat more than a third (36%) of the land that is thought to be suitable for crop production to some extent. Asia and North and Central America have the largest areas of arable land, accounting for 32 % and 21% of the total land area on the planet, respectively. The extent of irrigation land in the 21% of arable land of Asia has seen a steep growth in the last decade and with the growing population, it is bound to increase more.

So, it means that with limited accessibility to freshwater resources, there will be a huge demand for irrigation water.In emerging nations, intensification in the form of increased yields (67%) and cropping intensities (managing multiple crops) will account for around 80% of the expected expansion in crop output (12%).

The share of the intensification will reach 90% in arable lands of Africa and South Asia. The rising share of irrigated agriculture in overall crop production is partly responsible for the anticipated contribution of yield growth, as irrigated agriculture is often more intensive than rainfed agriculture. By 2050, worldwide agricultural water demand (including rainfed and irrigated agriculture) is anticipated to increase by 19%. This could result in a catastrophe if water is not adequately regulated.

Agriculture uses over 70% of the groundwater withdrawn globally and nearly half of the world's drinking water comes from underground sources. Many rural populations in Asia, the Middle East and North Africa, and Latin America have reaped significant socioeconomic gains from the groundwater irrigation farming development, with many economies reliant on groundwater.

India is among the three countries with the largest areas suitable for irrigation using groundwater with China and the USA.

Water Requirements for Different Uses in India (BCM) (1997-1998, 2010, 2025 and 2050)										
Uses	**Year 1997-98**	**Year 2010**			**Year 2025**			**Year 2050**		
		Low	**High**	**%**	**Low**	**High**	**%**	**Low**	**High**	**%**
Surface Water:										
Irrigation	318	330	339	48	325	366	43	375	463	39
Domestic	17	23	24	3	30	36	5	48	65	6
Industries	21	26	26	4	47	47	6	57	57	5
Power	7	14	15	2	25	26	3	50	56	5
Inland Navigation		7	7	1	10	10	1	15	15	1
Flood Control		-	-	0	-	-	0	-	-	0
Environment (1) A forestation		-	-	0	-	-	0	-	-	0

Environment (2) Ecology		5	5	1	10	10	1	20	20	2
Evaporation Losses	36	42	42	6	50	50	6	76	76	6
Total:	399	447	458	65	497	545	65	641	752	64
Ground Water:										
Irrigation	206	213	218	31	236	245	29	253	344	29
Domestic and Municipal	13	19	19	2	25	20	3	42	20	4
Industries	9	11	11	1	20	20	2	24	24	2
Power	2	4	4	1	6	7	1	13	14	1
Total:	230	247	252	35	287	298	35	332	428	36
Total Water Use:										
Irrigation	520	543	557	78	561	611	72	628	817	68
Domestic	30	42	43	6	55	62	7	90	111	9
Industries	30	37	37	5	67	67	8	81	81	7
Power	9	18	19	3	31	33	4	63	70	6
Inland Navigation	0	7	7	1	10	10	1	15	15	1
Flood Control	0	0	0	0	0	0	0	0	0	0
Environment (1) A forestation	0	0	0	0	0	0	0	0	0	0
Environment (2) Ecology	0	5	5	1	10	10	1	20	20	2
Evaporation Losses	36	42	42	6	50	50	6	76	76	7
Total:	629	694	710	100	784	843	100	973	1180	100

Table 1: Sectorial water requirements in India (in Billion Cubic Meters)

1.5 Precision-Irrigation: An Innovative Technology

As a result of heavy use, India is projected to suffer severe water scarcity in the next years. The approaching water crisis might generate conflict and displacement, as well as food shortages and economic insecurity.

Because agriculture consumes 80% of India's freshwater, central and state governments frequently propose precision irrigation as a solution to the country's developing water crisis. By offering a point solution to the irrigation distribution chain, the Pradhan Mantri Krishi Sinchai Yojana (PMKSY), a central government scheme, helps to stimulate the transition to precision irrigation and "more crop per drop." The goal is to improve irrigation efficiency by implementing modern technology such as drip irrigation.

The benefits of Precision-Irrigation are:

- Crop yields are improved, energy consumption is reduced, and transportation losses are minimal.
- Precision irrigation reduces evaporation, runoff, and deep percolation as well as the use of synthetic fertilizers and pesticides.
- It also provides other benefits such as avoiding the exploitation of groundwater, lowering the cost of weeding, and alleviating the effects of water-scarcity-induced labor migration.
- Because of its proximity and targeted application, precision irrigation saves a substantial amount of water.

Precision irrigation can boost yields while lowering water, fertilizers, and the cost of labor. The technique lowers water loss by conveyance, run-off, deep percolation, and evaporation by providing water directly to the root zone. Traditional irrigation approaches cannot avoid these losses; however, micro-irrigation has paved the road for improved water use efficiency of 75- 95% thanks to its water-saving approach.

Fertigation, which combines water and fertilizer application through irrigation, is another resource-saving strategy made possible by precision irrigation. Fertigation results in the balanced nutrient application, a 7-42% reduction in fertilizer requirements (saving the farmer money), greater nutrient absorption, and nutrient usage efficacy.

Farmers were able to cultivate 519.43 hectares of degraded land using the technology, according to a national survey conducted for the Union government. It also allowed for the irrigation of plants with saline water without generating salinity or osmotic pressure. Another benefit is that optimal soil moisture conditions are maintained, which helps to boost overall production and profitability. Precision-irrigation systems have been found to assist increase the output of both fruit and vegetable crops in several studies. Adoption of various cultivation practices has been another benefit.

1.6 Precision-Irrigation: Current Status

The country's average precision-irrigation penetration rate is 5.5%, which is substantially lower than the global average, and only a few states in India have penetration rates higher than the national average.

The states of Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan, Tamil Nadu, Telangana have progressively adopted precision- irrigation. Punjab, Jharkhand, Bihar, Chhattisgarh, Goa are under the performing states slowly but surely using precision-irrigation. Arunachal Pradesh, Manipur, Meghalaya, Nagaland, and West Bengal are the states that have yet to pick up on precision irrigation.

In 2012, the area under sprinkler irrigation grew at a CAGR of 58.6%, while the same area under drip irrigation grew at a CAGR of 41.4 %.

In 2015, the area under sprinkler irrigation grew at a CAGR of 56.4 %, while the same area under drip irrigation grew at a CAGR of 43.6 %. As a result, drip irrigation has seen a surge in popularity in recent years (2012-15), with its growth rate (CAGR 9.85 %) outpacing that of sprinkler irrigation (CAGR6.6%). Micro-irrigation potential is predicted to be 69.5 Mha, with cereal crops ranking first with 29.6 Mha.

1.7 Government Schemes available for Precision-Irrigation

Since 2006, the Government of India has acknowledged precision irrigation as a focus area in different Centrally Sponsored Schemes (CSS). The National Mission on Micro Irrigation (NMMI) updated it from 2010 to 2014, and the National Mission for Sustainable Agriculture (NMSA) upgraded it in 2014-15. An insufficient subsidy, poor cash management, a land restriction of 5 ha, and lack of uniform implementation was all drawbacks of this scheme.

In the 2014-15 fiscal years, the National Mission for Sustainable Agriculture (NMSA) comprised four components:

- rain-fed region development
- on-farm water management
- soil health management
- climate change and sustainable agriculture.

This scheme had its share of major benefits as well as shortcomings.

The Pradhan Mantri Krishi Sinchayee Yojna (PMKSY), a major scheme established by Honourable Prime Minister Narendra Modi in 2015, has two unique slogans for water management:

- "Har Khetko Pani" - Irrigation Cover Extension
- "Per Drop More Crop" - Improving Water Use Efficiency.

Some state governments have taken the lead in implementing precision irrigation:

- Gujarat Green Revolution Company Ltd (GGRC), a Public Private Partnership (PPP) model, being one of them
- Gujarat State Fertilizers & Chemicals Ltd (GSFC)
- Gujarat Narmada Valley Fertilizer Company Ltd (GNFC)
- Gujarat Agro Industries Corporation Ltd created GGRC in 2005 during dynamic Gujarat (GAIC)

1.8 Agriculture in India

Agriculture sector is a large section of the Indian economy. India's agriculture sector covers over 47 percent of the country's land area. India's sector accounts for over 47% of the country's total land area. Agriculture supports more than 70% of rural households. Agriculture in India must ensure food security for a population of 1.2 billion people.

Many agricultural commodities, such as rice, wheat, pulses, groundnuts, sugarcane, cotton, jute, milk, fruits, and vegetables, are produced in India as the world's leading or second largest producer. Agriculture employs 263 million people in India's rural areas, who work as farmers or agriculture laborers, tilling an average of 1.15 hectares (ha) per household. Women make up a little more than one-third (34.9%) of the rural working population, according to the 2011 census. Female cultivators, on the other hand, made up a smaller proportion of the total (23.4%) than female agriculture labourers (43.1 percent).

Climate Variation

While Indian agriculture has so far been able to fulfil the needs of the country's rising population, it faces a number of issues that reflect both the country's socioeconomic situations as well as South Asia's environmental and climatic conditions.

Climate change, decreasing natural resources, geographical fragmentation, and other factors are all posing challenges to Indian agriculture. One of the primary decisive elements influencing humanity's future food security on the planet will be the impact of climate change on agriculture. Understanding weather variations over time and modifying management procedures to achieve a better harvest are both obstacles to the agriculture sector's overall growth. Agriculture's climate sensitivity is unknown due to regional differences in rainfall, temperature, crops and cropping systems, soils, and management approaches [26].

Small and Marginal Farmers Holding Less Land

Small holdings of land account for the majority of land in Indian agriculture, and as a result, both output and earnings/incomes are affected. This suggests that the lower the land holding, the lower the farmer's income. India's net arable land area is 141 million hectares.

In 1951, there were 6.99 crore land holdings, but by 1996, that figure had risen to 11.55 crore. In 2011, this value was estimated to be 11.88 crore. The average size of a land holding in 1996 was 1.41 hectare. However, in 2011, this average value fell to 1.15 hectare. 86 percent of the total land holdings were owned by small and marginal farmers.

Size of Land Holding (in Hectares)	**Monthly Income of farm Household in Rs.**
2	7,348
4	10,730
10	19,637
Above 10	41,388

Table 2: Emerging trends in size of land holding and monthly income of a farm land

The persistent problem of low productivity has been caused by the increasing proportion of small and marginal farmers, i.e., 86 percent. In India, one hectare of land yields less than 40% of agricultural earnings compared to US farms, and only 50% of farm earnings in China [29].

Country	Productivity per Hectare in KG
USA	7,638
China	5,886
Brazil	4,640
India	2.984
Russia	2,444

Table 3: Trends in cereal productivity per hectare in selected countries in 2014

Water Management Problem

In India, irrigation is everything; water is more valuable than land. If the monsoon fails, the agricultural industry will be shut down. The widespread consensus today is that the issue is not a lack of water, but rather one of poor water management, i.e., utilisation, extension, and storage. The country has 183 million hectares of cultivable land, 115.6 million agricultural families, 400 million metric tons of yearly precipitation, and a favorable agro-climate for growing a wide range of commodities.

Agriculture employs almost two-thirds of the country's population and feeds over 1000 million people every day. Even now, India's agriculture is strongly reliant on the monsoons. Rain is required for over 70% of the net sown area.

Water is a three-pronged issue: it is a problem from the supply side, the demand side, and the quality side. By 2030, India would need to produce 60% more rice with significantly fewer resources. Irrigated agriculture accounts for only 46% of India's cropped area, yet it produces almost 56% of the country's agricultural output and 60% of the country's food grains. Water - rainfall or irrigation – plays a big role in farming efficiency or lack [27].

Affect of Economic Reforms Policies

Despite the fact that the Green Revolution was initiated with the intention of making the country food self-sufficient and improving the well-being of agricultural dependents, it has only served to enrich huge farmers. Increased agricultural costs, low-quality fertilisers, decreased crop yield, stagnating crop production, and essentially no advantages from agricultural crops were all challenges caused by the Green Revolution.

The Indian government implemented massive economic reforms in 1991 to combat poverty, unemployment, and income inequality. The Uttar Pradesh State Government implemented economic reforms primarily after the adoption of the State Industrial Policy in 1998, which aimed to reduce unemployment and poverty by attaining economic growth by focusing on industrial and agricultural growth.

In these policies of economic transformation. Agricultural development was not given a direct focus, but it was thought that agricultural trade would indirectly support agricultural development. Although these economic changes had some impact on agricultural development, the focus of economic reform policies on the service sector and the absence of policy attention on agricultural development had a negative impact on agricultural development and worsened small farmer problems [62].

Factors Affecting Crop Productivity

Due to overexploitation of fertilizer, wrong arrival of season or monsoon, and overexploitation of land, the area, production, and productivity of food grains and important crops have reduced.

People in cities are migrating to the countryside for employment and business, transforming agricultural land into infrastructure land. Although a man is the owner of agricultural land, his current generation does not wish to pursue a career in agriculture. This will result in a reduction in experienced and skilled workers in the near future. Farmers are only getting sporadic benefits from agricultural schemes and projects.

Commercial banks and cooperative banks do not provide agriculture loans to Indian farmers in a suitable manner. The media, private companies, and Krishi Vigyana Kendra's extension and awareness programmes are less to crop session [58].

Degradation of Resources

With the majority of farmers holding less than one hectare of land, Indian agriculture is basically small farm agriculture. In India, small and marginal farmers currently account for more than 80% of farming households. The average size of a farm has been shrinking. Over the previous few decades, the land and water resource base for the average agricultural holding has decreased, implying that more food can be produced with less land and water resources.

There was obvious indications of technology fatigue, run-down delivery systems in credit, extension, and marketing services, and insufficient agricultural planning at the district and lower levels, in addition to stressed natural resources and severely inadequate rural infrastructure." Increased trade deregulation has presented new obstacles for Indian farmers, who are now obliged to compete on quality and price for a variety of products not only in export markets but also in domestic markets. However, small and marginal farmers are frequently left out of these partnerships since only large farmers are able to integrate their production to meet demand cycles and quality criteria [48].

Knowledge Gaps

Services and high-quality inputs are critical productivity boosters. Their best usage, however, necessitates knowledge. Farmers also require data on prices and markets, post-harvest management, determinants of food quality, and safety regulations. Some farmers gather information on their own.

The "resource-poor" majority, who raise a large portion of India's food, require external, science-based extension to supplement their local knowledge [17].

1.9 Maharashtra – Agriculture Sector

Maharashtra's primary source of income is agriculture. Maharashtra's economy is primarily based on agriculture. It is the people's primary occupation. In the state, both food and cash crops are farmed. Rice, jowar, bajra, wheat, pulses, turmeric, onions, cotton, sugarcane, and a variety of oil seeds such as peanut, sunflower, and soybean are among the most important crops. The state includes vast regions dedicated to fruit farming, with mangoes, bananas, grapes, and oranges being the most popular. A total of 33,500 square kilometres of irrigated land has been utilised for crop cultivation.

Climatic conditions

Maharashtra experiences normal monsoon weather, with hot, rainy, and cold seasons. Tropical weather can be found across the state.

Summer: The hottest months are March, April, and May.

Rainy Season: The rainy season usually begins in the first week of June. In Maharashtra, July is the wettest month, however August also sees a lot of rain.

With the arrival of September, the monsoon begins to leave the state. Winter: From November to February, a cool dry stretch with sunny skies, mild breezes, and pleasant weather prevails. However, rainfall does fall on the eastern part of Maharashtra on occasion. During this season, the temperature ranges from 12°C to 34°C.

Rainfall: Maharashtra's rainfall varies from region to region. The districts of Thane, Raigad, Ratnagiri, and Sindhudurg receive an average of 200 cm of rain every year. Nasik, Pune, Ahmednagar, Dhule, Jalgaon, Satara, Sangli, Solapur, and parts of Kolhapur, on the other hand, receive less than 50 cm of rain. Rainfall is concentrated in Maharashtra's Kokan and Sahyadrian regions. Maharashtra's central region receives less rainfall. Eastern Vidarbha, on the other hand, benefits from the Bay of Bengal's impact in July, August, and September [77].

Weakness

1. Agriculture that is primarily rain-fed (irrigated land accounts for only 18% of total Gross Cropped Area).
2. Rainfall is dispersed throughout regions, with one-third of the state receiving little rain – the state contains 24% of the country's drought-prone land.
3. Well irrigation accounts for 65 percent of the total irrigated land in the state.
4. Despite significant investments in surface irrigation, inadequate irrigation potential and project delays have resulted.

Threats

1. Water scarcity for irrigation, as well-irrigation is the primary method of irrigation, and several districts have seen water table depletion.
2. Water logging has resulted from the cultivation of water-intensive crops.
3. Natural disasters such as cyclones, unpredictable rainfall, and prolonged drought spells result in significant farm losses.
4. Inadequate horticultural infrastructure, such as roads, markets, communications, and energy. In rare situations, high pesticide residues in crops cause export consignments to be denied.

Pune District

Pune district is Maharashtra's second largest geographically. It is located in the western region of the state. The district's overall geographical area is 15.62 lakh hectares, accounting for 5% of the state's total geographical area.

Food grains cover 67 percent of the GROSS CROPPED AREA in Pune district, with cereals accounting for 60% and pulses accounting for 7%. Low- value grains such as rabi jowar, which accounts for 35.6 percent of GROSS CROPPED AREA, and kharif bajra, which accounts for 10.3 percent of Gross Cropped Area, dominate the cropping pattern in Pune district. Productivity of these crops is lower than state average. The area under oilseeds is 6 percent of gross cropped area.

Productivity of groundnut, the main oilseed in Pune District is lower than state average. Since animal husbandry activities, especially dairy is very important in Pune district, low growth rate in fodder is a serious problem.

There is indiscriminate use of irrigation water leading to soil salinity and water logging. The irrigation potential created in the district is not fully tapped. Further, only a negligible portion of the area is under drip irrigation. Further, major portion of the irrigated area is devoted to sugarcane crop. Lack of irrigation facilities is also responsible for low cropping intensity which is barely 114 percent.

According to the land ownership pattern, 80.5 percent of farmers are marginal or small, owning 43.55 percent of the land. Due to a lack of suggested crop rotations in the sugarcane cropping system, fertility and production have decreased, as well as pest concerns. Sugarcane cultivation is depleting water supplies and threatening farming's long-term viability in many locations. Intercropping and crop rotation are also lacking.

Irrigation and Groundwater

The Pune district has a net sown area (NSA) of 9.92 lakh hectares, including 2.62 lakh hectares of net irrigated land. Only 26.4 percent of net seeded land is irrigated, according to this data. Indapur, Baramati, Junner, Shirur, and Daund had 34 percent, 28 percent, 31 percent, 24 percent, and 25 percent net irrigated area to net cultivated area, respectively. The rest of the talukas have a substantially lower percentage of irrigated land than the district average. The district's total irrigated area is 3.13 lakh hectares.

Rivers

Bhima, Neera, Mula, Mutha, Indrayani, and Ghod are some of the rivers that pass through this area. These rivers carry a large amount of water, and many irrigation dams have been built across them. The district has a diverse physiographic profile, with highly undulating mountainous topography on the western side and a huge plain stretch on the eastern side.

The majority of the talukas in Pune district are prone to flooding. River Bhima (Tal. Shirur, Daund, Indapur, and Haveli), River Mula (Pune city), River Mutha (Tal. Punecity and Mulshi), River Indrayani (Tal. Khed, Haveli, and Maval), River Ghod (Tal. Ambegaon), River Mina and Pushpavati (Tal. Junnar), and River Nira (Tal. Indapur and Purand), River Pavana (Tal. Haveli).

Canal irrigation and well irrigation account for 46.3 percent and 53.7 percent, respectively, of the total irrigated land. Dams such as Khadakwasla, Ghod, Ujani, Veer, Pavana, Chaskaman, Kukadi, and others, as well as their irrigation canals, are the district's main sources of irrigation. 71 watersheds have been created within the district. Out of them, 44 were deemed safe, whereas 11, 2, and 14 were deemed semi-critical, critical, and over-exploited, respectively.

The district's Net Groundwater Balance is predicted to be 45197 Ha-m. 9 talukas are classified as safe, but the remaining 4 talukas, Baramati, Purandhar, Junnar, and Ambgaon, are classified as semicritical, based on the state of groundwater development in the district. Drip irrigation is used on 29027 hectares in the district.

Geographical Area

Pune district is Maharashtra's second largest geographically. It is located in the western region of the state. The district's overall geographical area is 15.62 lakh hectares, accounting for 5% of the state's total geographical area.

Topography and Agro-Climatic Conditions

Except during the monsoon, the district's climate is characterised by a dry atmosphere. Summers are hot, with temperatures ranging from 360°C to 460°C. The annual rainfall averages 905 mm. The rainfall pattern varies from 5080 mm in the western mountainous region to 457 mm in the eastern plateau, with the latter gradually decreasing eastwards.

Zone- 6: Scarcity Zone- With kharif - cum Rabi Cropping

The famine area of Maharashtra is a huge region in the state's mid-western region. It includes the districts of Pune, Ahmedngar, Nasik, and Dhule (excluding the portions covered under plain Zone).

With 8.21 lakh hectares, this zone is the largest in Pune district. Agro-Climatic Zones-Pune District occupy 11 hectares, or 53% of the district's total area. Purandar, Baramati, Indapur, Daund, Shirur, Junnar, Ambegaon, Khed, Haveli, and Bhor talukas of the district are included.

Rainfall and Temperature

Rainfall is widely distributed within the district due to topographical circumstances. As previously stated, about 73 percent of the district's cropped land is farmed in rainfed conditions. The district's average rainfall is lower than the state average, and one of the key limits in the district's agriculture is the fluctuation in rainfall between different blocks within the district as well as throughout different years. According to a study, anytime there is a decrease in rainfall, agricultural commodity productivity drops dramatically.

Land Capability Classification Approximately 60% of the land in all talukas is classified as moderately to fairly good land for cultivation. Only around 14% of the land is suitable for cultivation, and the rest is unsuitable for cultivation.

Soil Type

The soils of Pune district range from deep black plain and scarcity zone soils to shallow red or reddish brown sub mountain and western ghat zone soils. The Pune district's soils are divided into five categories: black (45%), red (5%), alluvial (8%), sandy (12%), and sandy loams (12%).

Soil Fertility Indices

Soil fertility refers to the soil's natural ability to give nutrients in sufficient amounts and proportions for crop growth and output. The practise of selecting high yielding varieties to increase yield has led in nutrient deficit in soils, which has manifested as deficiency symptoms in plants. As a result, knowing the fertility status of the district's soils is necessary for applying the requisite fertiliser dosage and planning fertiliser distribution over the region.

Land Use Pattern and Land holdings

Approximately 23% of the land is used for non-agricultural purposes, such as forest, non- agricultural land, cultivable waste, permanent pasture, and various trees and groves. Approximately 7% of land is used for current and other fallow purposes, while the remaining 64% is sown.

According to the agricultural department's data, the land holding pattern in Pune district in 2011 shows that roughly 80% of farmers have land holdings of less than 2 hectares (marginal and small farmers). However, around 20% of farmers own more than 2 hectares of land. As a result, the average land holding of the district's marginal and small farmers is 0.44 and 1.42 hectares, respectively.

Rain Intensity

Highest rainfall intensity zone are Mulshi and Maval

Moderate rainfall intensity zone are Bhor, Ambegaon, Junnar, , haveli,

Lowest rainfall intensity, the dry and semi-arid zone are Shirur, , Indapur and Baramati [78].

1.10 Modern Technology and Agriculture

"If agriculture fails, nothing else in the country has a chance to succeed." Agriculture has long been the backbone of the economy. It is the primary source of income for the technologically underdeveloped and economically disadvantaged.

Urbanization and Agriculture

All people were shifting from rural to urban areas as a result of increasing population pressure. This will result in a rise in urban population pressure. As a result, the government will push for the expansion of urban areas, which will have an impact on rural areas and agricultural production.

This will reduce the fertility of the land, resulting in lower crop and food production productivity. As a result, urbanisation poses a constant danger to agriculture and farmers [76].

What is Digital Transformation?

To satisfy changing company and market requirements, digital transformation is the process of leveraging digital technology to construct or improve existing business processes, culture, customer experiences, and agriculture. Simply said, use digital technologies and digital innovation to build new items or modify old ones [74].

Important of Agriculture & Technology

Farmers gain from agricultural technology in numerous ways, including higher crop productivity, reduced use of water, fertilisers, and pesticides, which lowers food prices, less impact on natural ecosystems, reduced chemical mix in rivers and ground water, and increased worker safety. Farmers' contributions to agricultural technology, such as increased efficiency and cheaper pricing, better foods, and safer crop growing conditions, reduced the ecosystem's environmental and ecological impact [76].

Technology Makes Smart and Sustainable Farming

Technology and the Internet of Things (IOT) have infiltrated our lives and businesses in order to make our lives more efficient and comfortable. Technology, according to the United States Farmers and Ranchers Alliance (USFRA), is about more than just being better and faster; it's also about being sustainable. This has implications for farmers and ranchers in terms of food production and the role of technology in agriculture.

Many farmers are employing modern technologies such as moisture sensors, drones, smart irrigation, terrain contour mapping, self-driving tractors, and GPS-enabled tractors to produce food in a more sustainable and effective manner. Farmers are being 'teched up' when it comes to growing food that is both sustainable and profitable, according to economists who study the future of agriculture. Agriculture is predicted to boost productivity and raw materials for the high rating of increased production pressure between 2016 and 2050, growing to 9.7 billion people [76].

Agriculture, as the primary source of food grains and other raw materials, is regarded as the foundation of human life. It is critical to the country's economic development. It also gives them with a significant number of job options. Growth in the agriculture sector is essential for the country's economic success.

Unfortunately, many farmers continue to adopt traditional farming methods, which results in low crop and fruit yields. However, whenever automation has been deployed and humans have been replaced by automated machines, the yield has increased. As a result, current science and technology must be implemented in the agriculture industry in order to increase yield [21].

Technology will undoubtedly guide farming practises. Agriculture is transformed by technology by addressing issues such as quality, quantity, distribution, and storage of supplies. Robots, temperature and moisture sensors, aerial photographs, GPS technologies, and other technologies aid agriculture. Agriculture and technology are intertwined and interdependent. Agriculture will not be able to progress to the next step without the use of technology [75].

Technology Revolution in India

The Green Revolution in India refers to the period during which India was able to implement contemporary agricultural methods and technology in order to enhance food production.

The promotion of High Yielding Variety (HYV) seeds and crops, tractors, irrigation facilities, herbicides, and fertilisers is the main source of the green revolution. M.S. Swaminathan, who was initiated by Normanbarlaug, developed the Green Revolution, which enhanced agricultural research and technology to increase agricultural output among developing countries throughout the world. Increased food production, such as paddy and wheat, is the main goal of the green revolution [76].

Agriculture currently employs only 2–3 percent of the population. Not only has the number of people working in agriculture decreased, but the average age of those living in farming homes is also rising in most developed countries. The global workforce has shifted away from agriculture and toward manufacturing and manufacturing service industries.

Thus, despite the fact that agriculture employs only 5% of the world's population, it generates more than 60% of global revenue. Accepting this reality, developed countries such as the United States and Japan are using mechanisation, automation, and modernization to address agricultural concerns. The 4IR will be an excellent opportunity to expand agriculture's size and commercialisation.

Future agriculture is predicted to expand into high-tech sectors as a result of this trend, with systems incorporating artificial intelligence and big data. The systems will merge into a single entity that includes agricultural machinery, soil seeding, farm management, production forecasts, and irrigation.

The 4IR will have a significant influence on the agricultural sector in three ways. For starters, exact optimization will solve a slew of present agricultural issues. Second, the return of rural production aspects, such as human resources, will have a significant impact on agriculture. Fourth, 4IR technologies will have a major impact on weather-related issues [68].

Intelligent Robots

As farmers have accepted more technology in the pursuit of higher yields throughout the centuries, the concept that 'bigger is better' has come to dominate farming, making small-scale enterprises untenable. However, advancements in robotics and sensing technology are threatening to destabilize the current agribusiness model. "Intelligent robots have the potential to revolutionise the economic paradigm of farming, making it possible to be a small producer again," says the author.

Robotics and sensing technologies in the twenty-first century have the ability to tackle challenges as old as farming itself. We can make crop production far more efficient and sustainable by switching to a robotic agriculture system. Engineers are researching automation as a means to cut expenses and improve quality in greenhouses dedicated to fruit and vegetable production [32].

Autonomous System Architectures

The use of robots in agriculture is motivated by the need to enhance food quality and output while reducing labour expenses and time. Another key cause for robotic agriculture is the lack of skilled labour in the agricultural industry, which has an impact on emerging countries' progress. Seeding, harvesting, weed management, grove supervision, chemical applications, and other agricultural tasks have all been effectively completed by robots. As a result, if farmers are given the tools they need to succeed with the help of robots, the nation's agricultural output will skyrocket.

Agriculture in developed countries must discover innovative ways to increase efficiency. One strategy is to use available information technologies in the form of more intelligent machines to more effectively cut and target energy inputs than in the past. The introduction of autonomous system architectures allows us to create a completely new line of agricultural equipment based on small smart machines that can perform the right thing, in the right place, at the right time, and in the right way.

Spraying can be done more correctly with an automated guiding system, reducing regions where too much fertiliser has been applied. Pollution and the time required to complete farming operations are both reduced as a result. Furthermore, because the tracking work is conducted by the tractor itself, such automation can improve the farmer's comfort [50].

Irrigation System and Agriculture Automation

Agriculture automation and irrigation systems are becoming major problems and rising topics for each country. Crop disease influxes, a lack of storage management, pesticide control, weed management, and a lack of irrigation and water channelized systems are all obstacles that are producing problems in the agriculture sector.

In a developing country like India, where water is one of the most significant restraints for people working in agriculture, the government is attempting to provide more support for the use of automation in irrigation and agriculture. The problem of water usage among Indian farmers leads to a smart irrigation method that also results in the efficient use of water resources [34].

Automated Monitoring Integrated System in Agriculture

As the rest of the world moves toward new technologies and implementations, agriculture must follow suit. Monitoring environmental variables is not a complete strategy for increasing agricultural productivity. There are a number of additional elements that have a higher impact on productivity. As a result, automation in agriculture must be applied to address these issues. To address all of these issues, an integrated system must be developed that considers all aspects affecting productivity at each level [67].

Impact of Technology on Agriculture Sector

In reality, when compared to other sectors, agriculture expansion is quite quick in reducing poverty and food insecurity. In developing countries, the impact of contemporary agriculture technology adoption on output variance and production hazards. Increased farm technology development and implementation can help enhance agricultural output while reducing yield fluctuation on the downside.

The evaluation of technical impacts gives grounds for programme discontinuation, modification, or expansion. This is necessary to avoid technology failure and negative consequences for early adopters. Farmers can make more informed and essential judgments about their crops as a result of technological adoption [18].

In the field of food and agriculture, digitalization, automation, and artificial intelligence are becoming increasingly important to farmers, academics, and decision-makers.

Digital technologies are being presented as a solution to developing social and environmental concerns in agri-food by industry and decision-makers. The use of digital tools (such as GPS, sensors, and data modelling software) in conjunction with automated technology (such as smart tractors, drones, and robots) will boost revenues, improve farmer livelihoods, improve livestock health and welfare, and reduce environmental consequences.

The Canadian government is currently investing in "climate smart" and "precision" technologies that "will contribute to Canada's position as a world leader in agricultural clean technology, assisting farmers in developing new and efficient energy uses while also protecting our natural resources and mitigating climate change [52].

Watering systems are one of the technologies that could be modified for agriculture. Crop irrigation is the world's greatest water user, accounting for over 70% of worldwide freshwater withdrawals.

Increasing irrigation locations, especially in wealthy countries, are used to meet rising food, feed, fibre, and bio fuel demand due to population increase. Farmers and field employees are at the heart of any transformation process, and they must be encouraged and guided toward water conservation using appropriate technologies and techniques [38].

Agriculture also necessitates water and energy infrastructure. Pumping systems, manmade and natural water storage, monitoring networks, and water governance and management are all examples of water infrastructure. The electric grid, bio fuel production, and fossil and carbon energy generation are all examples of energy infrastructure. Computing research has released game-changing powers in precision agriculture during the last two decades, allowing farmers to maximise farm returns, avoid wasteful fertiliser and pesticide applications, conserve natural resources, and deal with looming weather catastrophes.

Precision agriculture is an integrated food, energy, and water system that takes a holistic approach to agriculture. Farmers keep track of crop or animal growth and yield while also keeping an eye on water and energy usage [59].

Water is a critical element for increasing agricultural production and ensuring agricultural sustainability. In recent years, no other country has paid as much attention to irrigation development as India. Irrigated agriculture has proven to be the most effective way to boost food production. Water loss in transportation and distribution has been estimated to be as high as 50- 70 percent, with losses in water courses alone accounting for about 20% of the water provided at the canal outlet, significantly higher than what was originally anticipated. Depending on the texture and other soil properties, irrigation system, cropping pattern, and other factors, water losses on the farm can be significant.

Both water scarcity and water plenty have negative consequences for agricultural production. Our country has a plentiful rainwater supply (about 115 cm per year), yet agricultural output in rainfed areas remains poor and uncertain. Rainwater management is important in both low and heavy rainfall locations to reduce rain-induced damage and increase on-site and off-site agricultural production. Adopting cost-effective and efficient water management practices/technologies requires a lot of attention [73].

Agriculture is undergoing a new technological revolution, which is being backed by policymakers all around the world. While smart technologies such as artificial intelligence, robots, and the Internet of Things have the potential to boost productivity and reduce environmental impact.

The first was a transition from hunting and gathering to settled agriculture, the second was the British agricultural revolution in the 18th century, and the third was post-war productivity advances connected with industrialization and the Green Revolution in the developing world. While agricultural technology is not new, emerging technologies such as the Internet of Things, Cloud Computing, robotics, and Artificial Intelligence (AI) have the potential to transform farming beyond recognition, resulting in the shift to agriculture 4.0.

Precision agriculture, when combined with more productive crop varieties/livestock and the use of decision support systems to stimulate evidence-based decision-making, can lead to more efficient input utilisation and higher returns. Furthermore, robotic technology could aid farming communities by compensating for lost labour, which is becoming a big concern in the developing world as people migrate to cities [51].

Precision farming offers a novel system-based answer to today's agricultural difficulties, such as balancing production and environmental concerns. It is built on the use of cutting-edge information technology. It entails characterising and modeling soil and plant species variance, as well as combining agricultural practices to satisfy site-specific needs. It tries to maximise economic returns while also lowering agricultural energy input and environmental effect.

Precision farming is widely used in industrialised countries, but it has struggled to gain traction in India, owing to the country's unusual land holdings, limited infrastructure, farmers' unwillingness to take risks, and socioeconomic and demographic factors. Precision farming entails examining the greater efficiency that can be gained by comprehending and managing the natural variability found in a field.

Precision farming is a farm management approach that uses information and technology to discover, evaluate, and manage variability within fields for maximum profitability, sustainability, and land resource protection.

New information technology can be utilised to make better decisions regarding many elements of crop production in this kind of farming. The goal isn't to get the same yield everywhere, but to manage and distribute inputs on a site-by-site basis in order to maximise long-term cost/benefit.

Precision farming is one of the agricultural methods that entails the use of technology to better manage variability in the field. With the help of this technology, the human processing task is reduced, lowering the time and effort required to complete a task [35].

Engineering, technology, biology, and physical sciences are all important in modern agriculture. Agriculture activities have been mechanised, which has reduced manual labour and enhanced farm efficiency and output. Haryana and Punjab, for example, have very high degrees of mechanisation, whereas north-eastern states have very low levels of mechanisation.

Farm production is being impacted by rapid urbanisation, rising population, promising employment, and the expansion of other industries. Agriculture production can be raised by up to 30% and input costs can be reduced by up to 20% by automating agricultural activities.

America and Europe are in the forefront of the agricultural mechanisation revolution, followed by Japan, and now the rest of the globe is following suit. India's mechanisation levels are currently between 40 and 45 percent, lagging behind other BRIC countries such as Brazil and China. The annual food grain production must increase to 333 million tonnes by 2050, up from 257 million tonnes in 2014 [65].

ICT (Information Communication Technology)

The National Policy for Farmers stresses the use of ICT at the village level to reach out to farmers with the appropriate recommendations and information. Information is essential for the development of any industry. Agriculture isn't an exception. Agriculture can be greatly aided if relevant and timely information is provided. It aids in taking timely action, planning tactics for the following season or year, speculating on market changes, and avoiding unfavourable situations. As a result, how quickly and appropriate information is delivered to end users may have an impact on agricultural development. Other traditional techniques of providing information to end users exist. They are mostly inoculated, untimed, and only communicate in one direction. It will take a long time to gather information and receive input from end consumers.

Many businesses and institutes are employing information technology to deliver cost-effective and proper business models answers to the difficulties encountered by the agriculture sector. It should be noted that the ICT provides a wide range of initiatives for both social and economic development. An assessment of the impact was deemed necessary in order to evaluate whether the farmers' behaviour changed significantly before and after using ICT in agriculture. It should be remembered that a change that a farmer did not have before to his ICT application in agriculture may occur after his ICT application in agriculture.

In the context of agriculture, information technology (IT) can be evaluated in two ways: (a) as a tool for direct contribution to agricultural productivity, and (b) as an indirect tool for empowering farmers to make informed and quality decisions that will have a positive impact on the way agriculture and related activities are conducted.

Precision farming, which is prevalent in industrialised countries, makes considerable use of technology to boost agricultural productivity. To boost agricultural output, remote sensing using satellite technology, geographic information systems, agronomy, and soil sciences are applied. The indirect benefits of information technology in empowering Indian farmers are substantial, and they have yet to be fully realised.

For making decisions, the Indian farmer desperately requires quick and accurate sources of information inputs. Currently, the farmer is reliant on the delayed and inconsistent trickle-down of decision inputs from traditional sources. Information is not only valuable, but also crucial for Indian farmers to stay competitive in their changing environment [40].

Agriculture and information and communication technology (ICT) convergence is a recent phenomenon in India that aims to improve efficiency in all production, distribution, and consumption processes. An integrated agriculture system is another term for this system.

Data processing and digital control apparatus for digitization, data transfer, data gathering, network, and agricultural activity automation are the fundamental keys of the integrated agricultural system. It primarily focuses on cost reduction at the production level, labour burden reduction, high quality and organic manufacturing, and facility quality management.

Second, by constructing a system that distributes food safety information, it is critical to meet customers' needs at the manufacturing and distribution stages. This implies that IT applications in the agriculture farming automation system must be expanded.

Furthermore, modern distribution methods based on IT, such as distribution data convergence, must be implemented at the distribution and processing phases. These are just a few small parts of the digital agriculture system that contribute to the creation of a large database for the entire agriculture system.

In India, however, the introduction of farm technologies combined with a strong information and communication technology (ICT) framework is still in its early stages, but it has enormous potential to improve agricultural performance and increase farmer income. Technology has helped Indian agriculture overcome production stagnation, establish market links, and improve farm management on numerous occasions.

Growing more food was a tremendous challenge for Indian agriculture in the past, but it faces an even more challenging issue today and in the future: growing more sustainably and inclusively.

Declining total productivity, limited and degraded natural resources, a rapidly expanding demand for food (not only quantity but also quality), stagnating farm incomes, fragmented land ownership, and unprecedented climate change are all major difficulties facing Indian agriculture.

Technology adoption has been proven to update farmers' production processes, resulting in more consistent annual returns, reduced crop failure risk, and greater yields. The use of digital technology in agriculture has aided in the development of data and advanced analytics, allowing farmers to make informed decisions about farming and reap the benefits of cost-effective inputs and labour [56].

"Variations in field, labour condition, and many other elements affect fruits and vegetables, tree nuts, dried fruits, horticulture, and nursery crops. Precision agriculture is a site-specific farming approach that employs technology to measure and respond to crop variability both within and between fields.

It's been hailed as a crucial tool for enhancing agricultural productivity while also protecting natural resources. A decision support system (DSS) is the "brain" of precision agriculture, assisting growers in processing and responding to intra- and inter-field data.

Agriculture is becoming more data-rich as a result of recent technological advancements, particularly sensor technology and online data services. The specialty crop business in the United States, in particular, is undergoing a transition because to the application of information technology [70].

Agriculture is the mainstay of India's economic development. Climate change is the most significant hurdle that traditional farming faces. Climate change has a variety of effects, including heavy rainfall, more powerful storms and heat waves, less rainfall, and so on, all of which have a significant impact on production. Climate change has a number of environmental implications, including seasonal changes in plant life cycles.

In order to increase productivity and reduce barriers in the agricultural field, novel technologies and techniques such as the Internet of Things must be used. Technological advancements in respective fields are gaining traction, which means that the overview must be maintained. Environmental measurement and water management are the most critical aspects of smart farming. The reason for this is because plant development is influenced by environmental and water management [41].

Impact of Precision Farming/Automated Agriculture

A corresponding rise in agricultural productivity (yield) along with improvements in water and fertiliser efficiency will be required to meet future food demands from a growing global population while minimising any environmental damage. In this environment, irrigated agriculture will be crucial in sustaining greater output in dry and semi-arid regions, as well as improving crop quality in temperate and humid regions through supplemental irrigation.

Due to rising consumer demand for high-quality fruits and vegetables, as well as rising production (input) costs, farmers are beginning to assess the effects of irrigation non-uniformity on resource consumption, productivity, and crop returns [57].

Low and middle-income countries like India, China, and Brazil are seeing rapid urban population expansion. China and India ranked #1 and second in the list of countries with the fastest growing 100 cities, respectively.

Such drastic transformations have enormous ramifications for economic development, urbanisation, and energy use. With the increasing issue of biotic and abiotic stressors experienced by crops, the introduction and implementation of contemporary technologies in Indian agriculture is unavoidable in order to satisfy the massive food grain requirement of 480 million tonnes (Mt) by 2050.

Agriculture in the future will be fiercely competitive, knowledge-intensive, and driven by market forces. Despite the fact that India produces a big amount of food grain, the high cost of production and low productivity will force Indian farmers out of the free market economic rivalry arena. Increasing the productivity of small-scale farms in developing nations is an important component of addressing the problem of food insecurity.

To meet all of these new problems, an increase in pollution-free product productivity is unavoidable. This can be accomplished by employing innovative, environmentally friendly technologies that can effectively manage and allocate all resources for agriculture's long-term development. PA is a brand-new, highly promising technology that is fast gaining traction in developed countries. PA is based on a system approach to reorganise the entire agricultural system toward low-input, high-efficiency, and long-term sustainability [37].

Precision farming is a crop management concept focused on observing, measuring, and responding to inter- and intra-field variability. It's about doing the right thing at the right time and in the right location. Prescription farming, Variable Rate Technology, and Site Specific Crop Management are all terms used to describe PF. PF is a crop-management approach centred on watching, quantifying, and responding to inter- and intra-field variability.

It's about doing the right thing at the right time and in the right location. Prescription farming, Variable Rate Technology, and Site Specific Crop Management are all terms used to describe PF. Optimal profitability, long-term viability, and environmental protection Precision agriculture technologies have been created and are being used in agricultural production in recent years.

The new technologies have the ability to transform agriculture completely. In wealthy countries, PF is commonly used. In India, numerous institutes and organisations have taken the lead on precision farming initiatives. The Tamil Nadu Agricultural University executed the Precision Farming Project in high-value crops such as tomato, brinjal, sugarcane, and gherkins in Tamil Nadu [60].

Management strategies, soil attributes, and/or environmental factors all have a role in the differences. Because of the huge sizes and changes caused by annual adjustments in leasing arrangements in the farm region, maintaining a degree of awareness of field conditions is difficult. As a result, the entire farm must be divided into small farm units of $50 or less. Precision agriculture has the potential to streamline and automate data collection and processing. It enables management decisions to be made and implemented swiftly on tiny parts of bigger fields. The most extensively used and progressed among farmers is the application of PA techniques on arable land.

Machine vision methods have recently become popular in fruit and vegetable farming, allowing growers to grade items and monitor food quality and safety, with automation systems capturing metrics linked to product quality. Another key use of precision agriculture in arable land is to optimize fertilizer use, beginning with the three main nutrients Nitrogen, Phosphorus, and Potassium. These fertilizers are spread consistently over fields at specific times throughout the year in traditional farming [25].

Because of the greater farm sizes and changes in the areas cultivated owing to annual shifts in lease agreements that level of understanding of field conditions is difficult to sustain today. Precision agriculture has the potential to streamline and automate data collection and processing. It enables small-scale management decisions to be made and implemented swiftly within bigger sectors [45].

Water is a limited natural resource, and the agricultural sector has the highest demand for it. It is critical to make efficient use of available water for irrigation, but this is a huge difficulty. As a result, technological advances and interventions are critical for water development and management in order to ensure the long-term viability of agriculture. Because water is such a valuable resource in agriculture, every drop of water available at the delivery system, as well as its efficient use, is critical to total farm efficiency.

As a result, efficient use of available water is sensible and vital, and micro-irrigation is one such revolutionary method. The most prevalent micro-irrigation methods are sprinkler irrigation and drip irrigation. Economic return is a key factor in deciding whether or not to embrace a new technology, and land and water productivity are equally essential. As a result, new engineering measures are needed to make water productivity relevant in economic terms.

In arid and semi-arid regions of developing countries, efficient irrigation technology enables considerable water savings in agricultural production. Crop yields, less energy use, and reduced use of chemical fertilisers and pesticides are all noticeable advantages. It also provides other benefits such as avoiding the exploitation of groundwater, lowering the cost of weeding, and alleviating the effects of water scarcity-induced labour migration.

The irrigation efficiency at the field level can be used to calculate real water savings. Initiatives can be taken at the field level to improve water productivity for agriculture, and the saved water can be used for irrigation of more land or for environmental and social requirements [46].

In order to support increased farm production, the amount of fresh water used in irrigation must likewise increase. Agriculture currently consumes 83 percent of India's entire water supply. Unintentional water waste occurs as a result of unplanned water use. This shows that systems to prevent water waste without putting farmers under strain are urgently needed. Agriculture is rapidly becoming a very data intensive industry in the Internet era, where farmers must collect and evaluate a huge amount of information from a diverse number of devices (e.g., sensors, farming machinery, etc.) in order to become more efficient in production and communicating appropriate information. With the introduction of open source Arduino boards and low-cost moisture sensors, it is now possible to build systems that can monitor soil moisture content and irrigate fields or landscapes as needed.

The suggested system uses an ATMEGA328P microcontroller on an Arduino Uno platform, as well as IoT, to allow farmers to remotely monitor the status of sprinklers installed on their farm by knowing the sensor data, allowing them to focus on other farm chores [47].

Precision agriculture (PA) is a whole-farm management strategy that incorporates information technology, distant sensing, and proximate data collection. These technologies aim to maximise input returns while potentially lowering environmental consequences. Farmers and agronomists have already begun to use technology to help them be more efficient in their work.

Farmers may get extensive data on variables including soil and ambient temperature, irrigation water and soil conductivity, soil and irrigation water PH, nutrient composition data, irrigation water characteristics, and more using sensors installed in greenhouses. Communication technology and Artificial Intelligence (AI) paradigms could be used to communicate and analyse these data. Farmers use their smartphones to remotely monitor their crops and equipment, as well as to collect statistical information [30].

Agricultural water management is now widely acknowledged as a serious difficulty that is frequently tied to development concerns. Agricultural activity has deteriorated many freshwater resources, resulting in over-exploitation, nutrient pollution, and salinization. Irrigation is described as the artificial application of water to agricultural land, and it is one of agriculture's most vital components. Water scarcity in numerous areas necessitates proper water use, which means that water should only be delivered to those places where it is needed and in sufficient quantities. To deal with the water loss problem in traditional irrigation systems including flood irrigation and furrow irrigation, several irrigation technologies such as drip irrigation, sprinkler irrigation, and so on are used. As a result, a method for determining field conditions when water must be supplied to the fields is required. Sensor-based irrigation systems will lessen the farmer's workload while also assisting them in maintaining optimum soil conditions for greater crop output. As a result of advancements in technology, it is now possible to create systems that eliminate the farmer's direct involvement in irrigation of their crops.

As a result, a novel method of collecting real-time data from the field utilising a soil moisture sensor has tremendous potential for accurately monitoring soil water status in agricultural fields. Because the sensor nodes are relatively inexpensive, they can be used to create a dense population of soil moisture sensors that accurately mimic the intrinsic soil moisture variability seen in each field [49].

Disadvantages of Technology in Agriculture

There are also more downsides of technology in agriculture, such as [79]

1. The overuse of pesticides, which diminishes the land's fertility.
2. Farmers are unable to effectively operate machines due to a lack of practical expertise.
3. Maintenance costs are very high, which raises the cost of agricultural production.
4. Excessive usage of missions, which has an impact on the environment.
5. It is effective; however it has numerous side effects and disadvantages.

6. Access to technology is hampered by the lack of a diversless agriculture machine.
7. It enhances scouting programmes.
8. Because robots can't change their culture, we have to manually programme them.
9. Because the majority of farmers are illiterate, they are unable to use modern machinery and equipment.

1.11 Comparison of Agricultural Technologies in Different Countries

Israel:

In practically all indices, Israel's agriculture sector is one of the most productive and advanced in the world. With the support of contemporary technologies and active solutions in agriculture, the country was able to attain this outcome. Israel's agricultural development is based on the introduction of new technologies. The intensity compensates for limited innate potentiality. Traditional farming methods are not practised in the country. Although just about 20% of Israeli land is suitable for agriculture, Israeli farmers meet over 95% of the population's food demands. Some businesses assist Israel's agriculture sector in order to enhance it. Companies such as Sensillize, Biobee, Mi Robot, and Tal-ya aid in the most efficient use of land resources, the reduction of pesticide use, the development of insect breeds that eat harmful insects, the development of a robotic system that is used to make higher cow milking more efficient, and the introduction of higher level technologies to get more yield with the least amount of water. Roots Sustainable Agricultural Technologies", is Israeli firm that built robotic water pipes into soil that identifies the appropriate temperature for a given piece of land, assisting in the expansion of agricultural yields such as strawberries. Drip irrigation is a technique that has helped Israel alter agricultural around the world. Simcha Blass founded the Netafim corporation in the 1960s, using his slow-release tubing. Because some locations employ inefficient flood irrigation, about 70% of the world's water is used for irrigation.

Cropx, Saturas, and Manna, all Israeli enterprises, assist customers throughout the world in implementing efficient drip irrigation programmes that utilise the least amount of water while producing more crops. "Tipa" (drop), a kit that allows gravity to irrigate when water pressure is absent in rural areas, has had an impact on the availability of food in other countries [76].

Israel is one of the world's most densely inhabited countries. However, only 20% of the land is arable, with half of it requiring irrigation. More than half of the country is arid or semi-arid, with steep hillsides and forests dominating the remainder.

The country also has uneven rainfall, with the northern part receiving 700mm per year, the centre region having 400-600mm per year, and the southern portion receiving only 25mm per year [81].

Reasons for Success

- Kibbutzim (collective villages) and moshavim (cooperative villages) own and operate 80 percent of
  the country's farms.
- Kibbutzim frequently invent, design, produce, and market their own agri-technology inputs.
- These farmers collaborate with the country's 10 agricultural research institutes, including the Agricultural Research Organisation (ARO), which is part of the Ministry of Agriculture, to create drip irrigation, which later gave rise to Netafim. Various government entities and hundreds of private enterprises in the biotechnology and computer software sectors also sponsor R&D, as do 25 professional and marketing organisations.
- Because of the climatic circumstances and lack of natural resources, Israel has placed a strong emphasis on the notion of sustainable agriculture. Due to the peculiar circumstances, farmers, scientists, the government, and local agricultural concerns have had to work closely together.
- The Ministry of Agriculture is committed to encouraging water recycling and efficient use of water and treated waste water. Farmers who use sustainable agriculture technologies such as drip irrigation are eligible for a grant from the government.
- In the country, free market forces also play an important role, taking on turnkey projects such as more effective water use, irrigation systems, and crop and seed selection.
- In just four decades, strong political will, a focus on the notion of sustainable agriculture, and a special emphasis on R&D have resulted in practically all irrigation being done through drip.

Netherlands:

The Netherlands is the world's second-largest food producer, exporting about $92 billion worth of agricultural products in 2017. Food exports outnumber those of any other European country. The country is concentrating on developing new strategies for producing higher yields with less inputs.

Effective farming which Netherland uses are:

- When the global average output of potatoes is 9 tonnes, several farms in the Netherlands generate 20 tonnes of potatoes.
- Water usage for several crops has decreased by 90%.
- Chemical insecticides have been phased out of use.
- Increased use of new production technology:
- Vegetable yields account for 20% of the total.
- A 6% reduction in energy consumption.
- A 29 percent reduction in fertiliser usage is required.
- Green houses keep plants warmer than they would be if they were exposed to the outside climate, and they can be used to monitor and manage the growth environment, such as measuring soil moisture and watering the plants as needed.

China:

The Chinese government is taking the necessary steps to improve and advance agricultural technologies. The government encouraged investment in the agricultural sector in 2012. Agriculture-related businesses receive financial assistance from the government. To enhance yield effectively, scientists began employing biotechnology to modify seeds with nuclear technology and GMOs (Genetically Modified Organisms). Chinese farmers will be able to obtain new crop varieties with the desired qualities thanks to this technique. In China, companies such as Net Ease, Le Tv, and Lenovo have entered the agriculture sector. China feeds 22% of the world's population. Rice, potatoes, and other vegetables are among the country's top crops. The crop production branch of BASF offers crop protection solutions. BASF's products and solutions promote plant health by preventing disease, weeds, and insects, according to sustainable development ideals. BASF is actively working on a solution for improving soil water retention.

Australia:

Australia has the world's largest wheat production. Agriculture contributes a significant amount of Australia's exports in proportion to its size in the economy. In 2010-2011, it provided 3,50,000 employment. They employ drone technology to monitor crop health, soil moisture, and detect pests and weeds in the crop.

Drones save farmers time and increase crop health, which improves yields, saves producers time, and allows them to use fertilisers more effectively. Soil moisture sensors are used to keep track of the moisture levels in soils that are primarily used for irrigation.

Knowing the moisture content of the soil allows farmers to use water more efficiently and responsibly. Remote security cameras are inexpensive and are protecting valuables, such as farm produce and cattle, from theft. Some cameras on the market can alert farmers and relay video or photos of the action to them.

USA:

Agriculture technology in the United States is one of the most impressive in the world. Since 1979, 300,000 farmers have relied on agriculture, and since 1946, these employees have been cut in half. Increasing large-scale industries have a rapid impact on agriculture and the families that rely on it.

In American agriculture, the Archer – Daniel Midland (ADM) firm has come to dominate. Small farmers account for 91 percent of all farmers in the United States (less than 1000 acres). The environment in California assists farmers in understanding agricultural markets and technologies.

IBM is assisting American farmers in realising the potential of digital agriculture. With sophisticated capabilities in artificial intelligence analytics, IoT, cloud, and weather, IBM assists farmers in developing a suite of solutions that span the farm-to-fork ecosystem. The US government has partnered with Farmers Mutual Hail (FMH) to assist American farmers with crop planting and harvesting data. The agricultural marketing support platform is being developed by the Farmers Business Network. These are the government's agricultural plans in the United States.

The most significant sector in the world is agriculture. Many countries benefit from the use of modern technologies in the agriculture industry. Countries such as Israel and the Netherlands use innovative agricultural technologies to help them develop new crop varieties, protect farm fields, use less water for irrigation, and cut pesticide use, among other things. Even India can benefit from these advanced technologies for agricultural development, but India suffers from a severe water deficit, which is a major disadvantage. The use of advanced technologies by developed countries has proven successful. This also helps a country's long-term development, which is one of the most crucial elements. As a result, this article indicates that new technology can be purchased in the agricultural sector, but they should not have an adverse effect on the soil or farmland, as this reduces the soil's fertility.

1.12 Future Prospects of Micro Irrigation's Diffusion Rate in India

Micro irrigation will be critical for the future of Indian agriculture, given the need to boost output while conserving water.

In the present government's manifesto, "Har Khet Ko Paani" is mentioned, along with the Honourable Prime Minister's mantra of "Per Drop More Crop." In 2015, the Pradhan Mantri Krishi Sinchayee Yojna (PMKSY) was launched, including micro irrigation as a key component of the flagship scheme.

The overall potential of micro irrigation in India is believed to be around 69 million hectares, however only 7.7 million hectares are now covered (2015). With the current goal of covering 0.5 million hectares per year, realising the potential estimates of micro irrigation in India would take a long time [81].

While each government programme over the last decade has had its own set of benefits and flaws, there are a few key issues that have still to be addressed, including the following:

Lack of focus on micro irrigation: The National Mission on Micro Irrigation (NMMI) saw the fastest rise in micro irrigation penetration in the last decade during its years of operation. However, there has been a lack of focus on increasing micro irrigation in India since the scheme was shifted to a component within the National Mission for Sustainable Agriculture (NMSA), which is an ongoing issue with the Pradhan Mantri Krishi Sinchayee Yojna (PMKSY).

Lack of dedicated team and IT-backed operations: In the majority of states, tracking the installation of a micro irrigation system from work order initiation to installation and payment is still not possible, which is a major source of inefficiencies in a system where IT can play a key role. Furthermore, the teams responsible for implementing micro-irrigation schemes in many states (with the exception of a few) are not dedicated to the task, so a concentrated approach is lacking.

Delays in the publication of guidelines/government directives, as well as ambiguity and irregular revisions to scheme guidelines: The lack of smoother/longer-term standards is a significant difficulty, as illustrated by the fact that the schemes' average operational period is only 5 months, causing farmers to miss out on using the micro irrigation system during peak demand season.

Subsidy disbursement process: This is still a major roadblock to the industry's expansion. Unavailability of subsidy money for already-approved installations, as well as delays in the delivery of funds and the identification of beneficiaries, have all contributed to considerable delays.

Lack of simple financing options for farmers: Farmers encounter significant hurdles in obtaining financing for micro irrigation devices, and even if they can, the collateral requirements are substantial. Water has been the most important resource for agriculture over time, even surpassing soil. Crops can be grown in a soilless substrate while still requiring water! With approximately 4% of the world's fresh water, Indian agriculture is extremely reliant on rain.

Crop production reliant on rain has hampered the potential for high yields and the adoption of high yield generating variables. The importance of irrigation is highlighted by the low crop yields in rain-fed agriculture.

The following is a simple examination of the situation: India grows crops on a gross land surface of 195.8 million hectares (net area 140.9 million hectares and 55.0 million hectares with multiple crops) (Min. Agri. Directorate of Economics and Statistics), with a total irrigation capacity of 139.9 million hectares (if developed) (Central Water Commission). Unless we change the way water is consumed for irrigation, the country will never have total irrigation coverage for all of the gross cultivated land.

The real situation isn't so straightforward. Though the net irrigated area rose gradually from 1950 to 2010, the growth rates anticipated per ten years began to decline after 1990. There are a variety of reasons for this, ranging from a lack of public investment to a lack of focus on the restoration of previous irrigation works.

The main concern, however, is a failure to efficiently manage water supplies. Institutions are facing a huge difficulty in managing and maintaining irrigation canal networks and field channels. As a result, irrigation efficiency are lower, making it difficult to expand irrigation to greater land surface [82].

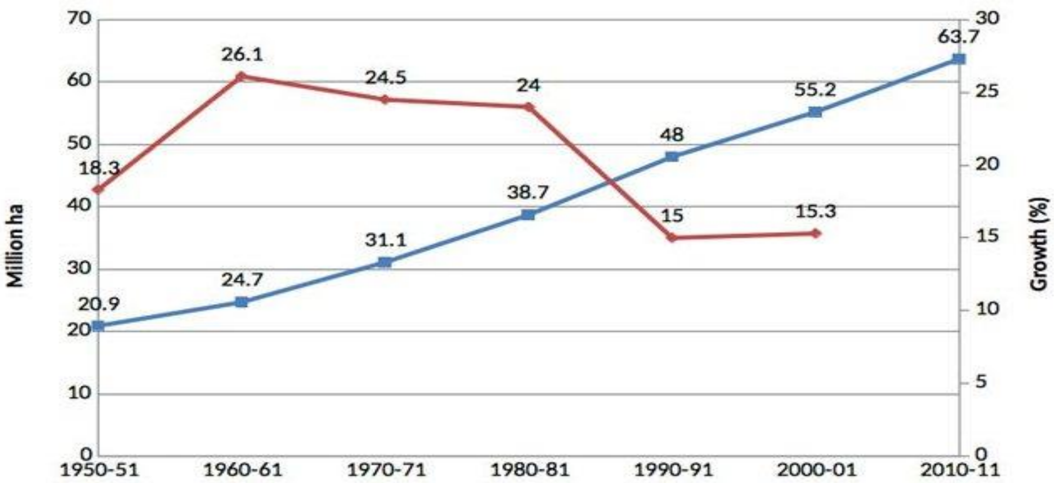


Figure 1: Net irrigated area and decadal growth

(Source: http://blog.jains.com/Drip_Fertigation_Technology_for_Sustainable_Crop_Production.htm)

The Indian government has begun focusing on converting irrigation to micro irrigation in the persistent belief that appropriate incursions are needed to effectively manage existing irrigation water resources (drip and sprinkler). Years of field work and patient presentations to government departments dealing with water and agriculture have led to the single point realisation that micro irrigation aids in increasing irrigation water use efficiency.

Indian farmers have demonstrated time and time again that drip irrigation, for example, increases productivity while using less water and energy. This is not just a win-win situation, but it also demonstrates sustainability in practise: more production with less resources. Micro irrigation penetration in Indian states Micro irrigation penetration is currently estimated to be variable. As indicated in the graph, the average penetration in India is 5.5 percent, which is substantially lower than in nations like Israel, the United States, and even China. India now has nearly 8 million hectares under microirrigation. This can be attributable to the enormous cultivable land and irrigation area. Micro irrigation system penetration in India is still relatively low.

There is enormous potential for promoting micro irrigation in India, with half of the country's cultivable land still being rain-fed.

The United States has a large area under micro irrigation, which can be attributed to farmers being more aware of and willing to adopt such systems. Israel has only 0.23 mh under micro irrigation, but this represents a penetration of over 90%, which came as a result of an acute water shortage and a strong political will to use innovation to protect their water resource.

1.13 Future Growth of Micro Irrigation Market in India

During the forecast period, the India Micro Irrigation Systems Market is expected to develop at a CAGR of

10.9 percent (2020 - 2025).

Farmers in India are increasingly being urged to use micro-irrigation systems on open fields to save water and boost agricultural productivity. The area covered by open-field micro-irrigation is more than that covered by greenhouses across the country. The majority of greenhouses in the country with micro-irrigation are used for horticultural output, with more farmers turning to greenhouse horticulture for advantages such as year-round production.

Due to increasing subsidies granted by the federal and state governments in several jurisdictions, the drip irrigation technology dominated the market in 2019. The most active players in the India micro-irrigation systems market include Jain Irrigation Systems Limited, Netafim, Avanijal Agri Automation Pvt. Ltd., Agsmartic Technologies Pvt. Ltd., and Flybird Farm Innovations Pvt. Ltd., among others. To get a competitive advantage over other participants in the market, these companies are focusing on product innovation [83].

Andhra Pradesh and Telangana have long been known for their abysmally low groundwater levels, with the states recording even lower levels in early 2019, at 15.75 metres below ground level (MBGL) and 14.14 metres below ground level (MBGL), respectively.

As a result, the micro-irrigation project (MIP) in the respective states has been encouraging farmer registrations, with 954,169 and 8,003 farmers respectively registered under the financial plan for 2019-2020 in both states.

According to NABARD consultant services (NABCONS), farmers in Telangana have saved a total of 25.54 TMC of water over the years as a result of the adoption of the micro-irrigation method, equating to a massive saving of USD 1.02 billion.

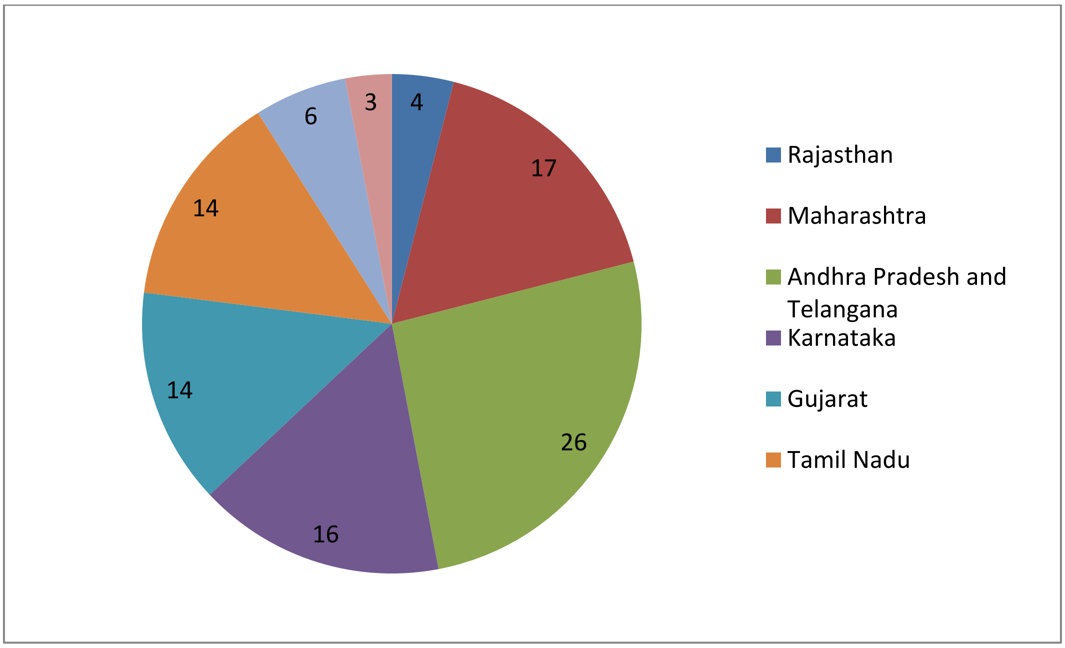


Figure 2: India micro irrigation systems market: revenue share (%), by state, 2019

(Source: Mordor Intelligence)

The Andhra Pradesh micro-irrigation project (APMIP) has allocated the most land to the production of mangoes, tomatoes, and groundnuts as fruits, vegetables, and agricultural crops, owing to their high competitive advantage in trade.

The market for micro irrigation systems is likely to increase during the forecast period, owing to low groundwater levels and supporting government-funded schemes to promote micro-irrigation in the region. From FY'2008 to FY'2013, India's micro irrigation system market grew at a staggering 27.3 percent compound annual growth rate (CAGR) and is predicted to reach INR million in FY'2018.

Despite the fact that farmers are increasingly using micro irrigation technology, market penetration remains low. Gujarat, Rajasthan, Madhya Pradesh, Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, Rajasthan, and Haryana are among the states with the highest demand for micro irrigation systems in India. Micro irrigation projects have also been proposed by the state governments of Gujarat, Andhra Pradesh, Tamil Nadu, Chhattisgarh, Himachal Pradesh, and Bihar as part of the Micro Irrigation Scheme.

Drip irrigation systems account for the majority of revenue in the Indian micro irrigation sector. Drip irrigation generated INR million in revenue in FY'2013, accounting for 44 % of the overall micro irrigation market revenue in India. Sprinkler irrigation, on the other hand, accounted for 23% of the market in FY'2013. In terms of flow rate, pressure needed, wetted area, and mobility, drip and sprinkler irrigation technologies differ. Both irrigation methods have huge potential in India.

The states of Maharashtra, Andhra Pradesh, Gujarat, Karnataka, and Tamil Nadu have the most micro irrigation coverage. In FY'2013, Maharashtra had the highest proportion of land under micro-irrigation, with a percent share [84].

The Micro Irrigation Systems Market is estimated to reach $8,321 million by 2022, growing at a CAGR of 16.6% over the forecast period of 2016 to 2022. Irrigation is the process of providing water to dry land in order to cultivate crops. Micro-irrigation is a method of supplying water at regular intervals above and below the soil surface.

Micro-irrigation systems are low- or medium-pressure systems that use sprinklers, sprays, mists, drips, and jets to provide water. Micro irrigation systems, as opposed to traditional irrigation approaches, have proven to be an innovative and effective alternative as concerns about water scarcity have grown. A growth in demand for food and agriculture goods, as well as a rise in water supply and storage problems, are the two key reasons driving the micro-irrigation systems market. The market's growth is hampered by the micro-irrigation system's costly initial investment and ongoing maintenance costs. For a farmer with a small plot of land, a micro-irrigation system is not a viable alternative.

Companies' increased investment, on the other hand, is likely to lessen the impact of these limitations. For this market, a number of companies manufacture cost-effective equipment. The high cost of equipment and low level of commercialization in developing nations provide difficulties to the micro-irrigation sector [86].

The research of micro-irrigation systems is included in the report, which focuses on the market's numerous growth opportunities and restraints. Porter's five forces analysis for the industry is highlighted in the report, which includes the impact of suppliers, rivals, new entrants, substitutes, and purchasers on the market. The value chain analysis for the global micro-irrigation systems market is also depicted in the study.

Valmont Industries, Inc., Hunter Industries, The Toro Company, Jain Irrigation Systems Ltd., Nelson Irrigation, Netafim Ltd., Lindsay Corporation.,Rain Bird Corporation, and Rivulis Irrigation are the major competitors in the industry.

Segment Overview

The market for micro-irrigation systems is divided into four categories: product type, crop type, application, and geography. Sprinkler irrigation and drip irrigation are the two product types segmented. Sprinkler irrigation systems generated the most revenue in the global market in 2015. Drip irrigation systems, on the other hand, are expected to grow at the quickest rate between 2016 and 2022.

The market is divided into plantation crops, field crops, orchard crops, and others based on crop type. In 2015, the orchard crop type category had the biggest revenue share, and this trend is likely to continue during the forecast period. Plantation crops, on the other hand, are expected to expand at the fastest rate during the projection period [85].

The market is divided into small farming, large & corporate farming, government, and others based on applications. Small farming dominated the market in terms of expenditure in 2015, and this trend is expected to continue throughout the forecast period. North America, Europe, Asia-Pacific, and LAMEA are the regions examined in the paper. Due to large irrigated areas and adoption of micro irrigation systems throughout difficult terrains, Asia-Pacific currently holds the largest market share in the world micro irrigation systems industry. India presently has about 8 million hectares under micro irrigation. This can be attributable to the enormous cultivable land and irrigation area. Micro irrigation systems, on the other hand, are still uncommon in India. Micro irrigation penetration varies by state in India. In comparison to countries like Israel, the United States, and even China, India's average penetration is only 5.5 percent. Farmers have used micro-irrigation mostly for fruits, vegetables, and other high-value crops until now. that can provide you a nice return on your investment. The most significant improvements in this industry has developed in China and elsewhere. India and China are the world's two largest irrigators. Where the micro-irrigated area is 88-fold and 111-fold, respectively, during the last two decades, respectively. India is now the world's most populous country, with roughly a billion people. 2 million hectares (about 5 million acres) acres) are irrigated with micro-irrigation. Some of the roadblocks in the way of our attempts to Micro irrigation is encouraged because there is a scarcity of water. Currently, the focus is on micro irrigation. There isn't a specific programme for Irrigation on a tiny scale.

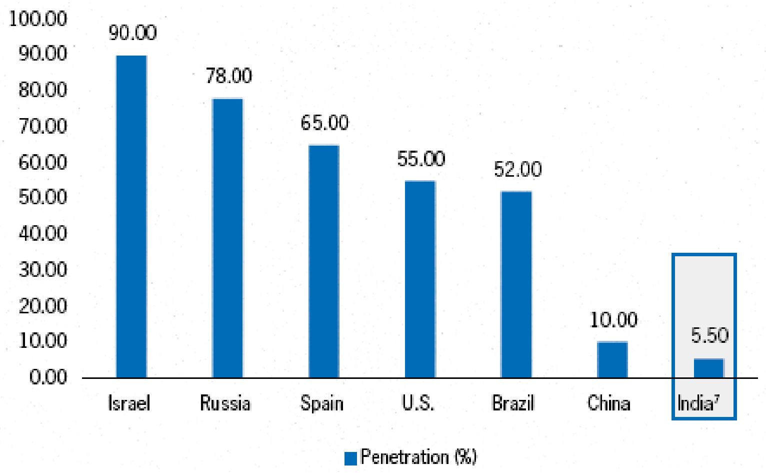


Figure 3: Current micro irrigation penetration estimate

(Source: National Mission on Micro Irrigation Impact study prepared for the Government of India, June 2014)

1.14 Impact of Micro Irrigation Systems on Agriculture's Input and Productivity

1. Micro irrigation: Efficient water use

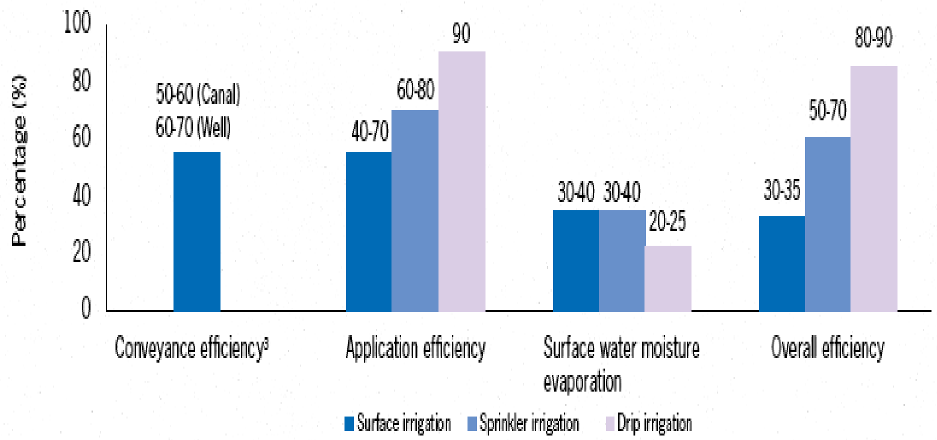


Figure 4: Water usage efficiency under various irrigation systems

(Source: National Mission on Micro Irrigation Impact study prepared for the Government of India, June 2014)

Conveyance loss is minimised when micro irrigation devices are used. Micro irrigation technologies also reduce evaporation, runoff, and deep percolation. Another advantage of using water sources with low flow rates, such as small water wells, is that it saves water. Because of its close proximity and targeted application, micro irrigation saves a substantial amount of water. Additional benefits of efficient water utilisation include an increase in the area under irrigation and more use of marginal/degraded land.

The area under irrigation increased by 8.41 percent after the implementation of the micro irrigation system, according to a survey conducted for the Government of India (which included 5,892 beneficiaries of the National Mission on Micro Irrigation (NMMI) throughout 13 states).

Farmers in the same poll said that 845.50 hectares of waste/degraded land were not being utilised for cultivation. Farmers, on the other hand, were able to cultivate 519.43 hectares of such land after implementing the micro irrigation system.

2. Impact of micro irrigation: Input savings and productivity increase

Micro irrigation can help with many aspects of the production process, from lowering input costs to increasing crop productivity. It's even allowed farmers the freedom to experiment with new crops on their property.

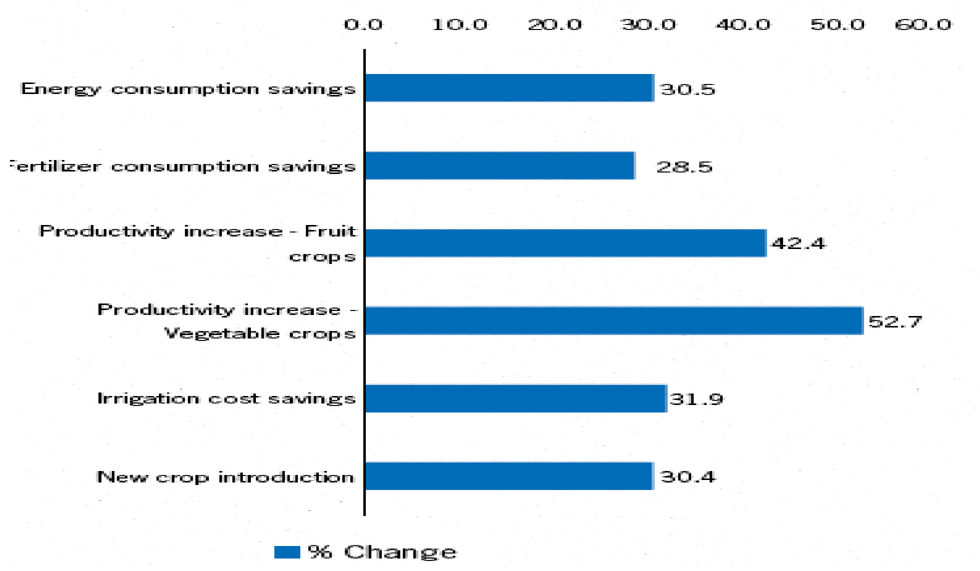


Figure 5: Impact of micro irrigation on input and productivity

(Source: National Mission on Micro Irrigation Impact study prepared for the Government of India, June 2014)

Very considerable electricity savings, on average 30.5 percent, have been predicted due to the smaller power units required as a result of decreased water requirements and hence fewer number of hours of irrigation. Applying fertiliser directly to the root boosts the efficiency of use, resulting in a 28.5 percent reduction in use on average.

Soil moisture can be kept at optimal levels by applying water in a controlled and targeted manner. The productivity of the crops rises as a result of this. Micro irrigation systems have been found to assist increase the output of both fruit and vegetable crops in a variety of studies.

Fruit crop productivity increased by 42.3 percent on average, while vegetable crop output increased by 52.8 percent on average. This, in turn, helps farmers earn more money. The overall irrigation cost has been proven to be reduced as a result of enhanced water use efficiency through judicious use in micro irrigation systems. There was a 31.9 percent reduction on average. Farmers have also reported an increase in the number of new crops they have introduced to their farms as a direct result of using micro irrigation. Farmers introduced new crops in 30.4 percent of cases.

3. Impact of micro irrigation: Energy and fertiliser saving

The effectiveness of use is improved by applying fertiliser directly to the root. Additionally, extremely considerable electricity savings per hectare have been projected due to the smaller power units required as a result of the lower water requirement and hence fewer number of hours of irrigation. The use of less energy and fertiliser results in huge cost reductions.

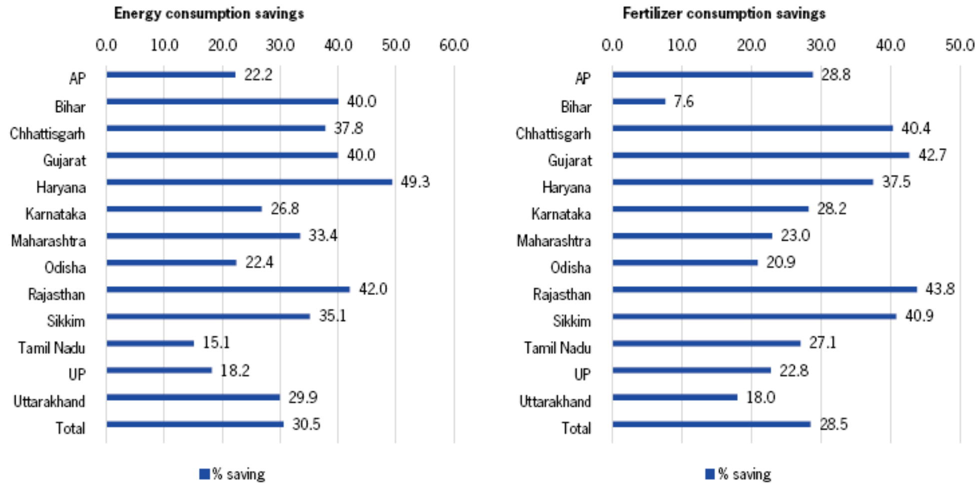


Figure 6: Impact of micro irrigation on energy and fertiliser (State wise)

(Source: National Mission on Micro Irrigation Impact study prepared for the Government of India, June 2014)

4. Impact of micro irrigation: Productivity increase

Soil moisture can be kept at optimal levels by applying water in a controlled and targeted manner. The productivity of the crops rises as a result of this. Micro irrigation systems have been found to assist increase the output of both fruit and vegetable crops in a variety of studies.

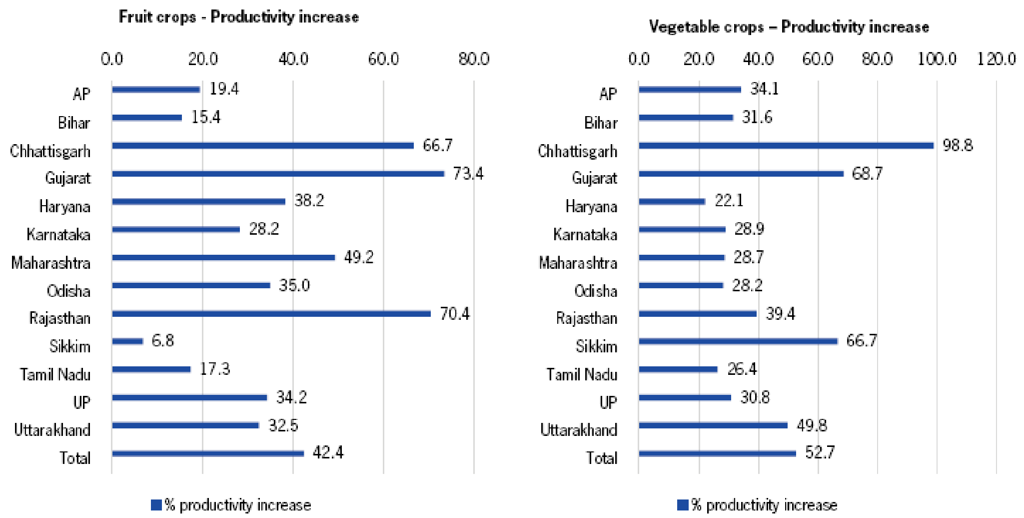


Figure 7: Impact of micro irrigation on productivity (State wise)

(Source: National Mission on Micro Irrigation Impact study prepared for the Government of India, June 2014)

Fruit crop productivity increased by 42.3 percent on average, while vegetable crop output increased by 52.8 percent on average. This, in turn, helps farmers earn more money.

5. Impact of micro irrigation: Irrigation cost reduction and new crop introduction

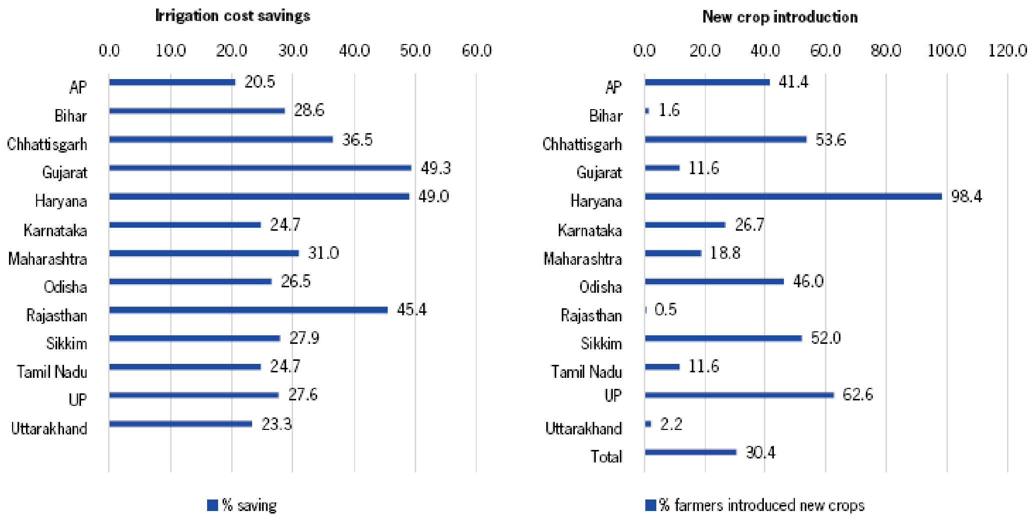


Figure 8: Impact of micro irrigation on irrigation cost and new crop introduction

(Source: National Mission on Micro Irrigation Impact study prepared for the Government of India, June 2014)

The overall irrigation cost has been proven to be reduced as a result of enhanced water use efficiency through judicious use in micro irrigation systems. There was a 31.9 percent decline on average. Gujarat, Haryana, and Rajasthan were the top three states, with Gujarat farmers having their irrigation costs nearly halved. Farmers have also reported a rise in the number of new crops they have introduced to their farms as a result of the use of micro irrigation. 30.4 percent of farmers experimented with novel crops.

6. Impact of micro irrigation: overall benefit to the farmer

In every case, the benefits to the farmer outweigh the expenses of installation, according to the average benefit-to-cost ratio for the crops farmed in each state. The farmer's income has increased by 42 percent on average.

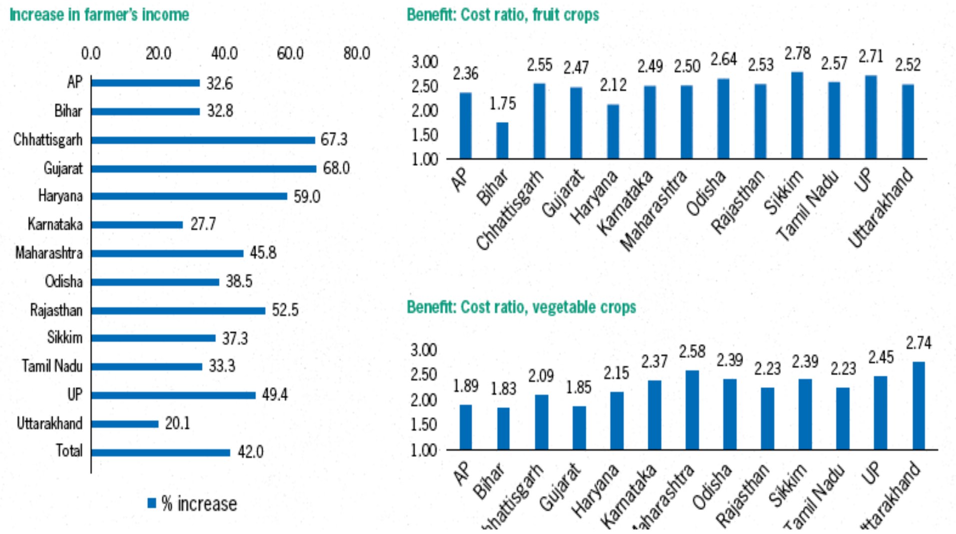


Figure 9: Impact of micro irrigation on farmers' overall benefit

(Source: National Mission on Micro Irrigation Impact study prepared for the Government of India, June 2014)

1.15 Statement of the Problem.

The rising population and more variable rainfall are anticipated to limit Agricultural water supplies and managing the water resource not properly leads the water scarcity problem. Degree of diversities among farmers to use farm irrigation could be attributed to a variety of variables, including economics, geography (physical), social, interpersonal, environmental, technical and organizational issues that leads a lack of widespread adoption of effective modern irrigation systems such as drip and sprinkler irrigation and as a result, the current irrigation efficiency in the country is about 30-40%.

1.16 Significance of the Study

Identifying the elements that influence the adoption of precision irrigation is critical for future development in the agricultural sector and, as a result, farmer welfare. This study will provide information on the current state of precision irrigation use and the factors that influence farmer adoption and several things that can influence a farmer's adoption decision. The study lays the groundwork for rethinking precision irrigation implementation tactics to achieve improved water production in the long run.

1.17 Scope of the Study

Precision irrigation technology as a strategy to improve water usage efficiency and farmers' welfare has acquired a key place in policy discourse in India as a result of escalating water shortage. The study examined the potential, uptake, and impact of precision irrigation technology at the farm level.

Field investigation showed differences in operational processes and modalities for executing precision irrigation schemes among states, resulting in a wide range of performance. The findings will be extremely useful to policymakers and strategists in developing and implementing policies that will accelerate the adoption of precision irrigation technology among farmers.

Presentation of Research Study

The first chapter is dedicated to the introduction, which covers the context, scope, relevance, and problem statement. The second chapter, Review of Literature, examines existing and similar studies on the topic of the current investigation. The study's methodology is presented in the third chapter. This chapter covers the study region and the sampling process that was used. The data analysis and hypothesis testing are covered in the fourth chapter. The fifth chapter offers the conclusion and recommendations.

Chapter-2: Review of Literature

2.1 Background of Study

Access to water for agriculture will be a significant issue in the future years across the globe. This chapter aims to describe the aspects of a precision irrigation system and how they might be used in the future of farming operations to make better decisions.

Every nation's economy relies heavily on agriculture, whether it is developing or developed. Agriculture provides the inhabitants with food and critical raw resources as well as a means of subsistence. Agriculture also plays an essential part in creating vast numbers of jobs for the population. A country's transition from a traditional to a modern economy necessitates increased agricultural output. As a result, science and technology must be given attention in the field in order to increase agricultural productivity and growth. In the agriculture system, seeds interact with soil, water, fertilizer, pesticides, and other inputs in many ways. This complicated system's long-term viability depends on optimizing the available resources. Due to population growth, unscientific use of agricultural resources to fill the supply/demand mismatch has degraded the resources and decreased crop yields. Furthermore, in this intricate system, climate uncertainty plays a vital role.

To manage the agricultural system, one must make optimal use of available resources. Agricultural systems are fundamentally variable in space and time, making it challenging to maximize productivity with minimal inputs. As a result, to stay ahead of the game, farming technology used worldwide must be upgraded regularly.

Agriculture has reached a new degree of sophistication because of several new technologies being developed around the world. Agricultural practices in the current world have changed dramatically since ancient times. It has been a while since the idea of precision agriculture first arose. To achieve high quality and sustainable agriculture, managing the farming technology smartly is a must. Using precision agriculture as an agricultural system can contribute to the development of sustainable agricultural practices [24].

2.2 Defining Precision Agriculture

Using diverse technologies and ideas to manage spatial and temporal variability in all elements of agricultural production is what is meant by the phrase "precision agriculture [5].

A standard management approach is followed by conventional agronomic procedures for a broad region regardless of the heterogeneity within and between fields. Farmers have been applying fertilizers for decades based on research and field trials conducted in specific agro-climatic conditions and suggestions from those sources. When agricultural inputs are applied uniformly over the field without accounting for local changes in soil and crop qualities, poor crop yield results.

To maximize the crop output from a given amount of input, Precision Agriculture considers in- field fluctuations in soil fertility and crop circumstances and matches agricultural inputs such as seed, fertilizer, irrigation and pesticide. As a result of this information-based and technology- driven agricultural system, maximum agricultural productivity was guaranteed.

At the same time, the environmental effect is reduced by adjusting sowing conditions, modulating fertilizer doses, applying water, pesticide, and herbicides to precise locations, among other things, are all part of it. Precision agriculture relies on irrigating farms based on predicted water needs in order to reduce water waste. Optimizing irrigation efficiency is critical because of the inadequate water supply [1].

Precision Irrigation

In today's world, managing water for agriculture is becoming a concern frequently tied to development issues. Agriculture uses 70% of freshwater or 1,500 billion metric cubes out of the total annual water use of 2,500 billion metric cubes. This water is lost due to evaporation, spillage, or absorption by the deeper soil layers beyond the reach of plant roots.

Because of the high rates of groundwater depletion and the salinity of the soil in some areas caused by over-irrigation in the post-green-revolutionary era, Indian agriculture is suffering from technological fatigue. Many crop systems are concerned about how to handle water more efficiently.

As water resources become scarcer, planners and farmer associations become increasingly aware of water-audit and water consumption efficiency. In the last three decades, many countries have made efforts to use micro-irrigation systems like sprinkler and drip irrigation. According to reports, India's micro-irrigation systems covered 1.15 million hectares in 2005 [2].

Farmers in developing countries having semi-arid regions who cannot afford to pay for powered irrigation heavily rely on rainfall for their crops. Farmers have to face significant financial losses as a result of poor weather predictions and ineffective irrigation techniques. As a result of the pressing need to increase irrigation system efficiency and reduce water waste, farmers are turning to develop an intelligent irrigation scheduling system that will allow them to utilize water more efficiently by only irrigating when and where it is needed.

Worldwide, precision irrigation is still a new idea. As part of precision irrigation, a plant's exact water requirements are met while minimizing environmental impact. As defined by most, sustainable management of water resources means applying the right amount of water to crops at the right time, place, and manner to help manage water variability on the field. This increases crop productivity and efficiency while also lowering irrigation costs. Precision irrigation falls into this category. Instead of the "uniform irrigation" treatment that is the foundation of standard irrigation management systems, it uses a systems approach to achieve "differential irrigation" treatment of field variance (spatial and temporal).

Precision agricultural practices are comprised of three major components: information gathering, data interpretation, and variable-rate application. These components are accomplished by using technologies such as Geographical Information Systems, Global Positioning Systems, Sensors, Variable Rate Technology, and Yield Monitoring.

2.3 Irrigation Systems and Agriculture

Agriculture is confronted with several issues, including rising production costs, a scarcity of irrigation water, and growing public concern about the environmental impact of agricultural production. Producers who want to be successful in the future international market must offer high-quality products at competitive costs while also adhering to ecologically responsible methods.

The increased use of environmentally hazardous fertilizers, insecticides, and other chemicals has contributed to the boost in agricultural output over the last few years. As a result, the usage of new technology adoption is considered one of the most critical factors in enhancing agriculture's production in the future.

Furthermore, as accessible resources (such as water, human capital, and land) become more expensive, it is projected that substantial research in precision agriculture will be conducted. This means that the concept of precision farming has become crucial to the philosophy of matching inputs to needs and becoming increasingly popular among crop producers who are applying a variety of technological techniques to their operations [3].

For this reason, several demand management strategies and programs have been implemented in Indian agriculture to help reduce water usage and increase the country's overall water efficiency. Micro-irrigation, which includes both drip irrigation and sprinkler irrigation, was one such approach that was only recently implemented in Indian agriculture.

It was found that MI was a more effective way of conserving water and increasing irrigation efficiency than the typical surface irrigation approach, which only used roughly 35% to 40% of the water. Even though drip and sprinkler irrigation systems have been around for around two decades, there do not appear to be much research on the potential and prospects of micro- irrigation in India's various states.

This research shows that micro-irrigation saves a significant amount of water while also increasing productivity compared to a commonly established irrigation approach. According to research, energy (electricity) requirements, weed problems, soil erosion, and cultivation costs can all be reduced with micro-irrigation. It also appeared that investing in micro-irrigation was economically viable, even without the assistance of the state. Despite this, drip irrigation (2.13%) and sprinkler irrigation (3.30%) have only covered a fraction of the full irrigation potential, which was estimated at 21.01 million hectares for drip and 50.22 million hectares for sprinkler irrigation.

While economic factors had a role in the delayed development of MI, it was discovered that farmers were less aware of the actual economic and revenue-related benefits. Because of this, the study recommended a variety of technical and regulatory measures to increase the uptake of these two water-saving innovations [4].

The adoption of new irrigation systems is influenced by several factors, including the risk associated with production. A moment-based approach was used to estimate the water use risk premium. During 2002 and 2003, a sample of 187 wheat farms in Iran's Pars province's three major districts was used to collect farm-level data. New irrigation technology, according to their findings, lowers the risk premium.

In addition, it is established that the relative risk premium paid by farmers influences their decision to use new irrigation technology positively and significantly.

As a result, farmers that are less risk-averse about water use are more inclined to adopt innovative irrigation technology that allows them to save water while also reducing their output (yield) risks. Finally, they concluded that to improve wheat farm water use efficiency and reduce farmer production risk due to water crop requirements, dissemination, education, and extension on the proper application of new irrigation technologies and information on the prevailing weather conditions are required for farmers [6].

The following were their primary recommendations for communication, distribution, and outreach strategy:

1. Information that makes it easier for farmers to put new irrigation methods into practice.
2. An insight lowers the risk farmers' face and empowers them to make more informed choices about new technology.

According to Singh, landholding sizes in developing countries are shrinking due to the increasing population, and the average holding is less than two hectares. In contrast, small landowners have increased land productivity and farm income by using high yielding modern varieties of dominant food staples, aided by public sector irrigation investment. However, modern irrigation systems and efficient technology have failed to meet the widespread demand for low-cost, dividable systems on small plots of land.

We need to reimagine technology, which has traditionally been reserved for the wealthy and massive farms, to make it more accessible to the smallholders. A few low-cost irrigation options for row and plantation crops are described, as are the challenges small farmers confront. An irrigation system designed by the scientists was also detailed, which might be economical for small farmers and applicable on most tiny plots worldwide for tightly spaced crops and cover large areas [7].

The impact of irrigation on crop yield, land prices, and cropping intensities is studied using plot- level production data from a national survey in India. For the most part, they used an identification technique based on a large enough number of households producing a diverse range of land uses.

The estimates showed that irrigation substantially impacted all of these outcomes after controlling for household fixed variables and plot characteristics. The effects on cropping intensities were the most notable. They discovered that irrigation quality is equally important. It was found in both the descriptive and econometric studies that irrigation significantly impacts land production.

According to the findings, the productivity impact varies depending on irrigation type and quality. The findings highlight the need to continue improving India's irrigation system to improve irrigation access and quality [8].

With a net irrigated area of over 47 million hectares, India boasts one of the world's largest and most ambitious irrigation programmes. As a result of inefficient planning and execution at all levels, irrigation potential established at great expense is underutilized and deteriorates further, putting the sustainability of the agricultural production system in jeopardy. Due to the significant increase in the financial, human, and environmental costs of constructing new irrigation potential, existing projects must boost irrigation efficiency and use saved water for irrigating new areas or fulfilling non-agricultural sector demand. Because poor irrigation efficiency can be mainly attributed to inefficient application, a switch from a surface to a pressurized system can significantly improve irrigation efficiency.

A pilot study was started at the Water Technology Centre for Eastern Region, Bhubaneswar, using a single outlet of a minor irrigation command to examine the concept's viability. There are four outlets for sprinkler irrigation covering a 2.8 ha area, while two outlets for drip irrigation cover a 1.9 ha area. The system has been designed to provide pipe transportation and surface irrigation for rice cultivation during monsoon season, while pressurized irrigation is used during the post-monsoon period.

The study's findings suggest that converting flow-based micro irrigation systems on plateaus to pressured irrigation is technically and economically feasible. They proposed that the initial investment costs are high, and a funding strategy needs to be planned for the benefits of society, the environment, and the economy [10].

2.4 Institutional Framework of Managing Water Resources

Irrigation water management in the irrigation plan has been evaluated by Gorantiwar using a methodology he developed. Planning, operation, and assessment were recognized and divided into three parts. Previous studies have established the conceptual framework for measuring irrigation scheme performance.

Irrigation water management has been broadened in this study in terms of quantitative and qualitative performance evaluation. The allocative type, which includes productivity and equity, and the scheduling type, adequacy (excess), reliability, flexibility, sustainability, and efficiency, were recommended as performance measures. They are classified using several variables to describe how they are performing.

When irrigation authorities had the methodologies to estimate these measures, they could see how sound irrigation water management was performing in the scheme and how their management capacity responded to climatological, physical and management aspects that changed over time. They could also see how well irrigation water management responded to these changes and how they could improve performance over time [11].

A cooperative society naming Shri Datta within Maharashtra, India, was the first water consumer's organization studied by any researcher. It aimed to elicit the water union association member's perceptions of the rules-in-use by focusing on the institutional frameworks that govern water usage and distribution.

Face-to-face interviews with irrigators and key informants, such as Irrigation authorities and WUA office bearers, were used to gather data. The WUA secretary gave a list of members, and respondents were chosen at random from that list. Seventy people were chosen to represent at least 20% of the overall membership.

For over a decade, the Water User Association (WUA) has successfully developed rules for water distribution, collecting fees and resolving conflicts. Recent social and economic trends, such as political heterogeneity, necessitate implementing more formal systems for resolving conflicts. Existing courts and legal institutions may assist the WUA to continue in the future by addressing these pressing challenges [12].

The failure of previous interventions in developing nations to provide all populations with water services has, according to Brunner, started a global reform process of water policies. Maharashtra, a state in India, is leading the way in implementing such reform policies. Its policy aims to make project implementation decisions based on demand, participation, and democracy. They assessed the reform policy's success in Maharashtra's Deccan Plateau communities, comparing Swajal Dhara and Aapale Pani, two funding schemes for water delivery projects.

Two distinct donors funded the initiatives, which were carried out following two different instructions to implement the reform policy. Increasing bottom-up decision-making while also strengthening organizational capability has positive results.

However, they also point out several dangers that can be reduced by using top-down control mechanisms that are applied selectively. As a result, the best results may come from a mix of bottom-up and top-down decision-making [11].

Food, water, and energy security present specific regional and sectoral concerns. The nexus of these three sectors should be eliminated to discover practical local solutions. Additionally, governance issues are at the centre of each region's nexus. Policy, institutional, technological, and financial alternatives used at the global, regional, national, and local levels have governance implications. Strong links between levels also motivate policy responses to specific occurrences and consequences. In places where they do exist, present governance mechanisms fall far short of meeting the needs.

They are rooted in a lack of strategic clarity, and power, voice, access to information, resources, and the ability to exert a good influence are distributed equally across stakeholders, resulting in equitable and long-term consequences. Individual stakeholders' short- term gains often had to be sacrificed for a more long-term, holistic solution.

The management of water was the most difficult. Due to its lack of boundaries, it is immune to political or administrative control. As a result, simple analytical tools like centralized or decentralized governance and markets vs states did not help analyze it. It asks for excellent governance at all levels, including an awareness of the responsibilities and connections between policies and institutions at various political and administrative levels.

This is particularly important for local governments. It called for the participation of all stakeholders, who had both short- and long- term effects on the outcome. The outdated approach of India's water sector fails to recognize the relevance of long-term strategic challenges or to take advantage of India's characteristics as a vast country. In order to avoid a more severe water issue, it was not learning lessons in a systematic or timely manner.

Water's changing position in a fast-rising economy with demographic demands on unparalleled resources in scale and complexity necessitates a holistic strategy rather than fragmented measures.

To address the tremendous pressure of water management, it will need central leadership, and it will need to ask such radical questions as:

1. If water use in some states has already reached a critical point, should the government halt new electric pump installation in those areas?
2. Is it better to take the high road and gradually raise water and power rates to improve water efficiency?
3. For example, the farmer constituencies which are politically active but are not receiving the high-quality services they require in a constituency should be dealt with differently.
4. Which of its successful measures can it use as a model for scaling up systematically?

Such an approach necessitates broad agreement among the political and administrative establishment on possible remedies. Because of the financial crisis in developed countries, it has become evident that reaching a consensus requires extensive analytical work. It would necessitate bold, communal leadership as well as creative problem-solving.

To ensure India's long-term food and water security, it took dedication to execution, thorough monitoring of interventions and results, and a stronger focus on management with a single-minded focus on better outcomes for the masses. The new information technology will be crucial in enhancing efficiency.

Developing Nations and Precision Agriculture

Different developing countries have different sustainable agricultural development statuses, limitations, and essential factors. Some developing countries are experiencing rapid socioeconomic development, opening up new opportunities for PA. Most of this expansion occurs in countries with low and intermediate incomes like India, where the urban population has increased by tenfold over the last century.

For example, India's rapid economic development is causing a hitherto unheard of movement in the country's population into metropolitan areas. The world's 100 fastest growing cities include 11 Indian cities. In these rankings, India comes in second, only behind China.

If their economies continue to prosper, China and India could have even higher urban populations in 2020 than forecasted by the UN. Africa now has more urban residents than the United States. Remarkable transformations in economic development, poverty alleviation and energy consumption will have far-reaching consequences.

Many developing countries have begun to use PA components, particularly on experimental farms, but adoption is still relatively low. These countries include Argentina, Brazil, China, India, Malaysia, and others. Keeping tabs on how quickly technology is being adopted can help focus research efforts. A thorough assessment of PA's current condition in developing countries is therefore critical [14].

2.5 Applications of Precision Agriculture

Tea is a major export from India and other emerging countries like Sri Lanka, China, and Tanzania, earning significant foreign cash. PA can be an excellent technique for increasing the profitability of tea cultivation. In terms of structure, tea is a block-grown crop with several distinct parts. Positioning systems can be avoided if each block has been thoroughly surveyed and uniquely identified.

In order to create yield maps, tea pluckers weigh the tea they pluck and note which block they pluck it from. Treatment maps are implemented by splitting the workforce into teams that apply the desired amount in each region. Inputs are also applied by hand. As a result of the well-structured fields and an existing recording system, the implementation costs in this system are pretty minimal [15].

In India, researchers are working on a tea plantation management system that is GIS-anchored. These tasks include creating a digital map from an existing paper map and high-resolution satellite images, creating an elevation model, creating soil maps, creating land use and cover maps, creating drainage maps, storing the data in a centralized location, and transferring the data from field instrumentation sensors to palmtop computers, among other things [16].

Rubber plantations in Malaysia receive site-specific fertilizer, whereas rice fields do not. Malaysia has begun using PA technologies on its oil palm plantations. For plantation agriculture in tropical regions and huge farms in northern Mexico and possibly South Africa, PA is likely to be used.

PA technology can be used on a wide range of high-value crops in a tropical climate. Sugarcane cultivation takes up around 20.3 million hectares of land worldwide, with Brazil accounting for a quarter of that total. In Brazil, the sugarcane industry has a good chance of adopting PA-based tillage and soil erosion control technology on a big scale. This technology concentrates on saving inputs by modifying ploughing depth according to soil conditions [19].

Brazil developed a precision agriculture system exclusively for sugar cane crops. They found a connection between the sugar cane yield monitor's output and the harvested load weight, and the system's performance remained steady and reliable throughout the tests.

In Mauritius, PA is also being used on sugar cane. The experimental results of Zn site-specific application in Uruguayan fields have shown that the profit level can exceed $50 per hectare, which is an advantage of this method [18].

In Costa Rica, researchers tested the effects of PA on a banana farm. Farms can access a soil database and, using yield monitoring, make site-specific decisions about soil fertility and disease concerns. To save money, the DGPS system was replaced with a cable one [20].

Usage of Precision Agriculture for Small Size Land Holders

There is a widespread belief that PA will not work on small farms in developing countries. This theory holds if just 'hard PA' is taken into account. Researchers confront a significant issue when trying to find "suitable PA technology" for micro-farms. According to Cook et al., there are several ways to implement the PA principle in these countries.

Small farms in underdeveloped nations may benefit from several low-cost, low-tech technologies. Portable diagnostic instruments like the SPAD chlorophyll metre and the LCC leaf colour chart can be used to decide when to apply N topdressing to rice fields, making them ideal for developing countries. The chlorophyll metre technique is adapted for transplanted and wet- seeded rice, local cultivar groups, soil, crop and environmental circumstances on farms in three countries. Regarding rice crop N status, the LCC is not as precise as the metre that measures chlorophyll content in the leaves. Farmers' cooperatives in the Philippines, Indonesia, Vietnam, Bangladesh, India, and others have initial positive responses on LCC implementation. By the end of 2006, about 250,000 of these four-panel LCCs had been deployed to Asian countries. Small farms are beginning to use GIS. Improved information leads to more effective decision- making in GIS, as the adage goes. As a result of government initiatives, web-based GIS systems are being developed on small Asian farms in Japan, South Korea, and Taiwan. The idea is to get farmers to use the Internet and get free information about their farm's soil attributes, such as fertility and nutrient levels, by promoting this programme.

Reassessing acceptable agricultural land use in Indonesia is being done via GIS. Using the technique, one can determine which locations make good arable land and determine what crops would do best in a particular area [22].

Adoption of yield monitors

Crop production monitoring is a fascinating task for every farmer. Some emerging and transitional countries have begun utilizing grain crop yield monitors previously only available in industrialized nations. There were around 560 yield monitors in Argentina in 2001, and about 4% of the grain and oilseed area was harvested using headers fitted with yield monitors. In 2001. Some large Brazilian and Mexican farms utilize yield monitoring. According to unconfirmed sources, Australia's 2000 harvest made use of approximately 800 yield monitors. South Africa's 1999–2000 agricultural season saw 15 farms adopt the yield monitoring system.

India and Adoption of Precision Agriculture

The success or failure of adopting precision agriculture in India will largely depend on how the institutions or the government will implement the precision agriculture schemes. Thorough research must be conducted on precision agriculture before the policymakers understand the lock screen implementation of precision agriculture in the Indian context. Precision agriculture can be studied from three perspectives: current State, intermediate State, and Future State.

The current state will be focusing on the management of soil, spreading the awareness about precision agriculture among the five months using different mass media techniques.

The intermediate state will create the zones randomly and conduct the research to understand precision agriculture and its outcomes nationwide; this will also focus on analyzing the computer-based data of different zones. Coated State will focus on using sensors and computer-based data to simulate the farming conditions and then decide based on that to create a positive farming outcome.

Generally speaking, PA can be divided into the "soft" and the "hard." It may be stated that the employment of soft and hard PA in a balanced manner will be the determining factor in its commercial success in India. Land fragmentation is widely regarded as the most significant impediment to the widespread adoption of large-scale agricultural mechanization in India.

For centuries, modest farmers have been adopting intentionally or unknowingly "soft" PA technology on these fragmented lands, which are farmed according to a family responsibility structure [23].

Currently, India produces more than 200 million metric tonnes of food grain, making the country self-sufficient in food production. However, merely a large enough quantity of produce will not be enough to meet the demands of the international agricultural market.

To compete with others, excellent quality and high production will be essential, and PA has tremendous potential in this regard. In terms of crop output, India is in the top ten in the world in the case of most crops production (wheat, rice, pulses, and cotton). Other factors, such as a lack of automation on a large scale and a minimum average holding size, exacerbated the problem. In comparison to other countries, India has a relatively low overall fertilizer consumption rate [28].

Several studies have demonstrated that thorough soil testing, followed by judicious use of NPK fertilizers, may increase productivity by 2–3 times in most Indian states. The expensive cost of traditional soil sampling, on the other hand, is one of the factors contributing to incorrect fertilizer application. As a result, in these states, inexpensive dynamic soil sampling technologies and nutrient status analysis on a broad scale via RS and GIS can make a significant difference in agricultural productivity [31].

Punjab and Haryana, for example, have seen significant mechanization and use of fertilizers and pesticides. Punjab, for example, occupies just 1.5% of India's total land area yet consumes 1.41 million tonnes of NPK fertilizer and 60% of the country's herbicides. Overuse of agricultural inputs and overexploitation of land are common problems in these regions. Natural resources are already showing signs of exhaustion, which is why policymakers and planners are pretty concerned. These locations are more or less suited to 'hard' PA [33].

Status of Precision Agriculture in India

In India, the use of PA technology is still in its early stages. There have been a few discrete steps taken toward putting this technology to use. Indian-US working groups on knowledge initiatives on agriculture have selected PA as a critical area of emphasis [36].The National Agricultural Innovation Project (NAIP), which focuses on agricultural technological advances and has an announced budget of US$ 285 million, is planned to include PA research as a critical component.

To execute in Dharmapuri and Krishnagiri districts, the Tamil Nadu State Government has sanctioned the "Tamil Nadu Precision Farming Project," which will span 400 ha. According to this Plan, various high-value crops will be grown, including hybrid tomatoes, capsicums, baby corn, white onions, cabbage, and cauliflower. Similar programmes will be introduced in six additional Tamil Nadu districts as part of an expansion strategy. Each district will implement the Plan on 100 acres of land.

Modipuram and Meerut (Uttar Pradesh state), in partnership with the Central Institute of Agricultural Engineering (CIAE) in Bhopal, also began the application of variable rate input in various cropping systems with the Project Directorate for Cropping Systems Research (PDCSR).

Ahmedabad has begun trials at the Central Potato Research Station farm in Jalandhar, Punjab, with the Space Application Center (ISRO) to examine the function of remote sensing in mapping spatial and temporal variability.

PA is predicated on the creation of specialized facilities and a scientific databank. Through 17 Precision Farming Development Centers (PFDCs) spread across India, the PA technology is being developed and disseminated in a regionally tailored manner [39].

Additionally, PFDCs train a significant number of farmers on PA and other high-tech applications to boost production through their use. All of these PFDCs, however, are primarily concerned with managing irrigation water with accuracy. A new precision farming centre has been established by MSSRF (M.S. Swaminathan Research Foundation – a non-profit trust) in Kannivadi, Tamil Nadu, with financial support from the National Bank for Agriculture and Rural Development, an example of a collaborative effort between private and government agencies (NABARD). Assisted by Israel's Arava R&D Center, this Precision Farming Center strives to reduce poverty by employing PA technologies.

For Tata Chemicals Ltd., a private sector company exploring the potential for IT application in agriculture, the company was established to provide farmers with infrastructure assistance, operational assistance, coordination and control of farming activities, and strategic assistance. In Uttar Pradesh, Haryana, and Punjab, the Tata Kisan Kendra model has been successfully duplicated. There is a claim that the project can be scaled up or down and replicated [45].

It is not uncommon for private sector companies like the Indian Tobacco Company (ITC) to set up e-choupals and village internet kiosks that provide information on the weather and markets while educating farmers on scientific farming practices disease predictions well as expert crop advice systems. In four Indian states, about 1200 e-choupals have already been developed. e- choupals for specific regions and crops (such as soybean, coffee, wheat, pulses, and rice) are being developed to give poor farmers in all distant corners of the country more precise information [43].

ISRO and the Planning Commission are developing the Agro-Climatic Planning and Information Bank (APIB). This concept-demonstration project provides users of agriculture and adjacent industries with a single-window of access to all agriculture-related information and decision support.

The GIS map aided in locating the best locations for future cold storage facilities to serve both large and small farms. Directly or indirectly, all of the projects mentioned above will contribute to India's PA revolution. These actions will assist in laying the groundwork for India's PA revolution. So far, there has been no evidence of the widespread use of hard PA technology. However, Indian farmers have been using soft PA approaches based on visual observation of crops and soil and management decisions based on past experience and intuition for decades. Some regions have begun implementing a need-based nutrient application for paddy, and IT use in Indian agriculture. In order to reap the maximum benefits of PA, a coordinated, well-planned, and long-term policy tailored to the Indian agricultural industry is required [44].

Strategically Adopting Precision Agriculture in Indian Farming

Considering the challenges of land fragmentation, the absence of highly complex PA technical centres, and the low economic conditions of general Indian farmers should be part of India'sfuture PA adoption strategy plans. It is critical to balance public and private sector support in a strategic way to encourage quick adoption.

India's land fragmentation problem may be solved through virtual land consolidation while maintaining the ownership structure, opening up new PA routes. Existing studies demonstrate that the current 'transborder agricultural system' can save between 15% and 25% on needed farmland and between 20% and 30% on needed labour and save a significant amount on total operating costs [49].

As a result, the field area (or simulated field) is considerable when considering adjacent fields with the same crop (usually under similar management approaches).

Of the 115.6 million farms worldwide, 107.08 million have a land area smaller than 4 hectares. Government attempts to arrange dynamic soil sampling and build nutrient maps using already available information technology are therefore envisaged for large farms. The zone-specific computer simulation model can extend the time between future soil samplings by accurately anticipating intermediate conditions. Panchayats can share these nutrient maps and the simple fertilizer recommendations for each field management zone.

Individual farms could be handled as management zones within a field if PA is introduced, and some centralized institutions could provide information to the individual farmers on a cooperative basis. This is another approach. The 'dead reckoning system' can alleviate the issue of expensive positioning systems for tiny fields. For tiny, consistently shaped fields, the dead reckoning technique relies on in-field markings like foam to keep the application uniform.

According to the World Bank, a nationwide Agricultural Advanced Technology initiative should be launched immediately and run for the next ten years to investigate the potential applications of currently developed information technology and satellite-based technologies in the agricultural field.

Crop and weed characteristics differ from one region to another and from one country to another. It is, therefore, necessary to begin building software and hardware for Indian crops and weeds, and this IT package will be utilized for remote sensing technologies of PA.

It is also necessary to design and adequately validate a zone-specific computer simulation model dedicated solely to PA applications. It is recommended that two-hundred Agricultural Advanced Technology Parks be developed in each region throughout the country, which will allow for the collection of experience and the development of methodologies to apply PA precisely in a region-wise format throughout the country (for example, China has already developed 153 such parks).

These parks must attempt to meet the farmer's needs while emphasizing the operational execution of technology and a thorough examination of the expenses and savings that can be realized. Records of these parks would help determine the root cause of operational inefficiency and identifying appropriate corrective actions. These parks can be used to teach progressive farmers and early adopters, expose nonparticipating farmers in the surrounding area to new technologies, and demonstrate the technology's effectiveness for both short- and long-term management.

When it comes to establishing the platform for PA adoption, the research, development, and subsequent popularisation of low-cost electronic gadgets that can boost the profits of small farms can be highly beneficial in terms of softening the farmer's attitude toward modern technology.

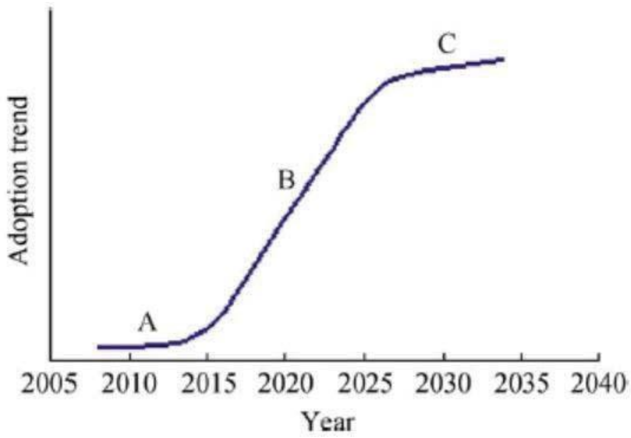
To create professionals and extension workers/consultants capable of utilizing information and communication technologies (ICTs) in sustainable crop production, profit maximization, and natural resource management, educational institutions must modify their curricula, teaching methods, and training procedures. To establish high-speed data/information connectivity systems, rural areas must first be connected to the Internet. To do this, farmers, farm associations, community groups, non-governmental organizations (NGOs), machinery manufacturers, research and extension agencies, and other public and private entities must work together in close collaboration.

There should be a thorough calculation and significant emphasis placed on the indirect benefits of PA implementation. There is numerous business potential in India for PA technologies, including geographic information systems (GIS), global positioning systems (GPS), and remote sensing (RS). The potential for supporting new hardware, software, and consultancy companies tied to PA is constantly becoming more expansive. In Japan, it is estimated that the market for geographic information systems (GIS) is worth approximately US$ 100 billion and that the market for GPS and remote sensing is worth approximately US$ 50 billion.

To maximize the potential of PA, commercial banks and other sources of financing must be informed on the subject. When it comes to R&D operations in Pennsylvania, it may be worthwhile to implement a programme of subsidized loans to make them possible in the beginning. As is the case in most developing nations, the absence of sanctions for pollutant creation in India has contributed to excessive use of harmful inputs in the country's economy. The proper evaluation of environmental benefits, effective canvassing, and the imposition of pollution levies can all contribute to the adoption of PA.

The typical S curve pattern is most likely to be followed when it comes to PA adoption in India. Farmers' intentions to use PA technologies are favourably influenced by their attitudes of confidence toward using PA technologies, their views of net benefit, the size of their farms, and their educational levels as farmers. As a result of all of this virtual land consolidation, cooperative system introduction, AAT programme, particular software development, and AATP development, the first segment of the S

curve will be formed, and it is expected to be finished by 2014. To be completed by 2015, the second steep part of the S curve, namely the rapid adoption and implementation of PA technologies, should have begun (B segment of S curve).
It is anticipated that the rate of adoption of appropriate PA approaches would gradually slow down and that by 2030, the rate of adoption will have stabilized in the majority of prospective application areas (C segment of S curve).



(Adapted From M Basu and M Pinaki)

2.6 Requirements of Precision Farming

After reviewing various kinds of literature, we come to understand that precision farming requires the following things:

1. Systems of management and decision support should be tailored to fit the specific requirements of individual farmers.
2. Systems should have a straightforward user interface that can be customized to meet the needs of different user profiles. A user-friendly user interface is especially crucial for people new to the software and unfamiliar with it.
3. Data processing methods that are both automated and simple to use are required for success. Systems should be flexible enough to allow for integrating and developing new automated processes based on user-defined rules.
4. The user must also have complete control over the system, including access to all parameters for processing and logical operations. Expert users may seek to exert control over and experiment with novel solutions.

5. In order to be feasible, the entry of expert knowledge (for example, rule-based knowledge) must be made possible This may provide an opportunity to fine-tune the systems to local conditions, as well as to incorporate the user's expertise, methods, and preferences into the system design process (such as risk profiling, for instance).
6. It is necessary to have more integrated and better-standardized computer systems. This may lower the amount of money spent on technology, the length of the learning curve, and the requirement for technical support.
7. With the use of open data standards, open interfaces, and open protocols, it is possible to integrate and interoperate with other software packages (including simulation packages), with other data sources (such as meteorological data and market data), and with other systems locally or remotely via the Internet without difficulty. This is especially crucial when it comes to accommodating legacy systems and dispersed applications.
8. Scalability is essential in order to meet a variety of needs.
9. It is necessary to include support for meta-data in order to facilitate data exchange between apps.
10. It should be low-cost to ensure widespread adoption of PF across all social and asset holding groups, as previously stated.

Though there seems to be a plethora of agronomic and economic research related to precision agriculture, the social sciences have been slow in analyzing the adoption and use of precision agriculture [55].

The basic principle of precision farming is as follows:

1. Precision Farming is a process of management, not a technological innovation.
2. Calculate the variability in space and time.
3. Determine the economic and environmental impact of unpredictability.
4. Explain what has been expected from crops and farms as a result of precision farming.
5. Consider the crops and regions unique requirements.
6. Develop strategies for dealing with unpredictability so that the desired result can be achieved.
7. Consider ways to minimize or redistribute inputs and evaluate the failure risk.
8. Selectively treat crops and soil based on their nutrient requirements.

Many studies have shown that precision farming has economic and environmental benefits, as well as socioeconomic and agricultural characteristics, hurdles, and influences on its adoption in developed nations compared to developing ones [53].

The study of precision farming and water resource management would therefore be highly beneficial to policymaking reasons. Although there is extensive literature on precision farming and water resource management, no systematic work has been done to examine the levels of precision farming technology in developing nations, particularly in India, as the above brief account of the existing research reveals. The current study examines, describes, explains, and predicts precision agriculture technologies for water resource management in India. It is, therefore, a pioneering study to discover in India the precision farming technique for water resource management that is now being conducted in the study under consideration.

Benefits of Precision Irrigation

Precision irrigation offers the ability to reduce water consumption while simultaneously increasing economic efficiency. It has been stated that precision irrigation (Drip and Sprinkler) can increase water application efficiency by up to 80-90 per cent, compared to 40-45 per cent when using the traditional surface watering method [54]. The results of case studies involving variable rate irrigation revealed that water savings ranged from zero to fifty per cent in different years, depending on the study. Precision irrigation can benefit by lowering the cost of inputs while simultaneously boosting yield for the same inputs.

Water savings

Precision irrigation's primary goal is to use the least amount of water feasible across the entire field. Many academics have concluded that this is the best strategy for achieving significant water savings. Site-specific or variable-rate irrigation, which is regarded as a fundamental or essential component, is believed to be missing from precision irrigation [57].

The majority of scientists believe that water use will be reduced in specific fields if not all of them. According to certain studies, variable rate irrigation can save between 10 and 15 percent of the water consumed in conventional irrigation. With improved application efficiency, Hedley predicted water savings of up to 25 per cent when using spatially variable irrigation methods for irrigation [63].

Yield and profit

According to King, the experimental investigations were carried out to determine the yield of potatoes when different irrigation applications were applied in different locations. Over two consecutive years, it was observed that yields were higher when uniform irrigation management was used [61].

Booker investigated cotton yields and water use efficiency during four years under spatially variable irrigation. They concluded that cotton appears to be unpredictable in its management when subjected to spatially variable irrigation [10].

2.7 Government Institutions, Schemes and Subsidies for Micro-Irrigation in India

Background of Micro-Irrigation in India

In 1981, the Department of Chemicals and Petrochemicals established the National Committee on Plastics in Agriculture. The NCPA adopted several initiatives to promote the use of plastics in agriculture, particularly micro-irrigation systems. As a result, many people in India now believe that the government is actively supporting drip irrigation. Given that India's agriculture sector is the country's largest consumer of plastics, NCPA was transferred to the Ministry of Agriculture in 1993 and renamed NCPAH in 2001-02.

It is part of the NCPAH mandate to popularise horticultural plasticulture applications. It gives advice and assesses the progress made in the micro-irrigation area. 17 Plasticulture Development Centers were developed to promote precision farming and plasticulture applications for high-tech horticulture in the various agro- economic zones, renamed Precision Farming Development Centers in 2003. They help with technical and scientific aspects of micro-irrigation development.

Since 1985, NABARD has financed micro-irrigation systems. In the years 1985–86, a total of Rs. 385 crore was set aside. In 1989–90, this grew to Rs. 499.76 crore. As a result, actual distribution was significantly lower than expected (only Rs 49,85 lakhs for drip irrigation and Rs 686,50 lakhs for sprinkler irrigation from 1988-89 onwards), primarily due to farmers' lack of awareness and technical assistance.

Since 1980, the government has implemented several subsidy programmes to encourage and promote the widespread use of micro-irrigation throughout the country. All farmers were eligible for subsidies under a centralized programme that was implemented in 1982–83.

According to the 7th Five-year Plan, Rs 10 crore would be allocated for small farmers and SC/ ST farmers, respectively, with a 25 per cent and a 50 per cent subsidy. Small farmers now receive a 50 per cent subsidy under the 8th Five-Year Plan [23].

State	Area ('000 ha)	Share to all-India (%)	Share to the state (%)	
			Drip	Sprinkler
Andhra Pradesh	1323.21	15.34	71.99	28.01
Bihar	107.92	1.25	9.04	90.96
Chhattisgarh	271.15	3.14	6.67	93.33
Gujarat	1068.81	12.39	50.01	49.99
Haryana	576.83	6.69	4.27	95.73
Himachal Pradesh	7.82	0.09	54.77	45.23
Jharkhand	20.75	0.24	52.20	47.80
Karnataka	953.35	11.05	51.08	48.92
Kerala	30.32	0.35	75.46	24.54
Madhya Pradesh	430.66	4.99	52.12	47.88
Maharashtra	1309.67	15.18	70.59	29.41
Odisha	104.84	1.22	18.49	81.51
Punjab	47.09	0.55	73.65	26.35
Rajasthan	1752.67	20.32	11.62	88.38
Sikkim	9.09	0.11	66.52	33.48
Tamil Nadu	363.36	4.21	90.38	9.62
Telangana	94.97	1.10	79.82	20.18
Uttar Pradesh	42.66	0.49	39.40	60.60
Uttarakhand	1.01	0.01	68.77	31.23
West Bengal	51.18	0.59	1.18	98.82
All India	8626.78	100.00	45.44	54.56

Table 4: Status of micro irrigation-adapted from Govt. of India, agricultural statistics at a glance-2016

As a result of the government's emphasis on civil engineering achievements in most irrigation development programmes and efforts, the country has made considerable gains in irrigation potential. Aside from being demographic and behavioural, potential irrigation utilization affects people in society on multiple levels. This makes it social, socio-cultural, and economical. In implementing most government-backed projects and initiatives, such features are insufficient or lacking, resulting in low increases in potential irrigation use.

The Government Schemes

To encourage micro-irrigation, the government has come up with several different programmes over the years. This section discusses some of the critical central government micro-irrigation programmes that were implemented after the seventh Plan. This also shows how government is taking efforts to spread the awareness about the creation technology among them farmers of India.

Centrally Sponsored Scheme on Use of Plastic in Agriculture (1992)

To spread plasticulture applications like drip irrigation, mulching, and greenhouses across the country, the government had sponsored Rs 81 crore in 1997-98.Small & marginal farmers, SC/ST farmers, and women farmers received up to 90 per cent of the system's cost (or Rs. 25,000 per hectare) in support for drip installation (starting in 1996-97). To compensate other farmers, the government set a 70 per cent cost cap or Rs. 25,000 per hectare. Subsidy of Rs. 22,500 or 75% of the system cost per hectare was provided to establish drip demonstration farms.

Rural Infrastructure Development Fund (1995)

With a budget of Rs. 2000 crore, NABARD launched the Rural Infrastructure Development Fund in 1995–96, which provided loans to state governments for funding rural infrastructure projects and 31 activities, including irrigation. To date, a total of Rs. 61,540 crore has been approved. NABARD's programme offers 7-year loans with a fixed interest rate (currently 6.5 per cent).

Rural roads and bridges received 44% of the subsidies from 2007-08, while irrigation received 34% of the funds. Andhra Pradesh's micro-irrigation project was recently sanctioned with Rs. Two hundred thirty million by NABARD as part of the state's RIDF- XVII (2012) to expand the spread to 114,000 hectares. In 2008, it approved Rs 19 crore for the micro-irrigation of 11,180 hectares in Punjab [38].

Accelerated Irrigation Benefit Programme (AIBP) (1996)

The Government of India initiated this initiative in 1996-97 with an investment of Rs. 900 crore, which was later reduced to Rs. 500 crore to speed up the completion of selected ongoing irrigation projects to realize the anticipated benefits from invested investments in these projects. This programme began with two parts. A major multipurpose project is one whose cost exceeds Rs.1000 crore and whose resources are beyond the competence of the States to provide.

Additionally, irrigation projects may be finished with only a bit of funding, allowing farmers to get guaranteed water supplies of up to one lakh hectares over the next four growing seasons (two agriculture years).

After the amendment, irrigation projects costing more than Rs. 500 crore would be considered. AIBP receives funds from the central government in the form of 50 per cent matching loans to the states.

Rs 500 crore was granted to various States during Annual Plan 1996-97, and the Ministry of Water Resources reported that around 16180 ha. The AIBP- approved expenditures in Annual Plans 1997-98 and 1998-99 totalled Rs.1300 crore and Rs. 1500 crore, respectively.

Centrally Sponsored Scheme on Micro-Irrigation (2006)

According to the Task Force, the Task Force had identified sixty-nine million hectares of potential on Micro Irrigation in 2004; however, only 2 million hectares had been covered by 2006. A government-sponsored micro-irrigation programme was initiated in January 2006 as part of the 10th Plan to put drip and sprinkler irrigation systems in place around the country.

According to the Plan, the National Horticulture Mission would implement the programme at the district level, emphasizing horticulture crops (NHM). For the MI System's overall costs, it was recommended that the Central Government shoulder 40% of them while the State Government bears 10%, leaving 50% to be covered by the beneficiary out of her funds or a low-interest loan from financial institutions. Small & marginal farmers accounted for at least 25 per cent of those eligible for subsidies, while women accounted for 30 per cent of those eligible, with a maximum subsidy area of 5 ha. By reducing weeding expenses and inter-cultural activities, improving water use efficiency (60-70%), increasing yield (30-100%), and conserving fertilizer consumption (up to 40%), the Plan intended to improve productivity and reduce costs. The scheme's original goal was to cover 1.5 square miles.

Dripper irrigation covers one million acres, while sprinkler irrigation covers just half that amount. The strategy was put into action with the help of a three-tiered organizational structure. When it came to national coordination, NCPAH was in charge, and Action Plans were given final approval by ECMI (the Executive Committee on Micro Irrigation). While the State Micro Irrigation Committee was in charge of coordination at the state level, the District Micro Irrigation Committee was monitoring the program's implementation at the district level.

PFDCs were tasked with conducting research and providing technical assistance for the state- level implementation of the programme. Over Rs. 280.48 crores was allocated in 2005-06 to cover 0.21 Mha under the project. Similarly, in 2006-07, Rs 337 crore was allocated across 16 states to cover 0.33 million acres.

A budget of Rs 550 was allocated to cover 0.4 Mha in 2007-08 under the programme. As a result of implementing this Plan since 2005-06, the area irrigated with Micro-irrigation has expanded by 800% in Madhya Pradesh, 150% in Orissa, and 30% in Uttar Pradesh.

National Mission on Micro-Irrigation (2010)

Drip/sprinkler irrigation was reinstated as a national goal during the 11th Plan period under the micro-irrigation system undertaken by the Ministry of Agriculture during 2005–06. It was decided that small and marginal farmers should receive 60% of the entire system costs, while general farmers should receive 50% of the system costs. This includes a 10% state contribution.

To lessen the financial strain on farmers, some governments have boosted their share of subsidies from 10% to 20%–50%. With the cost norms revised, over 3 million hectares of land were placed under micro-irrigation. The North Eastern States and the Himalayan States implement the NMMI scheme because micro-irrigation systems are better suited to steep terrains. Drip/sprinkler irrigation was used to water 0.6 Mha of land in 2009–10 and 0.42 Mha of land in 2010–11 until October.

Ministry of Agriculture's 2010-11 plan called to span at least 0.7 million hectares (ha) (MoA, 2010). It is shown in Table 4 how far the programme has progressed from 2005 to 2012, and the NMMI has encouraged farmers to grow vegetables with tighter lateral spacing and mini and micro-sprinklers in the field to save water and increase production quickly so that they can earn more money from the same plot of land. Using NMMI will save money on water and fertilizer using the latest technology, including different types of valves and filters, as well as the fertigation component.

Task Force on Micro Irrigation, headed by N. Chandrababu Naidu of India, recommended increasing the area under micro-irrigation by 3 million hectares in the Tenth Plan and by 14 million hectares in the Eleventh Plan, with investments of Rs. Ten thousand five hundred crores and Rs. 51,000 crores respectively. Overall, the Indian government paid subsidies worth Rs. 341 crore in 2009–10, with Andhra Pradesh receiving 124 crores and Maharashtra receiving 86 crores.

Below the researcher has mentioned some tables which will give brief idea about the irrigation and its different aspects.

Type of Irrigation Filter/s used by the Farmers (%)															
State	Total Beneficiary	Total Responses	Hydro-cyclone Filter	Screen filters	Sand Media Filters	Disc Filters	Hydro-cyclone Filter &Screen filters	Hydro-cyclone Filter & Sand Media Filters	Hydro-cyclone Filter & Disc Filters	Screen filters & Sand Media Filters	Screen filters & Disc Filters	Sand Media Filters &Disc Filters	Hydro-cyclone Filter & Screen filters & Sand Media Filters	Hydro-cyclone Filter & Screen filters & Disc Filters
AP	672	672	0.15	95.83	4.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bihar	516	6	0.00	83.33	0.00	0.00	0.00	0.00	0.00	0.00	16.67	0.00	0.00	0.00
Chhattisgarh	384	156	4.49	31.41	0.00	54.49	0.00	0.00	3.85	0.00	5.77	0.00	0.00	0.00
Gujarat	576	517	22.44	18.76	0.19	19.73	3.48	0.19	23.40	0.19	11.03	0.58	0.00	0.00
Haryana	320	320	1.25	2.19	0.00	0.00	64.69	1.25	0.31	18.75	0.00	0.00	10.94	0.63
Karnataka	576	576	0.35	79.69	4.17	15.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maharashtra	672	670	1.49	84.78	0.75	10.45	0.00	0.00	0.00	0.60	0.30	1.64	0.00	0.00
Odisha	480	480	0.21	94.38	0.21	3.96	0.00	0.00	0.00	1.04	0.21	0.00	0.00	0.00
Rajasthan	574	568	1.41	86.80	10.56	0.00	0.00	0.18	0.00	0.53	0.35	0.18	0.00	0.00
Sikkim	50	50	0.00	98.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tamil Nadu	455	455	0.44	87.25	6.37	5.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
UP	527	524	2.48	84.73	0.00	0.00	12.40	0.00	0.00	0.38	0.00	0.00	0.00	0.00
Uttarakhand	90	90	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 5: Types of irrigation filters used by farmers

If we see the above statistics its very evident that in India maximum beneficiaries for micro irrigation are from Andhra Pradesh and Maharashtra states are there. And if we see the filter usage maximum filter which is use by farmers are screen filters followed by disc filters.

State	Total Responses	Inline	Online	in %	
				Inline	Online
AP	512	414	98	80.86	19.14
Bihar	6	4	2	66.67	33.33
Chhattisgarh	153	98	55	64.05	35.95
Gujarat	450	344	106	76.44	23.56
Haryana	236	128	102	54.24	45.76
Karnataka	575	359	216	62.43	37.57
Maharashtra	577	366	211	63.43	36.57
Odisha	118	84	34	71.19	28.81
Rajasthan	118	79	39	66.95	33.05
Sikkim	45	34	11	75.56	24.44
Tamil Nadu	384	256	128	66.67	33.33
UP	322	220	102	68.32	31.68
Uttarakhand	30	12	18	40.00	60.00

Table 6: Types of emitters used by beneficiary

This table shows that over 70% of farmers in AP, Gujarat, Sikkim and Odisha use in-line drip irrigation systems, but over 45% of Haryana and Uttarakhand's beneficiaries use on-line drip irrigation systems, indicating that in-line drip irrigation is more popular.

State	Total Beneficiaries	Procedure Related		Quality Issues		Higher Prices Charged under Scheme then Available in Market		Delay in System Supply (Committed date vs. Actual date		Other Charges (Not covered in the scheme/ additional money paid)	
		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
AP	672	0.00	100.00	0.60	99.40	0.60	99.40	0.60	99.40	0.15	99.85
Bihar	516	0.78	99.22	1.55	98.45	1.55	98.45	2.52	97.48	7.17	92.83
Chhattisgarh	384	0.26	99.74	0.00	100.00	0.00	100.00	0.00	100.00	0.00	100.00
Gujarat	576	2.5	97.5	3.13	96.88	1.91	98.09	2.78	97.22	1.39	98.61
Haryana	320	0.94	99.06	0.94	99.06	0.63	99.38	2.81	97.19	0.00	100.00
Karnataka	576	0.00	100.00	0.00	100.00	0.00	100.00	0.00	100.00	0.00	100.00
Maharashtra	672	0.30	99.70	0.89	99.11	0.74	99.26	1.04	98.96	0.74	99.26
Odisha	480	0.00	100.00	0.00	100.00	0.00	100.00	4.79	95.21	0.21	99.79
Rajasthan	574	13.59	86.41	8.54	91.46	10.45	89.55	10.45	89.55	10.45	89.55
Sikkim	50	0.00	100.00	2.00	98.00	0.00	100.00	0.00	100.00	0.00	100.00
Tamil Nadu	455	0.00	100.00	0.00	100.00	0.00	100.00	0.00	100.00	0.00	100.00
UP	527	1.52	98.48	2.09	97.91	1.14	98.86	2.85	97.15	0.19	99.81
Uttarakhand	90	35.56	64.44	38.89	61.11	54.44	45.56	35.56	64.44	8.89	91.11
Total	**5892**	**2.33**	**97.67**	**2.29**	**97.71**	**2.46**	**97.54**	**3.04**	**96.96**	**2.05**	**97.95**

Table 7: Constraints faced by farmers

The above results show that beneficiaries in most sample states did not have many problems with procedures, quality, costs, or delays in system installation, among other things.

State	Total Irrigated Area before installation of Micro Irrigation system (ha)	Total Irrigated Area after installation of Micro Irrigation system (ha)	% increase in irrigated Area
AP	1013.43	1139.41	12.43
Bihar	2296.56	2368.02	3.11
Chhattisgarh	494.74	571.96	15.61
Gujarat	1358.91	1550.07	14.07
Haryana	1233.68	1362.63	10.45
Karnataka	1038.05	1064.92	2.59
Maharashtra	1025.51	1254.00	22.28
Odisha	1241.89	1383.10	11.37
Rajasthan	1005.77	1078.50	7.23
Sikkim	60.40	60.81	0.67
Tamil Nadu	709.56	741.16	4.45
Uttar Pradesh	1583.70	1604.15	1.29
Uttarakhand	258.62	262.75	1.60
Grand Total	**13320.86**	**14441.47**	**8.41**

Table 8: Increase in irrigated land due to MI installation

It is quite evident that the irrigated area has been increased due to the usage of MI systems for farmers.

2.8 Why India's Farmers Need Precision Farming

Information and Communications Technologies (ICTs) have been the most major move in agricultural management this century. Crop production methods are carried out in the correct location and time at the right site for maximum profitability, sustainability, and land resource protection using an information technology-based farm management system.

Many researchers have worked on precision agriculture (PA) technologies, but only a small percentage of farmers are using them to transform their entire farming system into low-input, high-efficiency, and sustainable. To use precision farming, ICT inputs had been used precisely to boost average yields compared to standard cultivation methods. Precision farming, a vital issue in India, is the limited size of the farm field. More than 58% of the country's operating famrs are smaller than one acre (ha).

Nearly two-thirds of agricultural land in Punjab, Rajasthan, Haryana, and Gujarat are more than four hectares in operational size. A broader potential for PA in cooperative farms is evident in commercial and horticultural crops alike. Sustainable PA is the most significant advancement in farm management in the twenty- first century, thanks to the use of Information and Communication Technologies. Sustainability and healthy food production are at the core of this most recent breakthrough in technology, which aims to be profitable while increasing productivity and reducing environmental costs.

Challenges

Precision agriculture faces several problems, the two most prominent of which are educational and economical in scope. Lack of local specialists, money, scholarly research and extension professionals are among the factors that contribute to educational obstacles more so than the rest of them. In terms of economic challenges, the impact of PA and upfront expenses is more significant than those of the other issues.

Why precision farming

1. Increasing the productivity of agriculture.
2. It helps to keep the soil from degrading.
3. Reduction in fertilizer usage in crop production.
4. Optimal utilization of available water resources.
5. Modern farming approaches are being spread to help with quality, quantity, and production costs.

6. Changing one's mindset to be more positive.
7. Changes in farmers' socioeconomic standing because of precision farming.

Advantages

1. Agronomical approaches by analyzing the crop's individual needs.
2. A technical viewpoint makes effective use of available time.
3. Crop management from an environmental standpoint Eco-friendly techniques.
4. Using farm inputs, labour, water, and other resources efficiently enhances crop yield, improves quality, and lowers production costs.

Environmentally Friendly Precision Farming

For this goal to be achieved, it is vital to practice climate-smart agriculture methods. PA can be a strong strategy in food-insecure nations if used appropriately based on local crop and site- specific variables and implemented correctly. Therefore, new techniques should begin with a simple and affordable mix of technologies and behaviours in less developed areas to ensure their success.

Utilizing digital advisory services to assist in agriculture capacity building

Best practices adoption and digital communication are crucial in bridging the technological gap. In the distribution of new technologies, agricultural research plays a critical role. The commercial sector is becoming prevalent in this area. Today, Digital Advisory Services can be found as a standalone for-profit business model or as part of a more prominent input provider's overall offering. Free DAS is a differentiating tactic to promote manufacturers' core products. India has a significant advantage over most Sub-Saharan Africa regions regarding DAS adoption due to a lack of digital infrastructure and widespread illiteracy.

Drip irrigation

Drip irrigation is the ideal way to apply soluble fertilizers since it has several advantages over other irrigation methods, including better yields. As a result, the requirement for herbicides and weed-killing equipment was dramatically reduced. There are a few prominent local and foreign brands in India's established micro irrigation market.

Pumps powered by the Sun

The use of solar pumps to raise well water for use in drip irrigation systems multiplies the system's advantages. Although solar pumps have no impact on the environment and require little maintenance, adoption is sluggish for this new photovoltaic system. According to government estimates, at a solar unit cost ranging from $1,500 to $10,000 for several farms, approximately twenty million well pumps in India currently function. Currently occurring changes to subsidy regulations may assist pave the road for widespread adoption, which will boost the role of private companies in the proliferation of solar pumps.

Soil and crop monitoring

Drones with imaging capabilities are becoming increasingly inexpensive for small farmer communities on both a technical and a financial level, making them ideal for tiny plots and contract farming in particular. Early soil and crop deficits diagnosis and repair benefit both farmers and off-takers. Drones and imaging analysis can be included in the amount farmers are paid for their products purchased and operated by large agribusinesses.

New kinds of capital utilization spearheaded by the private sector, which is already spreading from industrialized countries into emerging markets, can also benefit from using soil and crop monitoring equipment in farming cooperatives and contract farms [71].

Drawbacks of precision farming

1. The price is excessively high.
2. A scarcity of technical knowledge and expertise
3. Small landholdings cannot use it because it is either difficult or expensive.
4. Cropping system heterogeneity and defects in the market

The strategy for promoting precision farming on farms is described here:

1. Find the market niches where crop-specific precision farming can be promoted.
2. Developing interdisciplinary precision agriculture teams should consist of agricultural scientists from diverse domains and engineers, manufacturers, and economics.

3. Provide farmers with full technical help so they can create replicable pilots or models.
4. Precision agriculture deployment should be tested in a pilot study on a farmer's field.
5. Cultivating a consciousness among farmers regarding irrigation, fertilizer, insecticide, and pesticide unbalanced doses.

2.9 Maharashtra's Current Status of Micro Irrigation

It was estimated that Maharashtra would spend Rs 653.33 crore on micro-irrigation in 2019-20, of which the Central Government will contribute Rs 400 crore and the State Government will contribute Rs 253.33 crore. Even though farmers receive subsidies for installing drip irrigation systems and sprinklers, their response to the programme has been muted thus far due to the lack of assurances of continued government financial support. The state administration has urged the central government to increase funding for the Pradhan Mantri Krishi Sinchai Yojana (PMKSY) to irrigate at least half of the state's agricultural area with micro-irrigation during the next five years.

Furthermore, it has encouraged the centre to expand the 'More Crop Per Drop' programme to include crops other than sugarcane and bananas, which use much water. After years of drought in Marathwada and parts of Vidarbha, the state administration has prioritized micro-irrigation. Chief Minister Devendra Fadnavis, who chairs a powerful group of ministers for agriculture transformation in India, has also pushed for making micro-irrigation essential, arguing that it promotes effective water management and higher quality farm output. Micro-irrigation has covered 23.86 lakh hectares of land in Maharashtra since 1986, including 17.09 lakh hectares of drip irrigation and 6.77 lakh hectares of spray irrigation. In other words, it is a lot.

According to government data, farmers have access to 69,979 sprinkler systems covering 63,617 acres, while 1,21,689 drip irrigation systems covering 1,10,623 acres have been provided under the micro-irrigation programme.

Individual farmers receive direct credit to their bank accounts for the cost of sprinklers and drip irrigation systems. A drip or sprinkler system is available to every qualifying farmer as part of the programme. However, there are concerns concerning the practicality of micro-irrigation. Vasantrao Naik Sheti Swavalamban Mission (VNSSM) chairman Kishore Tiwari said, "Farmers must be effectively trained and given with the required infrastructure for the project to succeed."

Subsidies for drip and sprinkler systems are 55% for small and marginal farmers, and 45% for everyone else, according to guidelines published by the Center for Small and Marginal Farmers. Farmers with landholdings of up to five hectares receive micro-irrigation subsidies. Between 2018 and 2019, the state government got 3.46 lakh applications via e-thibak (e-drip), a specially created software for accepting applications from farmers. 2.24 lakh applications have been approved and processed up to this point in time [72].

Pune District from Current Research Perspective

Pune is Maharashtra's second-largest district, located in the western section of the state. It covers 5% of the state's total land area. Ahmednagar district lies to the north and east,Solapur district lies to the south-east, Satara district lies to the south, Raigad district lies to the west, and Thane district lies to the north-west. The district of Pune has been located between the Bhima and Nira river basins of Maharashtra. It forms a triangle with its base in the western Sahyadri Mountains and apex in the extreme south-eastern corner near the Nira River.

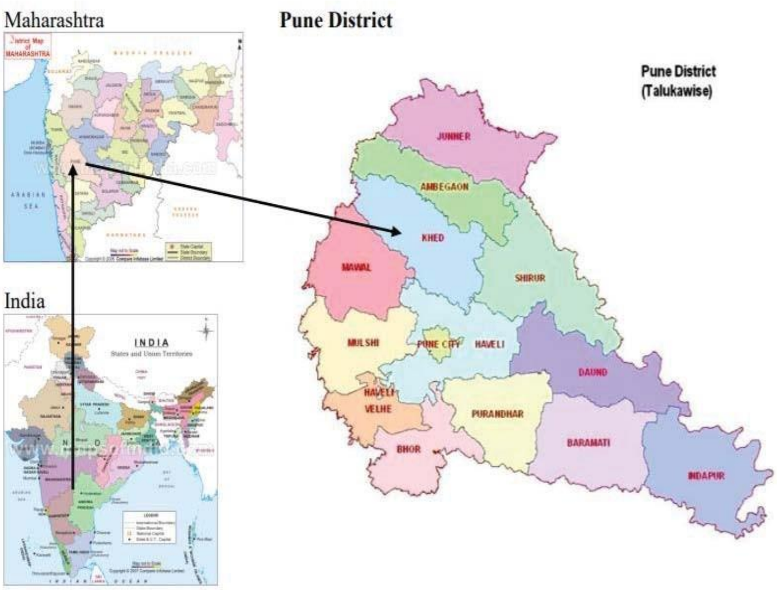


Figure 10: Location map of Pune district

Demographic Profile

Pune district has a population density of 603 people per square kilometre, according to the Census 2011. It has 57.51 lakh rural residents and 36.78 lakh city dwellers.

The female population to male population ratio was 915 to one. SCs make up 12.51 percent of the population, while STs make up 3.69 percent. The district has a high literacy rate of 86.15 percent, with rural areas having an average of 80.98 percent literacy and urban areas having an average of 89.45 percent literacy.

Below is a breakdown of the district's taluka-level characteristics, including land area, number of villages, gram panchayats, and overall population size. There are 52.22 percent men and 47.78 percent women in the population. Two municipal corporations serve the Pune district, as well as three cantonment boards. In total, there are 1866 villages and 1407-gram panchayats spread across the district's 13 block area.

Sr. No.	Taluka	General				Population (2011) '000	% to District total		
		Area (sq.K.M.)	% to total	No. of revenue villages	No. of Gram Panchayat		Total	S.C. (%)	S.T. (%)
1	Pune city	184	1.2	0	-	3305	35.051	4.741	0.392
2	Haveli	1337	8.5	108	102	2436	25.835	3.977	0.541
3	Mulashi	1039	6.6	144	95	171	1.814	0.191	0.074
4	Bhor	892	5.7	195	155	186	1.973	0.117	0.053
5	Mawal	1131	7.2	187	102	377	3.998	0.382	0.308
6	Velha	497	3.2	130	70	55	0.583	0.032	0.021
7	Junnar	1385	8.8	183	142	399	4.232	0.191	0.859
8	Khed	1400	8.9	188	163	450	4.773	0.318	0.520
9	Ambegaon	1043	6.6	143	103	236	2.503	0.106	0.541
10	Shirur	1557	9.9	117	93	385	4.083	0.350	0.127
11	Baramati	1382	8.8	117	100	430	4.560	0.679	0.032
12	Indapur	1463	9.3	143	113	383	4.062	0.647	0.053
13	Daund	1290	8.2	103	79	380	4.030	0.605	0.106
14	Purandhar	1103	7.0	108	90	236	2.503	0.180	0.064
	Total	15703	100.0	1866	1407	9429	100	12.515	3.691

Source: District Social & Economic Review- 2011 and census 2011

Table 9: Number of talukas in Pune district

Rainfall and Temperature

Rainfall in the district is dispersed due to the geographical circumstances. Due to the high terrain and dense forest cover on the district's western outskirts, rainfall here is more than it is in the district's eastern reaches.

The southwest monsoon winds bring most of the rain during the summer, and monsoon months account for around 87% of total rainfall. The monsoon season begins in June and ends in September, with the heaviest rains occurring in July and August.

Among the talukas in the region with the heaviest rainfall are Velha, Mulshi, and Maval. Bhor, Ambegaon, Junnar, Khed, haveli, Pune city, and Purandar Talukas are among those with moderate rainfall intensity. Shirur, Daund, Indapur, and Baramati Talukas have the lowest rainfall, making them part of the dry and semi-arid zone.

Over 73% of the district's cropped land is rainfed, as previously indicated. As a result, the development of agriculture is dependent on the monsoon rains. In terms of rainfall, the district has less variability than the state as a whole, and this makes agriculture in the district difficult because the district's average rainfall is lower than the state average.

According to the results of an analysis, agricultural productivity plummets whenever rainfall is reduced. Because food grains and other crops are mostly grown under rainfed conditions, this is the case.

Sr.No.	Taluka	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Pune city	2	0.9	3.3	14.9	31.5	107.4	168.9	96.5	130.1	78	29.9	6
2	Haveli	2	0.9	3.3	14.9	31.5	107.4	168.9	96.5	130.1	78	29.9	6.6
3	Mulshi	1.2	0.5	2.7	10.1	24.3	235.3	680.1	437.3	164.7	73.4	29.8	3.3
4	Bhor	1.7	6.7	3	13.7	31.9	138.9	381.7	237.7	129.6	79.3	33.6	7.4
5	Maval	1.4	0.6	1.3	9.9	25.8	187.6	498.4	305.8	151.3	79	27.8	3.4
6	Velhe	0.1	0.1	2.5	10.7	62.3	417.2	1047	679.9	258.8	120.4	36.3	5.7
7	Junnar	2.2	1.1	2.6	9.7	22.9	100.9	250.6	147.5	113.3	68.3	36.1	5.7
8	Khed	1.8	0.8	1.9	8.8	33.2	103.4	186.4	114.7	136.8	70.1	32.8	5.1
9	Ambegaon	1.9	0.2	2.1	10.8	28.4	112.7	265.3	143.7	131.3	70	34.3	3.9
10	Shirur	3	2.1	1.7	7.5	25.1	106.9	74.4	48.3	144.5	62.9	30	7.2
11	Baramati	4.2	0.8	2.2	7.7	27.7	78.5	56.7	67.4	150.1	72.2	32.1	5.3
12	Indapur	4.9	1.5	3.6	10.3	21.9	92.2	63	53.1	145.3	71.7	28.7	7.6
13	Daund	3	0.9	1	9	20.7	81.5	60.2	46.7	130.7	71.3	29.1	7.4
14	Purandar	1.4	0.6	3	16.2	30.4	88.7	110.7	64	112	87.2	33.1	9.1

Source –www.agri.mah.nic.in

Table 10: Taluka wise monthly rainfall

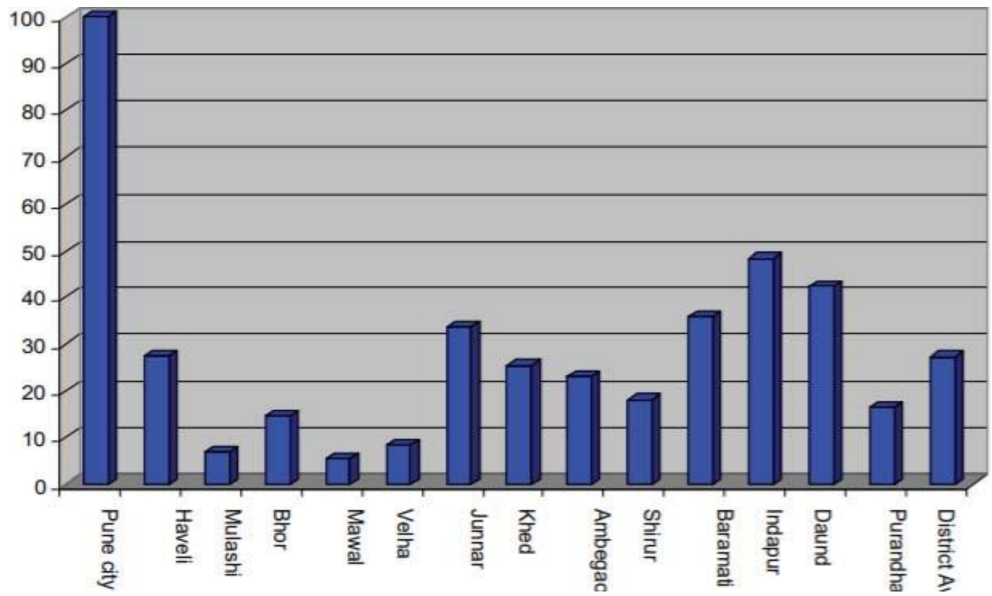


Figure 11: Taluka-wise area irrigated

Crops	Area coverage in 2011-12 (ha)	Micro Irrigation Plan (Area in ha)				
		2012-13	2013-14	2014-15	2015-16	2016-17
Bhor	20.26	0.00	11.89	34.47	37.9	39.8
velha	0.00	0.00	1.14	0.00	0	0
Maval	21.82	0.00	51.77	25.59	28.1	29.6
Mulashi	0.00	11.07	6.86	15.39	16.9	17.8
Haveli	189.23	124.08	214.60	92.66	102	107
Khed	32.76	197.10	85.59	103.48	114	120
Ambegaon	294.39	512.06	223.75	206.91	228	239
Junnar	1522.31	1655.93	589.43	399.26	439	461
Shirur	386.54	690.46	409.47	1016.97	1119	1175
Baramati	538.49	544.47	657.06	1228.67	1352	1419
Indapur	2739.27	3597.83	796.48	995.28	1095	1150
Dound	387.69	385.95	467.28	428.58	471	495
Purander	364.26	820.38	204.67	189.80	209	219
Total	6497.02	**8539.33**	**3719.99**	**4737.06**	**5211**	**5471**

DSAO, Pune

Table 11: The micro-irrigation plan of the Pune district

Special Programmes and the Ongoing Projects in the District

1. Deepsthamb farmer through ATMA: By implementing a prosperous farmer's Deepstambh Program, ATMA will train farmers to be more productive through their farming. Through this programme, successful farmers will be selected in the Pune district and supported through training programmes, demonstrations and exposure tours to become master trainers for other farmers. This programme will play a significant role in the district. These facilities will serve as meeting places for both successful and unsuccessful farmers to learn from one another.

2. Sugarcane Trash management Programme.

3. Collective farming.

4. Strengthening of extension functionaries.

5. Establishment of Agro Service Provider centre on PPP mode.

6. Reclamation of Saline and alkaline soil in Pune District

7. Agrotourism

2.10 OECD Perspective: The Adoption of New Technologies for Sustainable Farming Systems

In order to address agriculture's environmental issues, new technologies must be developed and disseminated. There is no better place for this workshop than the Netherlands, which has long been at the forefront of inventing and implementing novel farming methods.

The guiding principles of public policy

Over the past half-century, farming has undergone a dramatic shift. It has reduced food costs, fed an ever-growing population, freed up agricultural labour, and given customers a wider variety of options throughout the year. However, in many nations, those costs are artificially high due to support programmes.

In addition to environmental and social considerations, technology has played a significant role in these advancements. Agriculture, on the other hand, must be seen in the light of global economic trends. Agriculture is impacted by globalisation, agricultural policy change, and trade liberalisation. The way we think about agriculture is changing as a result of increased public awareness and a focus on long-term sustainability.

Agro-food policies in all of the OECD nations are now heavily influenced by interactions between agriculture and the environment. Upstream and downstream activities have a growing impact on agriculture. Farmers need the correct incentives, expertise, and technology to guarantee that agriculture provides enough food while preserving the environment.

In addition, a variety of policies must be in place, including those relating to agriculture, commerce, and R&D; these are just a few examples. In order to justify and explain policy decisions to all stakeholders, it is critical to use scientifically sound criteria.

Agriculture and the environment will be a topic of discussion in the next debates on international agricultural trade. It is no longer possible to debate international trade in isolation; other aims and concerns must be taken into consideration, without questioning the commitment of the WTO and the OECD to a freer, more open system of agriculture commerce. The problem is to come up with ideas that both parties can benefit from. Technology adoption for sustainable agricultural systems include both proven and available, but not yet implemented, technologies as well as those newly developed or yet under development. To begin with, I'd want to talk a little bit about the environmental implications of these new technologies.

Many nations believe that emerging biotechnologies should be evaluated in the context of sustainable agriculture, which encompasses both economic and natural resources. Biotechnology and genetically modified (GM) crops have generated a great deal of debate as to their current and potential advantages. Anecdotal evidence and scientific studies both support and challenge the advantages in terms of outputs, costs and environmental implications. However, it is still in its infancy and there is a lack of industry-wide experience. It's possible that the climate where you live has an impact.

Concerns about neighbouring farms being harmed by genetically modified crops are common among organic farmers, who are a tiny but rapidly rising section of the agricultural industry. Farmers' organisations believe that they should be shielded from culpability for any harm caused by GM goods as a result of laws protecting them from such liability. However, the fast expansion of genetically modified organism (GMO) crop cultivation in various nations illustrates that, contrary to common assumption, farmers can swiftly adapt new technology! As part of its ongoing environmental impact assessments, the OECD has looked at the effects of GM technology.

With modern technology like the Internet and social media, we can now access information in real time and from all over the world. As public financing for information dissemination and development efforts becomes increasingly scarce, farmers and policymakers are looking for new ways to communicate via the Internet.

As a result, there is a pressing need to guarantee that information can be transformed into knowledge that can be used by end users. Several examples may be cited of researchers utilising the Internet to interact with a variety of target audiences. If you're in the agricultural industry, which is typically plagued by distance from markets, e-commerce may help you receive information, sell your products, and publicise your other non- food outputs (like farm tourism).

In what ways is it crucial that technology be adopted?

Until recently, farmers' technology options were mostly dictated by their desire to boost output, profitability, and output per acre. Most of the challenges faced by entrepreneurs were related to the lack of finance and understanding of how to exploit new technologies, as well as market hazards that were covered by government laws. So "excellent policy practises" in the past focused on raising agricultural production and the goal of agricultural policies was to enhance agricultural productivity. Even small farms might benefit from a focus on agricultural research and extension services.

Agriculture now has to achieve a variety of goals, including being competitive worldwide, producing high-quality agricultural goods, and adhering to environmental standards. Agricultural producers must have quick access to new technology in order to remain competitive.

As a result, farmers must deal with a greater number of challenges as well as possibilities. To be lucrative, they must also fulfil environmental standards and laws, as well as cope with the pressures of both direct and indirect consumers and lobbyists. Many government and business sources may also bombard them, making it more difficult forthem to choose the best technology. I am certain that farmers can adapt their production and management techniques in response to agricultural regulations that take environmental factors into account.

In the future, the level of uncertainty may rise even more. Concerns about future policies, particularly in regard to assistance, trade, and the agro-food industry, may also be an issue. Farmers' adoption of new technology is an investment. Farmers may be reluctant to invest in an uncertain climate with more limits, where part of the advantages is for society, because it takes time for the rewards to come. Who should foot the bill: the farmer or the rest of us?

Agricultural production has increased and agricultural growth has been promoted as a result of technological advancement. Agriculture production is impacted by the development of innovative technology that farmers may quickly embrace if it is fit to their conditions. As a rule, agricultural innovation is developed and introduced by academics and extension workers, who are largely responsible for discovering and infusing economic and environmental elements into the process. Farmers either embrace or reject an innovation based on the aspects relevant to them, which is often described as a top-down approach where academics produce the invention, extension workers encourage its adoption.

Why is the OECD concerned about the adoption of new technologies?

The goal of the OECD is to enhance Member nations' policy practices and to influence worldwide discourse on policy problems. About 40 percent of the world's agricultural commodities are produced and traded by the OECD nations as a whole.

From conventional to organic, intense to extensive, and small to large, OECD nations' production technologies and agricultural systems span a wide variety of agroecological and meteorological circumstances. Despite these disparities, it is possible to gain through exchanging experiences.

The pursuit of sustainable development, including global concerns like climate change, sustainable use of natural resources, and protection of biodiversity, is a core priority for OECD nations, according to OECD ministers in May 1999.

Integration of economic, environmental and social factors into policy-making is essential to achieving this goal, particularly through the internalisation of costs, the development, and widespread use, worldwide, of ecologically sound technology." In a key OECD study on Sustainable Development in 2001, the OECD will focus on the sustainability of natural resources and agriculture. Additionally, the OECD looked into biotechnology and food safety, and submitted an input to the G8 Summit.

There has been some relief from natural resistance because of the Joint Working Party on Agriculture and the Environment's activities. A renewed emphasis on creating natural resistance to these agents can be expected as customers in OECD nations want goods that utilise fewer or no of these agents.

Targeted pesticides and disease-control technologies

In agriculture, though, there will always be a need for medicines and pesticides. Pesticides that are less toxic, less persistent, and less mobile through the soil are projected to continue to be developed as a result of technological advancements in pest management during the next several decades.

More efficient use of pesticides, particularly insecticides, should be possible for farmers in the future thanks to the decreasing costs of electronic sensors and computers, which will allow them to use pest control agents only when and where they are needed, rather than predetermined dosages and schedules.

Nutrient delivery systems that is more effective

Manuring and burning have long been used by farmers to give nutrients to root zones. Restoring decreased soil fertility and promoting livestock farming using grain and other feed components were some of the benefits of using inorganic fertilisers.

A lot of work has been done over the years to better understand the demands of certain crop-soil combinations and livestock. Technology that only applies fertiliser when and how much is needed might be predicted to boost crop yields while decreasing leaching and runoff of nutrients in the process.

Water management technologies that are more effective

Many of the irrigation methods still in use today are as old as human civilization. The problem is the same today as it was in ancient Mesopotamia: water is wasted when it is conveyed through open channels and furrows. Agriculture in OECD nations relies heavily on pipelines for the delivery of water, but new technologies like precision fertilisation can help increase efficiency by combining more exact measurements of crop demands with the ability to supply the water in more precise doses.

Harvesting technologies that minimise waste

In part, the demand for primary agricultural commodities is driven by the amount of waste that occurs during transportation. In nations with more readily available capital and infrastructure for agricultural production, such as those in the Organization for Economic Cooperation and Development (OECD), methods for harvesting, transporting, storing, processing, and distributing farm products are already efficient.

Even if simply for feed, fertiliser, or energy, nearly every portion of most crops and animals is salvaged for some commercial purpose. Post-harvest losses can be further reduced;however, the ultimate consumption point is where the majority of the food is wasted (in relation to the quantity purchased).

Knowledge-sharing technologies

Farmers in the past depended on their own knowledge and that of their neighbours when it came to adopting "excellent agricultural methods". Environmental impacts are becoming a more important part of the advice and information provided by government agencies and the agri-food industry. More information about sustainable technology may be shared via online resources.

Medicines that were more advanced reduced the strain on natural resistance. A renewed emphasis on creating natural resistance to these agents can be expected as customers in OECD nations want goods that utilise fewer or no of these agents.

Impacts of policy

Environment and agricultural policies, as well as trade and structural policies, influence the location and type of production, as well as the appropriate technology, of faecal matter; faecal matter, in turn, influences the scale of faecal matter; and faecal matter, in turn, influences the type and uptake of environmentally sustainable technologies.

Debate on policy incentives and disincentives has been a major topic in recent years. Is it appropriate for the government to offer farmers financial incentives to use environmentally friendly technologies if it isn't economical for them to do so?

This subject may also be examined in the context of agricultural methods that contribute to positive externalities, such as those that are ecologically sustainable (e.g. enhance biodiversity). Agricultural production and environmental results and public good parts of agriculture are linked in a new paradigm, in which technology must serve both to increase production efficiency and environmental performance.

A new technology is less contentious when it benefits the farm and the environment at the same time, which means that it is both financially beneficial and environmentally advantageous.

Factors influencing technology adoption.

An idea, activity, or technology spreads throughout a population through a process known as diffusion. As a result of their qualities, such as their relative advantages, complexity and divisibility as well as their capacity to be observable and compatible, technologies spread.

Farmers are more likely to embrace sustainable agricultural practises if information is efficiently disseminated. However, there is a contradiction that must be kept in mind. In other industries where transitions to less polluting or resource-conserving methods have occurred, governments have been shown to be inefficient if they are too prescriptive. That which sets performance requirements, rather than requiring the use of certain technology, encourages innovation that decreases the costs associated with reaching a given goal.

However, there may be a desire to speed up the adoption of new and valuable technology as it comes along. Teaching educators, extension agents, and others responsible for educating farmers about the benefits of the technology is too late at this moment.

Consequently, farmers must be involved in the distribution of better agricultural system technologies and the strengthening of current resource planning and research and extension capabilities.

Science, economics, and human behaviour all play a role in farm-level adoption of new and accessible technologies. The basis of technological development is based on one or more of the physical sciences or biology, and economics is a powerful driver for adoption. While less apparent, the psychological and behavioural components of technology adoption have a significant impact on whether or not a new technology is adopted.

Adaptation and adoption of new technology and change is most likely to occur when: the benefits of implementation will be quickly realised (within one to two years), the tools for implementation are readily available and accessible in the local marketplace, the risk of the implementation are small, and the change or new technology can be comfortably integrated into other basic on-going aspects of daily life.

Assimilation of new agricultural technology through extension has been delayed by many "barriers.":

- Issue to show a correlation between lucrative technology adoption and sustainable agricultural output at the farm level is viewed as a fundamental inability
- There has been a lack of progress away from a disciplined or one-dimensional approach to larger systems view.
- Farmers may not be encouraged to use new technology on their own farms if it is taught and shown in a controlled environment at a university research farm.
- Educators fail to take into account the psychological factors that influence students' willingness to accept new technologies as part of the educational process.

Adoption is a multi-stage process that encompasses a variety of personal, cultural, societal, and institutional variables. These include the phases of becoming aware, learning more, evaluating options, and finally, making the decision to adopt. In order to have a technology adopted, it is important to take into account its ease of use, its ability to show results, its utility in addressing an existing demand, and its minimal capital investment.

Farmers are extremely concerned about their bottom line. If you have a wide range of options and a slew of uncertainties, it's tough to know where and how to invest. If you have the chance to see a partner producer's investment in a lucrative technology, it may frequently assist you make decisions and influence the modifications you finally embrace.

According to surveys, farmers in the majority of OECD nations are getting more education and training as they go through their professions. This is great news, since farmers who are well-educated and well-informed have historically been among the most early adopters of new technologies.

Publicly sponsored extension services have always played a key role in disseminating information and guidance. Many countries, however, have privatised extension services since the 1980s.

A lot of changes have occurred as a result of privatisation. Extending services are becoming more reliant on the input of farmers' representatives. Provinces in the Netherlands, for example, have established agricultural offices to separate Extension advice on farm management from information on government policy provided by provincial offices.

The workshop's topics of discussion

Prior to detailing what I believe to be the most important topics this workshop should answer, it is important to review the session's objectives. In accordance with the OECD's Programme of Work on Agriculture and the Environment, the Joint Working Party on Agriculture and Environment is holding this workshop in this city today (JWP).

Sharing expertise and experiences, as well as providing advice to the JWP on the direction of its work in sustainable agriculture, are the primary goals of the workshop, which will especially address:

- Analyse diverse policy approaches and tools in light of country experiences in creating and supporting the use of relevant technology for distinct farming systems;
- Develop a better knowledge of how farming methods and technologies may be made more sustainable to meet future food and agricultural needs;
- Give a glimpse into the future of farming techniques, structures, customer preferences, and the agro-food industry;
- see how governments and markets may play a role in encouraging the use of relevant technology that help increase agricultural sustainability, and
- To increase farm-level sustainability, consider legislative options to encourage the use of new technology.

When it comes to adopting technology for long-term farming systems, these goals raise several questions. The OECD is particularly interested in the relationship between technological uptake and governmental policies. In specifically, which policies impact technology adoption, how policies effect adoption, and how policy change and trade liberalisation influence the adoption of technologies.

Specifically. Policy and private, market-based methods are of special interest to us. The adoption of sustainable agricultural technology is also vital to consider the role of policies and markets in the entire agri-food industry, since what happens upstream and downstream may have a significant impact on the adoption of appropriate technologies at the farm level. In terms of "contextual" considerations, the economic, environmental, and social impacts of technological adoption are among the most important.

A few things I'd like the session to focus on are:

- Exist common elements that supported or impeded the adoption of sustainable technology among OECD states? The question is whether or not there are well established connections between farming methods and sustainable technology.
- Is it more cost-effective to focus on "centres of excellence" for research and collaboration, or may economies of scale be achieved by sharing and collaborating? Are the institutions in place to support the adoption of sustainable technology in an interconnected world?

- The increased demand for food necessitates the use of new technologies to increase production and productivity, but is these technologies sustainable?
- Are there new metrics we should be using to monitor and assess success as a result of the adoption of sustainable technologies? What kind of indications would these be?
- International cooperation and coordination—even the pooling of resources—in R&D relating to technology and procedures that help improve farming systems may be possible.
- In terms of cost-benefit criteria (taking into account economic, environmental, and social elements), can we determine which sustainable technologies produce the best return in the shortest amount of time?
- What can non-OECD countries learn from this? Non-OECD countries can teach the OECD countries a thing or two.

The function of policies (and which ones) necessitates us to explore questions about market failures, public goods, and what we seek to achieve. In a nutshell, we're trying to figure out if there are any market failures or public benefits that prevent the adoption of technology for sustainable agricultural systems. Now the question is how governments, farmers and other stakeholders can put in place tools to support the adoption process. I have high hopes that this session will contribute to the discovery of some of the answers.

2.11 Farmers' Perspectives on Adopting Sustainable Farming Systems' Technologies

Globalization and the growth of world agriculture are mostly driven by technological advancement. It's possible to make the following deductions:

- There is often a technical gap between affluent and poor countries.
- Advancements in farming technology are often to blame for the shifting social dynamics between farmers and society.
- International trade wars are increasingly being fought over cutting-edge technological innovations.

I would like to thank the OECD and the Dutch government for taking the initiative to explore the subject of how to incorporate new technology into farming systems in order to improve their sustainability.

Farmers must take into account the challenges of globalisation and sustainability while deciding whether or not to implement new technology.

Farmers face a worldwide marketplace that is extremely competitive. Some of the world's largest multinational corporations control the food supply, and they operate under a complicated regulatory framework. In addition, the government's support for the farming industry is decreasing. Farm production must be cost/price-driven in order to thrive. In order to boost productivity, new technology is required. Keeping up with technological advancements is essential for farmers.

However, the "problem of sustainability" is not just a financial one. The concept of sustainability in a policy context is much broader and varies from country to country, even though farmers must maintain a positive balance with their environment in order to ensure the production on which their immediate livelihood depends, as well as the long-term survival of farming as an economic activity In developing nations, food security and economic growth are the primary goals of technology adoption.

To be sustainable in the OECD region means ensuring food safety and quality; managing our natural resources; and keeping rural communities in place. Many factors contribute to farming systems' long-term viability.

Agriculture has a unique and vital role to play in creating a more sustainable society. The rural environment, with its animal habitat, genetic variety, landscapes, and cultural practices and traditions, can be preserved, in addition to providing a sustainable food supply to feed the world's fast-growing population.

Market dynamics and government regulations both have an impact on farmers' capacity to make this contribution. The use of improved plant and animal genetics has resulted in significant increases in farm output. Wheat yields in Europe averaged roughly 2 tonnes per hectare 50 years ago, but today the average is 7 tonnes per hectare and some farmers generate 10 tonnes per hectare.

Farmers are increasingly using more industrial inputs and adopting management practices that emphasis low costs and high yields as a result of market-driven technical advancement. However, in many situations, the demand on natural resources has increased as a result of this drive for increased production and efficiency. Consumers are increasingly concerned about the safety and the quality of food produced in contemporary, intensive agricultural systems.

As a result, many small farms have gone out of business. Because of this, post-World War II agricultural practices, which helped Europe escape from food shortages, are becoming unsustainable in light of society's shifting priorities. Most other industries don't view the introduction of new technologies as seriously as the agricultural industry. There are customers who are sceptical about the long-term viability of current farming methods in several OECD nations. Quite a few customers, in fact, would prefer that agricultural practices used in the past be returned to. In response to these concerns, most farmers are actively engaged in a variety of methods to improve agricultural sustainability. Farm inputs may be better targeted, and conservation farming practices can be used more frequently.

The following can be noticed in cases where this has occurred:

- Pesticide usage in various OECD nations has decreased by more than 50% in recent years.
- Integrated crop protection strategies have becoming more popular.
- Balanced nutrition can be achieved by nutritional tracking, for example. Intensive livestock enterprises have invested much in the storage and management of manure.
- filters have become ubiquitous near waterways, especially in areas where farmers do not use any pesticides.
- irrigation systems use water more effectively and waste water is recycled.
- 'no-till' and 'direct sowing' technologies are becoming more commonplace in the farming of crops.
- It is becoming increasingly common for greenhouse horticulture to be totally self- sustaining.
- Precision farming is becoming more commonplace.

Through the interchange of information and ideas between farmer and farmers' organisations, farmers' organisations are also helping to facilitate the transfer of technology and know-how.

As an example, such organisations have produced standards for environmental agricultural methods and quality assurance programmes. In addition, they have taken the lead in community-based, non-profit projects (e.g. setting up water user groups or land care programmes).

Despite these efforts, it is evident that market forces alone will not be able to supply the numerous services that society expects from sustainable agricultural systems. There is frequently minimal financial motivation to create technology that promotes sustainable agricultural systems' social and environmental elements. As a result, governments in OECD nations are increasingly considering technological innovation to be a public policy concern.

Agricultural policy must consider the whole system of production, natural resource management, and rural community livelihoods as a whole when making decisions.

Building on farmers' expertise and supporting farming systems to become more sustainable are essential components of this strategy. Any debate of public policy in this area brings up a slew of difficulties.

Among them:

- Doing research in a way that maximises returns.
- Customers, farmers, and society as a whole should be better informed about technological advancements.
- Finding the right balance between the many laws and regulations that govern what farmers can and can't do on their property and how they may do it.
- Bringing international legislation covering things like intellectual property rights, health and safety standards, the precautionary principle, multilateral agreements on the environment, and international trade norms into harmony.
- Competition policies should be bolstered.
- Farmers should be able to preserve their own seed for replanting on their land.

It is with grave worry that IFAP examines the decreases in government financing for agricultural research in the context of developing adequate technology for long-term farming systems. Many huge multinational firms are now monopolising the greatest scientific research, which is secured by patents. Who gets the advantages of research is heavily influenced by the question of who owns and controls it.

In order to ensure that agricultural research is accessible to everyone, more money should be invested in the public sector. A goal should be set to raise public spending for agricultural research to at least match that of the private sector. Public awareness of food and environmental concerns should assist attain this aim.

If the OECD wants to assist farmers protect their natural resources, it should stimulate the formation of research collaborations. This would allow farmers to satisfy environmental as well as social objectives. The business sector isn't interested in helping farmers in this area, but the public sector should have a part in it. To help steer and encourage technical innovation, policy research is equally critical. Intellectual property rights, biosafety, and food safety should be addressed. It's also necessary to effectively communicate technology advancements to customers, farmers, and other members of society, as well. While the number of individuals who are well-fed and have longer life expectancies than at any other period in history is increasing, the general public's attitude toward these developments is generally unfavourable.

In the present discussion on the adoption of new technology, farmers are damaged in the marketplace and international trade is disrupted because of emotional considerations. Because of this, education plays a critical role in ensuring a seamless transition to new technology. The examination and management of new technological hazards for public health, the environment, and the social sustainability of rural economies necessitates the use of objective criteria. For answers, we often turn to scientists, yet their voices are rarely heard in public discourse. They should be more active in the public education process on technology advancements in the future. In order for farmers to advance in a "knowledge economy," they must be well-educated.

Technology and policy shifts are on the horizon, so farmers must be aware of them. As a result, farmers need to be educated on how to adapt to new breakthroughs in research. Consider creating regional centres where farmers' organisations and others may obtain information on best practises and success stories.

An example of this would be the Wageningen Agricultural University. Concerned as a farm leader, I am alarmed by the dramatic decline in agricultural university enrollment in OECD nations. The OECD region's critical mass of agricultural knowledge appears to be decreasing as the number of farmers declines. Research and technical innovation should not, however, be based on the quantity of farmers.

Farming's ability to fulfil the requirements of the world's rapidly expanding population should not be a deciding factor, but rather the increasingly complex and multi-functional demands that consumers place on agriculture. So, if we want to build the knowledge foundation for sustainable farming systems, we need to invest more money in agricultural colleges rather than less. If we want to be "sustainable" in a world of quick and deep change, we must examine our own actions.

It is imperative that both farmers and governments assess the "sustainability" of their own activities in terms of policies, programmes, and structures. They cannot argue that they wish to protect small-scale farming, hedges for animals, or a beautiful environment without giving both the regulatory framework and the money to sustain it. The reverse will happen if market forces are liberalised. When it comes down to it, agriculture can only be long-term if it can recruit new farmers into the industry to keep it fresh. In order to maintain an economically viable agriculture and a thriving rural economy, it is necessary to use suitable technology, incentives, and policy frameworks for sustainable agricultural systems.

2.12 Public Perspective on the Adoption of Technology for Sustainable Agriculture

Introduction

We need this training right now, and I'm confident that it will help us better understand sustainable agriculture. I'd like to begin by outlining some of the most important points to keep in mind. Throughout the 21st century, I believe we will have to substantially alter our lifestyles due to our finite resources and the deterioration of our planet's natural environment. There is a wealth of information in the workshop papers, and I'm grateful for the opportunity to read it all. Traditional, current and emerging agricultural paradigms are presented in an Austrian study on organic agriculture, for example It is possible to sum up contemporary agriculture in six words: mechanisation; labour-saving; yield-enhancing; intensification; specialisation; concentration; and economies of scale. This has resulted in increased output in a shorter amount of time with less effort. Despite the fact that they are considered modern agricultural qualities, Japanese agriculture has not been able to satisfy them. To characterise other economic sectors, such as manufacturing, which has seen strong economic development in the past, the same phrase may be applied. Due to high productivity and specialisation, the Japanese economy is presently experiencing its worst slump since World War II.

The problem of industrial waste

It is fear that Japan's rapid economic progress in the past may lead to major environmental issues in the future. Although Japan is one of the world's leading exporters of money, it is also the world's leading importer of raw commodities in terms of volume or weight.

In contrast, we import 800 million tonnes of petroleum, iron ore, lumber and seed grain while exporting less than 100 million tonnes. In all, Japan's industrial "waste" is estimated to be 700 million tonnes. The United States exports and imports 300 million tonnes of goods each year, with Canada being their primary trading partner. As a result, trade flows to and from the United States have a smaller environmental impact than trade flows to and from Japan because of lower volumes and shorter distances. Remains, dung, and dioxin are dispersed over Japan in the form of waste. Ecological issues are now more important than economics or money to the Japanese people. Despite the present economic downturn, many Japanese citizens are more worried about safeguarding the environment than regaining their financial stability.

	Traditional Agriculture prior to 1950	Modern Agriculture 1950 - 1985	New Agriculture as of 1985
Technology	Relatively constant technology	Mechanization Agrochemical Better seeds and breeds	Information technology Biotechnology Integrated technologies
Organization	Relatively stable	Labour yield saving Enhancing Intensification Specialization Concentration	Quality orientation Protecting the Environment Direct Marketing Ethical marketing new products
Social impact	Static rural society	Dynamic structural change	Continuing structural Change Rural development Direct Plurality of payment types
Driving forces	Driven by tradition	Driven by economies Of scale (produce more, faster, easier)	Driven by markets Consumer preferences and information
Innovators	Individuals “Local geniuses” Outsiders	Technical experts Sector specific innovation	Social experts’ Strategic innovation
Technology forecast		Visions of technical experts What is the technical solution to a technical problem?	Social experts looking For mega-trends Technology assessment What is a good Technology that meets with consumer and social preferences?

Table 12: Agriculture's paradigm shifts

The Disposal of Manure

It's not just the industrial industry that has to deal with waste issues; agriculture is no exception. In order for agriculture to be more sustainable, farming techniques must be altered. Japan's livestock business is analogous to the manufacturing industry in that it imports a large amount of feed grain from the United States and processes it into beef, pork, eggs, and milk for export. There are no exports from Japan's cattle business, but this is a lucrative industry in the Netherlands.

Japan produces sixteen to twenty million tonnes of feed grain each year, which results in a significant amount of livestock excrement. Manure that has been exported to other countries should be returned and put on American farmland in accordance with society's material recycling ethic. To avoid this, the nitrogen levels in Japan will continue to rise while those in the United States will decrease by 30 percent. Even though I don't know what the present levels of soil nutrients in the United States are, I am aware that soil and groundwater in some regions of Japan are contaminated with nutrients.

The idea of food miles

To understand why Japanese people are so concerned about food safety, consider that Japan is one of the world's most polluted countries. Environment and the status of our planet are also major considerations. I think these concerns are shared by the OECD Member States.

Consumers become more worried about food safety and quality than price when the Engels2 co- efficient falls below 20.

Consumers want to know about the environmental effect of agricultural production practises, as well as about the products on the market. For example, information on these procedures is generally scarce, unlike for the creation of items. Due to the lack of information available to customers, it is difficult for them to determine the source of the agricultural goods they purchase.

Globalization has made it much more difficult to get information on food safety. Because of this, customers require labels on things like production procedures and substances utilised, for example, in order to make informed decisions (e.g. organic and GMO products). It's not always apparent how much information is available and how reliable the information is.

Consumer organisations in Japan, which are mostly made up of housewives, have begun to push the concept of food miles, which measures the distance between the location of production and the final consumption of a food product. When it comes to food, for example, tuna from Antarctica travels 6, 000 kilometres, beef is imported from Australia, and bread bought from the United States travels 4, 000 kilometres. As a result, a single meal's ingredients can travel more than 20 000 kilometres. An increase in food miles should be considered a red flag.

According to Buddhist teachings, the body cannot be detached from the land, and hence we should eat food that is grown in close proximity to where we live. In Korea, too, this is a common refrain. The enormous distances involved in transporting non-seasonal agricultural items, like strawberries, should be avoided by customers in order to reduce food miles.

Preferences of consumers

More and more customers are refusing to purchase agricultural goods that harm human health and the environment. Most Japanese people anticipate rural regions to be "areas that are symbiotic with the ric h natural environment" or "areas where farming techniques are mainly in harmony with the environment," according to a recent poll.

Consumer preferences are reflected in the buying of ecologically friendly agricultural goods. Consumers are willing to pay a premium for organic items because they are concerned about the environment.

An organic food certification system has been devised and is now widely utilised in many nations throughout the world. It's hard to pin down the reasons why people select organic foods: Is it for food safety, environmental protection on and off the farm, or both? If it's both, how do you find the right balance between the two?

Consumer signals must be used appropriately to maximise the beneficial impact of this shift. It is essential to build a dependable certification system in order to increase the trustworthiness of certification on specialised items, such as organic food. For example, in order to avoid "fake" products, both inspectors and farmers need to be given technical instruction. Tsukiji, Japan's largest wholesale market, saw around 45 percent of its agricultural items labelled as organic or organic-related food ten years ago, forcing the Ministry of Agriculture, Forestry, and Fisheries to issue recommendations and subsequently pass a legislation on the subject.

Public opinion

Three variables are critical in encouraging the use of sustainable agricultural methods in agriculture:

- Study and experimentation;
- Expansion of the service
- Spreading of knowledge

Study and experimentation

Nonlinear and complicated interactions between agriculture and the environment exist. Different temperature, terrain, and agricultural history, as well as disparities between industrialised and developing nations are factors that influence the impact of agriculture on the environment, as Mr. Doornbos remarked.

Agriculturists may also help preserve land and other environmental resources, keep landscape values high and assist local communities via activities that are in harmony with the natural environment. When we talk about the "multifunctionality" of agriculture, we mean the non- commodity outputs that come from farming together with the commodities themselves. Because these non-commodity outputs are economic externalities and their values are often undervalued in the marketplace, they are often overlooked by investors. At the WTO ministerial session in Seattle, one of the most hotly debated themes was the multifunctionality of agriculture.

There are several ways in which agricultural operations, such as soil erosion, compaction, and nutrient leaking may impair the ecosystem both on the farm and outside. To ensure that agricultural goods are sold at a fair price, farmers must be held accountable for environmental harm caused by their operations and shoulder the expenses of pollution mitigation measures.

That's why new regulations and assistance are needed to stop hazardous agricultural management practises and encourage farmers to switch to more sustainable methods. Environmental deterioration is a vicious cycle that can be broken with these solutions. It is possible for little levels of pesticides to cause significant environmental harm in some climates or if they are administered incorrectly, but it is also possible for much greater dosages to have no influence if they are done correctly. Farming techniques that are more ecologically and economically sustainable can't be encouraged just by the market.

In addition to correcting market problems, technological advancement is necessary. Farmers are more likely to embrace environmentally friendly farming techniques if new technology is available to measure the impact of agriculture on the environment. When it comes to particular activities, such as excessive fertiliser usage, it is helpful to distinguish between the general mechanisms and the site-specific consequences. These issues need the use of both experimental and empirical methods.

Study and experimentation

Having a good extension service is a must. Without enough information and assistance, it is difficult for farmers to modify their management methods, even if they are aware of their environmental impact. Reductions in fertiliser consumption, for example, might have a substantial impact on output and possibly lead to bankruptcy. Fertilizer industry advancements, on the other hand, have resulted in a shift in farming techniques as a result of better fertilisers on the market. When farmers see the benefits of the new goods and procedures, they begin to use them in their own operations.

It is also critical that new technologies are described in terms of their suitability for local settings. Research facilities and demonstration farms in the community play a critical role in disseminating this knowledge.

The 47 prefectures of Japan each have their own research stations, which employ roughly 10,000 extension workers each. State-run research institutions and experiment stations, excluding the National Research Institute of Agricultural Economics, are to become semi-governmental organisations in the next budget year, in accordance with the ongoing administrative reform. In particular, Mr. Doornbos was concerned about this issue. Farmers may utilise these findings to get the knowledge they need to make informed decisions about their farming techniques.

Spreading of knowledge

Technology-related information has to be disseminated. When it comes to adopting new technology, farmers are often conservative and require more time and knowledge to change their minds. Consequently, it is critical that the public sector supply accurate and detailed data. In the future, the OECD may focus greater attention on issues relating to information and technology. Reliable data and technical instruction tailored to local conditions are necessary for the smooth distribution of new technologies.

Farmers like to get their hands on a new technology in order to make an informed decision about whether or not to employ it. Farmers may use demonstration plots to learn about the practical aspects of adopting new technologies.

In addition, farmers must have access to a wide range of information, technical and non- technical. Farmers may reduce the risk of introducing new technology by having access to this level of knowledge and technical assistance. Because farmers have gotten appropriate technical assistance, there is likely to be a great deal of consumer confidence.

The amount of food produced may decrease as a result of a shift in farming technology toward more sustainable methods. Because of this, farmers may need to be compensated for their losses during the shift.

2.13 Measurement of Environmental, Economic, and Social Impacts of Sustainable Technologies in Developing Countries

Introduction

In recent decades, there has been an incredible increase in food production in many regions of the developing globe. Farmers in Asia, for example, have adopted high-yielding types of staple commodities such as rice, wheat, and maize as a result of the Green Revolution, and famines have been avoided. Sustainable improvements in yields have avoided over-exploitation of marginal land and decreased the rate of deforestation, both of which are key environmental advantages.

However, a number of questions remain. In Sub-Saharan Africa, where hunger is on the rise, modern agricultural technology has been largely unsuccessful. Nearly a billion people are still living in poverty as a result of rain-fed agriculture and unstable soils.

High-external input systems' yield increase is decreasing, environmental issues have surfaced, and water restrictions hinder future expansion of irrigated farming. A by-product of this is that the marginal returns to further intensification are dropping in many high-potential locations, making them less attractive than the potential returns of cultivating more vulnerable land (Hazell and Fan, 2000).

Farming technology and techniques must be developed in an effort to keep up with the rising demand for food and feed during the next several decades.

To alleviate rural poverty and hunger, the agricultural expansion process must be equitable and planned in a way that protects the natural resource base and reduces pollution. Agricultural innovation that enhances factor productivity and conserves the resource base is the driving force behind this sort of agricultural growth, according to the findings of Hazell and Lutz (1998).

A growing interest in agroecological techniques, which emphasise the importance of cultivating plants and animals in the context of a broader ecosystem, is helping to lessen the need for external inputs (Altieri, 1995). Diversification of activities, interaction between agricultural, livestock, and forestry activities, biological management of pests and diseases, and control of soil erosion and nutrient depletion are some of the major features of the latter system.

Biophysical metrics (soil organic matter and physical yields) are used to evaluate the advantages of different systems. More emphasis is paid to the impact on farm household income, consumption, and labour usage. SAI is a concept we propose to conserve the natural resource base, safeguard soil nutrient balances, and increase land productivity while also maximising farm household income, including returns to labour. SAI is an acronym for Sustainable Agricultural Intensification. We focus our attention on "win-win" technologies that may simultaneously improve on both agroecological and welfare metrics because of the inevitable trade-offs. All farm families may not benefit equally from such advances, though. Differences in access toresources, markets and knowledge and information across households can be a source of economic and social anxiety.

In the context of emerging economies, this section examines the environmental, economic, and social consequences of more environmentally friendly technology. We limit ourselves to the ex- ante evaluation and possible policy implications of new SAI techniques since empirical information on sustainable agricultural systems is currently sparse and frequently inadequate.

Five criteria for evaluating SAI systems and their potential implementation have been developed after some general observations on agricultural productivity development and sustainable land use. We'll take a quick look at how new systems like this may be assessed for their impact. After that, we'll talk about how to foster an atmosphere conducive to the rapid adoption of cutting- edge, environmentally friendly farming practises through public policy. The last portion of the paper summarises these and other findings.

Sustainability and productivity

Growth in productivity

Agricultural development has a unique and contradictory function in the process of economic growth. Increases in productivity are necessary at low per capita income levels in rural areas in order to boost rural incomes and preserve food supplies for urban populations and raw materials supplies for ago industrial growth as well as crash crop production for export revenues and tax revenue.

Farming's role in economic growth requires a clearly defined policy framework that encourages farmers to increase their production in a sustainable way while decreasing the need for public expenditures that has already been met.

Consumption expenditures move from food to non-food products as income rises due to increased factor productivity. While agricultural productivity continues to rise, the rate of agricultural production growth is often lower than that of most other economic sectors. When newer and more efficient technologies are used, they have the effect of diminishing the importance of agriculture in the macro economy.

The fact that agricultural output has increased while its size has shrunk has long been a problem for policymakers. Agriculture's supply response analysis is a major component of policy analysis of policy measures (e.g., relative pricing for agricultural input and outputs) that have a significant impact on the sector's capacity to respond to policy changes.

There are a number of ways to respond to a supply shortage, and each has a distinct impact on the environment and the distribution of resources. Rural families' responses will vary depending on their resources and risk attitudes, and they may be delayed as a result of disparities in expectations and the costs of adjusting to those expectations. Variation in households' access to markets, expertise and information is consequently an essential factor in the adoption of different technologies and diverse prospects for making money.

Ecologically sound land use

There are no definitive empirical studies on the influence of agricultural policy and structural adjustment on the sustainability of land usage. some say price changes stimulate soil depletion, while others say that farmers would engage more in soil conservation efforts as a result of price reforms (Barrett, 1991, provides a summary of the arguments).

Because of disparities in discount rates and relative risk aversion, there are conflicting views on the link between pricing and soil deterioration in this country. As a result, farmers may not be able to benefit from increasing production prices because of market flaws.

There are four possible responses to changes in relative prices on agricultural resource allocation: I area expansion (extensification), increased input use, technological change, and crop choice adjustment; (ii) area expansion, increased input use, technological change, and crop choice adjustment (output substitution). Adjusting recurring expenses (increasing productivity) and investing in fixed assets (preventing additional soil degradation) should be distinguished (i.e., terraces, windshields, etc.).

When analyzing supply responses to changes in relative pricing, it is common to look at the impact of soil loss on the availability of nutrients from natural sources. Natural soil fertility can be viewed as an investment in capital and/or labour in conservation efforts. In African agriculture, both components are in short supply.

In order to promote sustainable land use, it is necessary to apply complementary tactics such as selective intensification and productivity-enhancing soil conservation measures in addition to soil mining activities.

Agricultural policy, farmers' supply response, and the consequences for sustainable land use are not yet understood in full detail. Because more agricultural land is being developed, environmental consequences such as deforestation and overgrazing are likely to occur.

Increasing output prices led to an increase in area and a slight rise in yield, according to Binswanger et al. (1987). If cropping activity shifts at the same time as area expansion, the eventual effect on resource quality (i.e. soil) quality will be reliant on the negative consequences of cropping activities.

As a rule, the complementary impacts of input utilisation and soil chemical or physical qualities are overlooked. Consequently, changes in input efficiency (such as fertiliser and labour use) resulting from changes in soil organic matter or soil conservation investments are not fully recorded. For a deeper understanding of these concerns, a paradigm focused on the connections between welfare and sustainability consequences is required.

Assessment criteria from a micro perspective

In the context of SAI, farmers are attempting to enhance returns on finite resources in a way that preserves the quality and quantity of their natural resource base. Land production is a crucial measure of agroecological methods' success; labour returns are often overlooked (Low, 1993).

To understand how agroecological principles can help farmers increase their yields, farmers look at the following five aspects of profitability, namely the possible contributions to household income and consumption; (ii) the implications for input efficiency; (II) the consequences for input substitution and labour use. As a result of this discussion, we will identify a number of essential factors that boost the socioeconomic appeal of sustainable technology, which we will next address.

Profitability

Farmers are only likely to embrace sustainable farming techniques and technology if they have greater and more secure income and consumption options. A favourable output/input price ratio is necessary for a business to be profitable. Investments in soil conservation initiatives are discouraged by market distortions or inefficient trade networks. When farmers rely only on locally available resources, agricultural intensification may become unsustainable. Commercially-oriented farming operations are more likely to use yield-enhancing and sustainability-enhancing inputs than is often assumed (Reardon et al., 1999; Putterman et al., 1995). Chemical fertilisers, crop leftovers, and animal manure are commonly utilised in the cotton belts of southern Mali and Burkina Faso to grow cash crops that are profitable enough to justify the expenditures (Sissoko, 1998; Savadogo et al., 1998).

Animal traction and enhanced tillage also give larger returns when used on more fertile areas where commercial crops are cultivated. With animal traction, crop residue mulching appears to be viable in the Central Chiapas area of Mexico only where significant market-oriented farming operations are being carried out on the land (Erenstein, 1999).

In order for farming to be lucrative and long-lasting, farmers must participate in market trade. Commodities and consumer products can be purchased using money saved up by trading with other businesses. Low commodity prices will help households that have a positive food demand balance.

Off-farm work income can be used to fund investments in places where conventional credit services are unavailable (Ruben and van den Berg, 1999). Participation in the market exchange often enhances farmers' responsiveness to price incentives, while market development may encourage desire to spend further. Consequently, regulatory interventions remain a first-best choice when markets fail. Increased reliance on low-input external technology is the most common result of their absence.

Efficiency of input

Input efficiency, such as the marginal returns from an additional unit of (organic or inorganic) inputs, is critical to sustainable agricultural intensification. Production ecology techniques emphasise the importance of the availability of complementary micro- and macronutrients, such as soil organic matter and phosphorus, in nutrient efficiency (i.e., fertiliser absorption) (Van Keulen, 1982). Due to the immobilisation of nutrients and the slow breakdown of organic materials, substitutes for chemical fertilisers often have a poor recovery percent.

Enhancing recovery and uptake of nutrients is possible by reducing the soil's nutrient retention capacity (e.g., by conserving soil and water), as well as by applying nutrients often according to the crop's development cycle (e.g., within a few weeks after sowing and with enough rainfall). Both operations require a lot of time and effort, yet can't be automated.

The release of nutrients from the soil is accelerated by mechanical or animal tillage. It is only via the availability of input combinations that enable appropriate synergy effects based on tight complementarities between distinct growth-enhancing inputs (such as nutrient and water, phosphorus-nitrogen, and carbon-nitrogen ratios) that agricultural yields may be improved.

Soil carbon content and (in)organic nitrogen supply are linked functionally to prevent nutrients from becoming immobilised, and nitrogen and phosphorus are proportionate to provide a proper rhythm of organic matter breakdown (Penning de Vries and van Laar, 1982). When complementary inputs are not accessible at the proper time or in adequate quantities, input efficiency tends to be lower.

Farmers are well-versed in harnessing the synergistic effects of combining several productive activities. Combining locally accessible resources with judiciously applied foreign inputs is frequently the most effective strategy for achieving the greatest outcomes.

The use of bought inputs allows farmers to better schedule their operations, eliminates the need to hire additional workers during important periods, and improves the presentation of their goods in the marketplace.

Organically generated fertilisers (green manure, mulch, dung, compost) have a low nutritional content and a delay in nutrient availability, therefore the usage of chemical fertilisers cannot be fully abandoned. Optimal results are achieved when the use of chemical fertilisers is gradually reduced towards a minimal level since organic matter breakdown takes time.

Biological fixation of nitrogen from cover crops can be enhanced provided adequate phosphate is present. Adding phosphate fertiliser or rock phosphate to tropical soils can assist improve overall input efficiency because of a phosphorus deficiency (Kuyvenhoven et al., 1998a). Water and organic matter must be present in order for nitrogen to work. Selective use of complementing external inputs should be promoted where reliance on internal inputs compromises nutrient efficiency (Triomphe, 1996; Buckles et al., 1997).

An example of this is in integrated pest management (IPM) programmes, in which pests and illnesses are controlled with the application of enhanced nutrients. Farmers that use tiny amounts of chemical fertilisers are less likely to lose crops to competition or pests. A lack of fertilisers makes it easier for illnesses to spread through the fields, whereas excessive levels of fertilisers make it more difficult for weeds to thrive.

Substituting a factor

There is a widespread lack of attention paid to labour needs and returns to labour in most studies of natural resource management strategies. As a result, family labour is assumed to be a "inexhaustible" resource. An economic evaluation of agricultural profitability should take into account the elements that have a direct impact on the farm's ability to enhance its yields (i.e. water and 39 nutrients, energy, pests and diseases) (land, labour, capital, knowledge).

In addition, certain restrictions on the substitution of labour for external inputs should be acknowledged. The usage of labour in sustainable agroecological activities tends to be high.

However, in the Central American hillsides and West African lowlands, physical soil conservation techniques have led to moderate yield gains while necessitating a high amount of labour and material expenses for installation and upkeep.

These metrics are significant because of their high labour intensity and lengthy gestation time (Lutz et al., 1994; de Graaff, 1996). The collection, transport and under-ploughing of green manure methods and crop residue mulching necessitate additional labour. A lack of profitability in most agroforestry and mixed cropping systems can be attributed to the high expenses of setup, upkeep, and harvesting (Current et al., 1995).

Arable cropping benefits from the increased supply of manure from fodder crops, although both operations need a significant amount of additional labour (Breman and Sissoko, 1998).

With the switch from chemical to manual activities, the labour requirements for integrated pest and disease control are also rather significant. There are several natural resource management activities where mechanisation is not possible because of the steep terrain and small size of operations.

Natural resource management strategies must be evaluated from a farm family's perspective by comparing returns to land and labour at the same time (Reardon, 1995). The value of marginal returns (i.e. off-farm employment; land hire-out) must be taken into consideration. When sustainable agroecological methods can increase nutrient stocks and soil organic matter content, the yield benefit is generally insignificant relative to the higher input needs. In order to ensure that nutrients are available in a timely manner to the cropping system, labour is necessary.

Conventional technologies, which rely heavily on input complementarities, tend to overshadow the benefits of labour. Taking into consideration predicted yield impacts and labour needs, Figure depicts a broad overview of important natural resource management strategies.

Farmers' ultimate decisions on how to manage natural resources may be influenced by the labor/output price connection. Both soil fertility-enhancing methods and mixed crops and limited tillage produce the greatest outcomes. Cropping operations with a high added value and low labour costs benefit from soil and water conservation techniques and vigorous weeding.

Adoption may be hindered by the high labour intensity of most agricultural management approaches. Competition for labour arises when mulching, manuring, or crop waste recycling are introduced during times of soil preparation, weeding, and harvesting in semi-arid locations. In the absence of labor-led intensification of their agricultural system, resource-poor farmers are more prone to rely on off-farm activities to supplement their income (Reardon et al., 1988).

Farmers are only likely to change their production system if the increased cash generated by such activities outweighs the labor's opportunity cost. Off-season farm management procedures, such as physical soil conservation measures, can be carried out, but they eat up time that could otherwise be used for social or community activities.

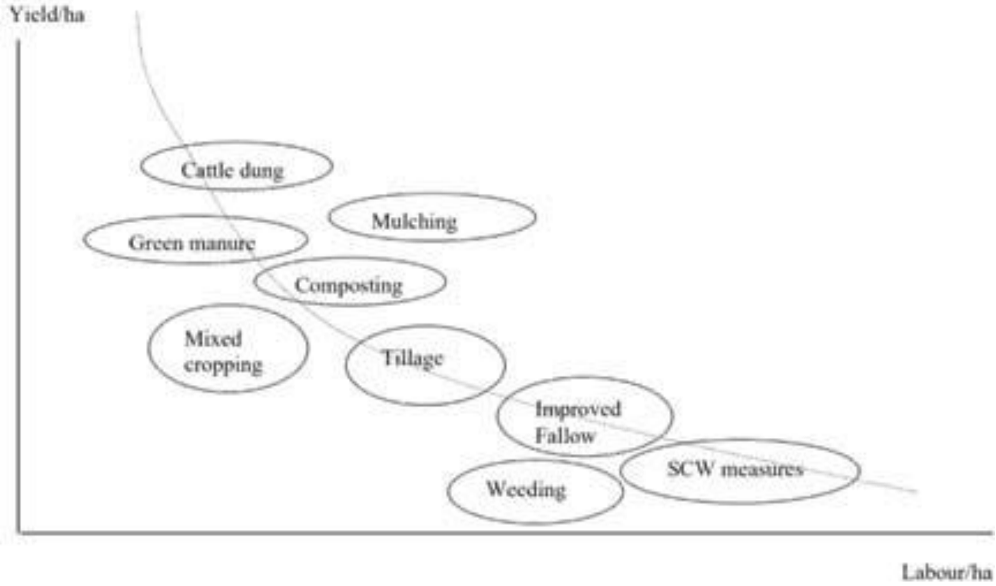


Figure 12: Effectiveness of key farming methods in terms of factor intensity and crop yield

Management of risk

Farmers with limited resources are more likely to rely on a wide range of activities to provide adequate risk management. Crop and animal production diversification and integration with (ago)forestry, aquaculture, and enhanced fallow techniques might strengthen agricultural systems through processes of nutrient recycling, biodiversity management, integrated pests and disease control (Muller-Samann and Kotschi, 1994). As a result, yields are more stable and the need for bought inputs can be decreased.

Farmers' participation in non-farm and off-farm activities may also help control risk, as is becoming more recognised (Reardon et al., 1994). Because these activities are less reliant on the weather, they provide a sufficient level of protection against covariate shocks (Udry, 1990). Additionally, diversification into non-agricultural businesses might be considered a risk management strategy. When the demand for agricultural labour can be decreased and family members have the necessary skills and knowledge to move into wage labour or self-employment, this option becomes viable (Reardon, 1997). The ability of farmers to change input utilisation in response to shifting weather or environmental circumstances is another problem connected to short-term risk management. Adaptive behaviour relies heavily on the ability to learn quickly in order to respond quickly to unexpected situations (Fujisaka, 1994).

Since the majority of agroecological techniques are based on farmer-to-farmer exchanges and farm field schools, there is a lack of knowledge about how production systems work. A case in point is Honduras' abandonment of 'companion technologies' including living barriers, contours, crop waste recycling, and reseeding, which may be traced back to a lack of sufficient reaction to weed invasion (Neil and Lee, 2000).

Sustainability

SAI means that the resource base's output capacity can be maintained throughout time. Not all agroecological balances should be rigidly maintained at all times, though. In theory, producers may accept resource depletion in the short term while investing in its recovery in the long term. Weak sustainability (Pearce and Turner, 1990) has been widely used in economic assessments of land use systems (Pearce and Turner, 1990).

It is common to see 'optimal depletion' at work when a traditional fallow system has been allowed to recover after a long period of continuous harvesting. Wild animal populations, fisheries, and forestry systems all have the potential to regenerate naturally in a similar manner (Bulte, 1997). Intertemporal welfare requirements can be satisfied by a given stock of renewable resources if prices and discount rates are known. Consequently, it may make sense to cut back on stock holdings in the short term and allocate cash for their recovery in the future.

From a trade-off standpoint, farmers' choice for poor sustainability may be explained. Discounting processes are used to compare present and future expenses and benefits based on farmers' respective time preferences. Risk-averse individuals are more likely to retain a high discount rate because they seek quick cash flow. As Current et al. (1995) show for the instance of agroforestry projects, investments with lengthy gestation delays are particularly susceptible to large discount rates.

When farmers consider the welfare and sustainability consequences of alternative technology, another form of trade-off develops (Kruseman et al., 1996). Farmers are only likely to embrace sustainable methods if they see a beneficial impact on their own well-being. Agroecological sustainability, on the other hand, often necessitates a trade-off in terms of revenue or consumption goals.

Although production systems can become sustainable at lower levels (field, farm), externalities might persist at higher levels (e.g., in the food chain) (village, region). The use of (agrarian) policy instruments can help overcome trade-offs in these situations, as well as the identification of appropriate incentives that allow for the simultaneous development of welfare and sustainability (see "win-win" scenarios; Kuyvenhoven et al., 1998b).

Analyzing the effect

Efficient practises and technologies that are environmentally friendly tend to be studied empirically by focusing on their production and resource balance The financial viability of a project is generally judged on the basis of land returns. However, a farm household's economic judgement of their appeal necessitates extra considerations. The socio-economic evaluation of agricultural technologies and production systems is based on five criteria, and several (combinations of) analytical methodologies may be employed to evaluate these technologies and systems (Ruben et al., 2000).

Agricultural intensification's profitability may be assessed using traditional cost-benefit analysis techniques (CBA). Achieving profitability is a crucial requirement for adoption, but it does not take into consideration non-income farm household goals. Average expenses and revenues at current prices are estimated by conducting a cost-benefit analysis (CBA).

Soil and water conservation, agricultural residue mulching, and agroforestry systems are just a few examples of the many natural resource management strategies that may be evaluated this way. Multi-criteria analysis may be used to take into account more than just revenue when conducting a CBA (MCA). On the other hand, its incomplete nature is usually preserved.

Detailed information on marginal returns to the elements of production is necessary for a full evaluation. This is why the PFA framework may be a beneficial analytical tool. PFA may be used to estimate the marginal returns to land and labour for agroecological and conventional production strategies, and can highlight the range of inputoutput price ratios where conversion is likely. Farm household characteristics that are associated with sustainable technology adoption can also be discovered.

Farm household modelling is necessary for a complete assessment of the economic attractiveness of sustainable technologies when factor substitution is taken into account (FHM).

For the evaluation of production and substitution impacts in tandem, farm household models explicitly incorporate complementarities between inputs. General equilibrium impacts and market connections are also included in village-wide models. Farmers' supply response to varied economic incentives may be assessed using FHM's policy simulation tools.

Programming models and econometric processes can incorporate aspects of risk management. However, an unique therapy is needed for farmers' risk behaviour and coping techniques.

Therefore, portfolio analysis may be used to examine the variation in household incomes (farm, off-farm, and non-farm) and to discover main techniques for smoothing consumption. Because of this, it is important to pay attention to non-agricultural connections and to account for changes in supply response between food-deficit and food-abundant households.

Finally, bio-economic modelling is proposed for a full assessment of the environmental impacts of industrial systems. It is possible to evaluate both present and alternative (more sustainable) technologies and their impact on farmers' well-being and agroecological sustainability using bio- economic models. The trade-offs between the two aims can be defined, and policy tools to encourage the adoption of sustainable practises can be found.

Effects on policy

Farmer organisations and non-governmental organisations actively promote environmentally friendly producing methods (NGOs). Developing alternate sources of nutrients and repaying the sunk costs of soil conservation measures are both made possible thanks in large part to local programmes. The long-term viability of these activities depends on their capacity to be economically viable and self-sustaining.

As a result, economic policies and well-functioning institutions must be put in place to ensure long-term use. Numerous factors impact adoption decisions, and this is well-documented. Farm families with better access to land and money resources and greater involvement in market trade are more likely to embrace new agricultural technology earlier and more frequently (Feder et al. 1985).

Farmers' desire to invest is influenced by a variety of other characteristics, including their age, education, and gender. Squatters in distant places where opportunity costs are minimal will likely use agroecological approaches to feed their families.

However, small and marginal farm households face significant challenges in adopting labor-intensive technology because of their high level of off-farm work.

Sustainable intensification of agriculture can only help reduce poverty if it increases the returns to land and labour at the same time. Therefore, agricultural policy should create incentives that ensure both the well-being of farmers and the long-term viability of the natural resources that they depend on.

Specific incentive regimes are required for agricultural programmes aimed to enhancing SAI and poverty reduction in marginal regions. The importance of training, education, and extension in enhancing access to knowledge and information about relevant technology and realistic marketing techniques is widely accepted. As participatory technology development (PTD) has grown in popularity, experimental study is needed to uncover crucial limiting variables.

Equally crucial is a farmer's participation in both market trade and institutional networks. Shockingly, subsidies for inputs often resulted in an overuse of purchased inputs in marginal crops. As incentives to move resources into sustainable production systems, stable and remunerative agricultural product market prices are more effective. Rural infrastructure investment can assist lower transaction costs and boost market growth in remote areas.

Since present production levels are low, significant yield gains may be achieved at relatively modest costs, as Fan and Hazell (1999) demonstrate, marginal impacts of investments in unstable regions are still large.

Agricultural intensification necessitates the efficient use of land, labour, and financial resources. New and better technology can help small farmers, but only if they are used in a coordinated fashion. Landowners are more likely to invest if they know that their rights to their land are secure and recognised. Farmers may invest in land upgrades and input purchases because to well defined land ownership, use, and transfer rights (Besley, 1995; Ruben et al., 2000). Aside from direct incentives, solid land rights can be obtained under common property systems.

Farmers must have access to rural banking institutions that allow them to borrow for investment, input buying, and insurance needs. There is a lot of potential for reducing transaction costs and hazards for rural investment through the use of local credit and savings programmes. Off-farm employment is a common source of investment capital for farmers who lack access to rural banking institutions.

There is little doubt that investment dollars should be mobilised in sustainable agriculture technology and practises, given their high returns.

Rural labour market characteristics have a significant impact on agricultural technology development. When labour is in short supply but the potential to obtain it is great, agricultural intensification is more likely to occur. In order to take advantage of new market prospects, the amount of labour available for land conservation techniques must be expanded (Tiffen et al., 1994).

It is typical practise for farmers to use non-farm operations to diversify their portfolio and mitigate risk, allowing them to fund the purchase of inputs. Technology that reduces wage labour and improves the marginal productivity of family labour is needed in the later circumstances. SAI's continued growth need institutional assistance from a variety of stakeholders (Picciotto, 1997).

Communication networks for providing access to knowledge and information on sustainable land use practises are critical to the development of non-governmental organisations (NGO). Cooperatives and other forms of social capital might be used to create risk-sharing frameworks that encourage private investment in local communities.

The primary function of the state is to ensure that property rights are protected and enforced. The growth of local factor and commodity markets can only be possible if public investment in physical infrastructure is put in place. Market surpluses are expected to motivate private and financial institutions to follow suit.

Technologies and farming systems impacted by changes in the Agro-food chain

An agricultural food chains

The agro-food chain is built on a foundation of five essential elements, and it is the interplay between these elements that has the most impact on the chain's evolution.

Producers of inputs (upstream industry), farmers, food producers (downstream industry), retailers and traders (downstream industry) are all part of the agro-food supply chain. The ultimate link in this network is the consumer.

Consumer and societal requirements, paradigms and knowledge, the economic framework, public research, agricultural, trade, and environmental regulations, and education and extension services are some of the external driving elements that help create the agro-food chain.

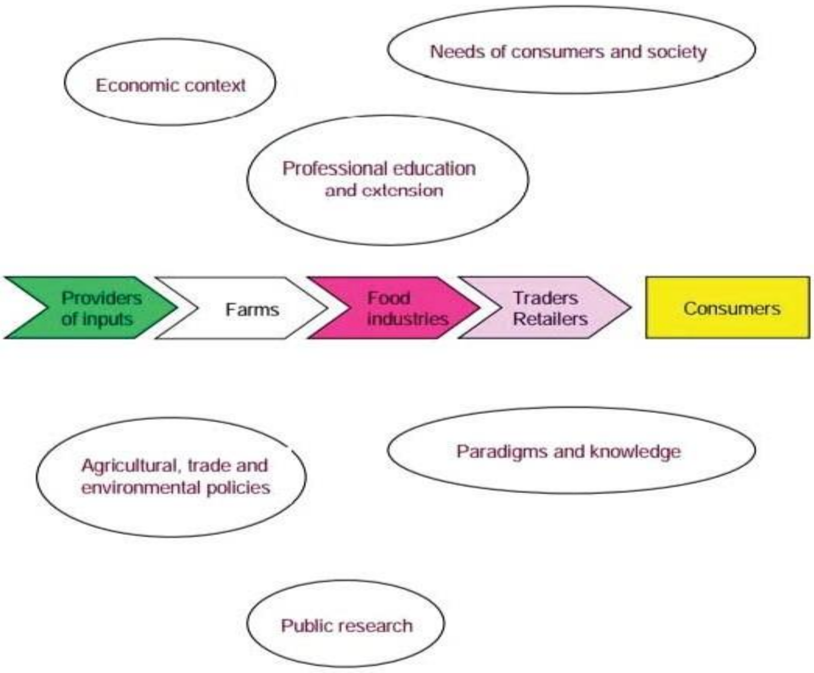


Figure 13: Context of the agro-food chain

Factors outside of the food chain

In addition to providing food, agriculture has a significant impact on the landscape and the ecosystems it creates. In order to better understand agricultural product demand, it is useful to break it down into two distinct categories: food and landscape and habitats. When it comes to food, you need to get "value for your buck". The term "value" refers to characteristics such as nutritional and health benefits, ease of use, environmental friendliness, and functional features.

In the modern day, landscape and habitat are no longer considered by many to be just byproducts of other human endeavours.

The fact that they are deemed to be enhancing public utility means that their usage need (democratic) control (value). An agricultural food chain's growth depends on current paradigms and knowledge levels.

Among them:

- Beliefs about the efficiency and efficacy of the commercial and governmental sectors.
- Views about the allocation of assistance.
- Agriculture's importance in society.
- Environmental and animal welfare awareness and attitudes.

The following economic aspects must be taken into account:

- There is a need for substitution in the agro-food chain because of the high cost of labour, capital, and other resources.
- The cost of goods and services provided by farmers. These provide another layer of distinctiveness to the product.
- The amount of direct agri-environmental payments available.

There are three broad categories of public research topics:

- Increased processing and decomposition of food are necessary in order to produce value for customers.
- Agriculture and other fundamental sciences should focus on efficiency, production, and environmental sustainability (quality and environmental impacts).
- As a result, agricultural economics should focus on boosting agricultural competitiveness while extending environmental and resource economics to better support sustainable development.

The three main pillars of the present policy framework are as follows:

- Assistive pricing- An increase in market sensitivity is implied by a decrease of the domestic-to-global pricing gap.
- No-fee payments - Payments are becoming more closely tied to environmental concerns; farmers are recompensed for the environmental goods they provide.
- Efforts to implement structural reforms - A goal of these strategies are to create a competitive and socially acceptable structural growth (social welfare for farm families).

In order for farmers to be successful and competitive in the face of diminishing producer prices, the education system should provide farmers with the necessary professional skills. Farmer education and extension must provide farmers with both the know-how and the know-why they need.

The changes occurring upstream of the farm gate

Investing in private research and development should focus on the following three areas:

1. Marketing for businesses to businesses.
2. Environmental and competitive factors
3. Brief "payback" period.

In reality, however, the focus is much too often on finding partial answers to issues.
A lack of long-term consideration of the "system" and a lack of "sustainable growth of the agro- food chain in its environmental context" are apparent in the research efforts. Since research efforts should be more stakeholder oriented and take into consideration direct usage, choice, or existence values it is necessary to emphasise this point.
Swiss farmers were the focus of a technology evaluation study project on GMO-use.
It demonstrated that the long-term impacts of technology adoption should not be evaluated using a limited set of metrics. Rape, wheat, maize, sugar beet, and potato (as well as various resistance) were among the genetically engineered agricultural plants examined during the experiment.
There would be less use of fungicides and insecticides on inputs, but a general rise in usage of herbicides. On the output side, this would lead to a more constant agricultural production with a reduced likelihood of crop failure. In the short term, this would lead to a 10% to 15% rise in gross margin per acre.
Consumer approval of these price increases (price effect) is not at all evident, but the crops' relative appeal would be affected. Evaluating the potential effects on biodiversity and GMO-free agriculture is also difficult.

2.14 Transformation through Farm Gate Concentration in the Retail and Manufacturing Sectors

It is expected that agricultural assistance will be increasingly focused on farm operations in the future and that the competitiveness of goods sold in small quantities and transported vast distances (farm industry) would decrease. Quality standards will also be required at the farm gate.
As a result of the concentration process, farmers and food industry experts in challenging conditions will need a new marketing approach. Lowering costs (adjustments, possible trade-offs with other tasks of agriculture) and product differentiation might help them become more competitive (demand).

Processing and retailing-related research and development

The food industry's reaction to "consumer and social requirements" is research and development in the processing and retail sectors. Three methods of food preparation are used:

- The traditional method involves combining agricultural goods with processing.
- In certain circumstances, organic products might take a sizable chunk of the market.
- The organization's This is the functional-convenience method: the farmer provides ingredients to the food business, which is the actual maker of food. In certain circumstances, it has a large market share.

The following is a suggested processing-types strategy:

- The old-fashioned way: traditional vertical cooperation, which includes verbal exchanges.
- Cooperative labelling conditions and communication are common in the organic method.
- Farmers' sole option is to focus on commodity production as their main strategy.

The necessities of society (agriculture and public goods)

Agriculture must provide goods that are competitive in terms of quality, price, and ease of use if it is to fulfil social demands. A wide range of public goods are produced and influenced by agriculture, in addition to the private good of "food."

The following elements should be taken into account when dealing with agriculture because of the direct influence on the environment that it has:

- Minimum impact on natural resources (water, air and so on) and soil fertility option value or existence value are all considerations in farmland management.
- upkeep of farmland that has been abandoned;
- Allowing alternative uses for the land (ecological areas, non-agricultural activities).

These external variables are becoming more and more influential. Externalities have so far been ignored in economic terms, such as the standard portfolio strategy. Externalities are becoming increasingly important, and it would be appropriate to construct an evaluation tool that takes this into consideration.

The conventional method to agricultural portfolio analysis

Complicated relationships may be easily and clearly depicted using the traditional portfolio technique. The research identifies the most important criteria for success. These variables take into account marketable performances (outputs).

However, the production and consumption of agricultural goods include externalities (side effects) that are not taken into consideration. The distribution of public goods is determined by both the quantity and the qualities of these resources.

As a reminder, selecting a criterion group is a delicate and tough task. The quality of the criteria used will always have an impact on the final outcomes. It's also important to keep in mind that the outcomes might change throughout time, depending on the natural and social surroundings.

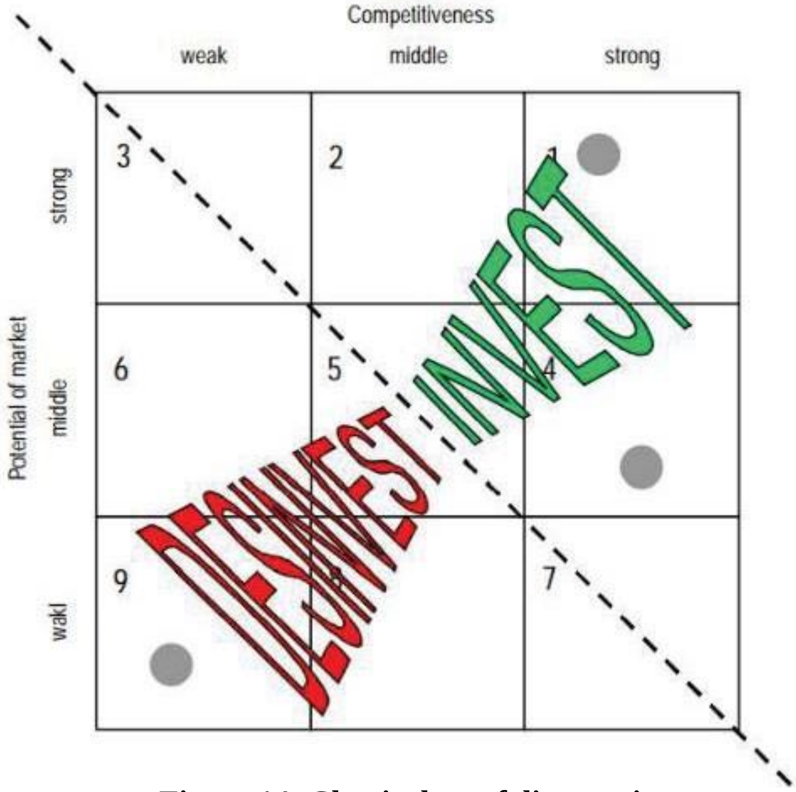


Figure 14: Classical portfolio matrix

Various crops and production strategies have different implications on the distribution of public goods, as seen in Figure below. For instance, traditional, integrated, and biological milk production management are all examples of these. In reality, it would be preferable to make a trade-off between the greatest negative and maximum positive extension "x."

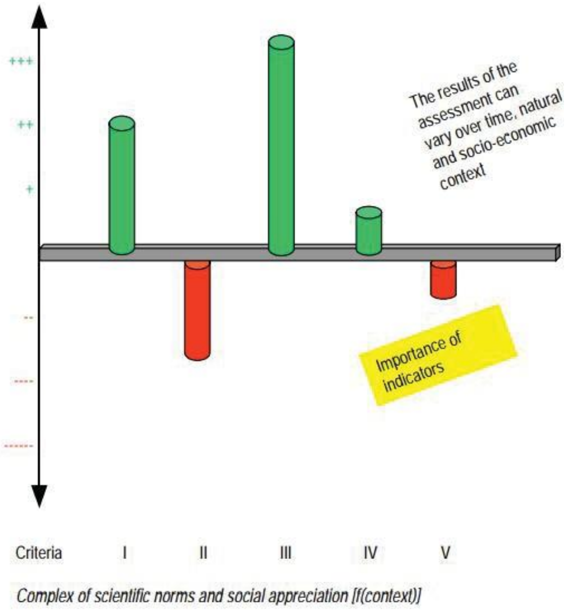
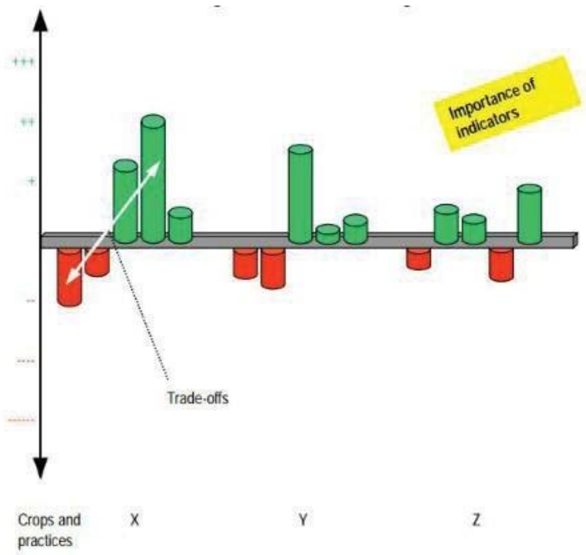


Figure 15: Assessment of the effects of production practices on public goods: one crop with one practice



Source: Own

Figure 16: Assessment of the effect of production practices on public goods: different crops and/or different practices

Figure below depicts a stakeholder group's evaluation of the landscape quality of various products. Those data are based on the still-unpublished "Valais" project. There are a lot of positive externalities associated with the "milk extensive" requirement, as is seen in the following figure. That's why public goods benefit greatly from it.

The "milk intensive" criteria, on the other hand, have a significant negative influence.

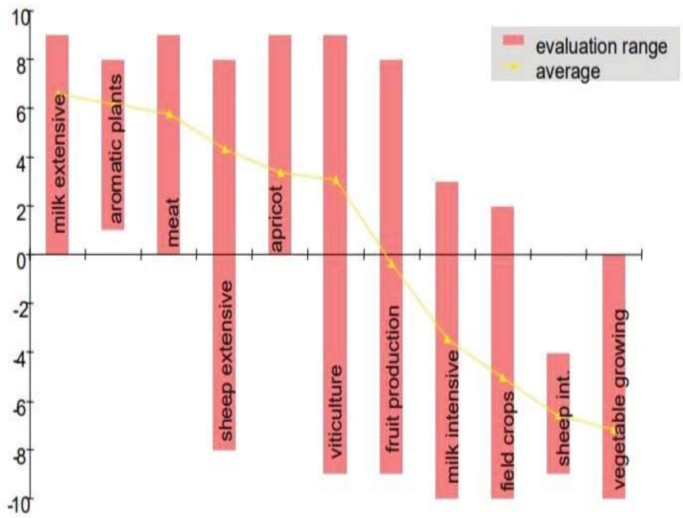


Figure 17: Assessment of landscape quality of different productions by a group of stakeholders

Agriculture's broader range of services

When allocating public goods, the impact of externalities on the allocation of private goods may be considered using the extended portfolio model for agriculture. It is thus not just from the point of view of economically effective criteria like competitiveness and market potential that agricultural production is examined. It is based on the basic McKinsey multifactor notion that the extended portfolio strategy is founded. By providing a third dimension, a double-sided beam illustrates externalities. Each beam shows the extent of the positive or negative externalities. There are three main degrees of classification for its quantity.

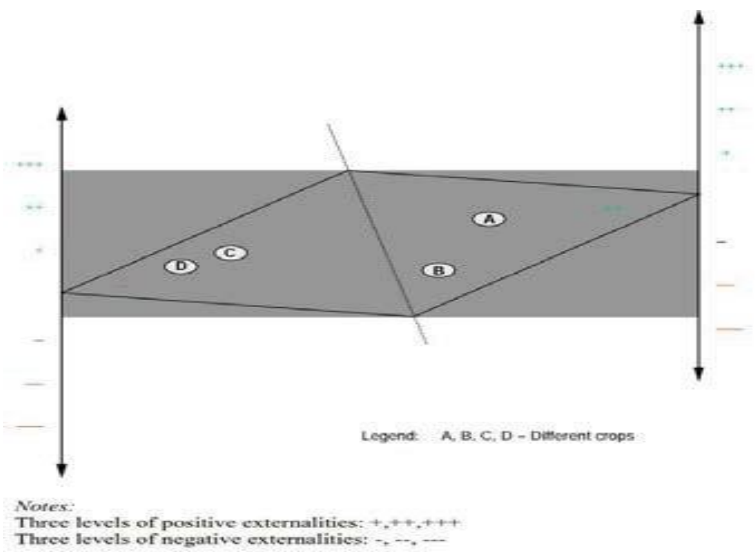


Figure 18: The extended portfolio for agriculture

Agriculture has a wider range of options. A case study on "Valais."

"Valais" is an attempt to alter this long-term approach to farming. The study's goal is to determine which agricultural techniques and crops have the greatest impact on positive externalities. Increased global competition means that positive externalities are increasingly important. In contrast to the majority of "traditional agricultural product," they are not movable and can only be "made" by local farmers.

Figure 19 illustrates the range of probable externality extension parameters for four distinct crops. As a starting point, it is important to create the ability to aggregate externalities. Among the presumed characteristics:

- Crop A: very competitive with a surplus of "positive external effects".
- Crop B: competitive with "a surplus of negative external effects".
- Crop C: not competitive with a surplus of "high positive external effects".
- Crop D: not competitive with a surplus of "high negative external effects".

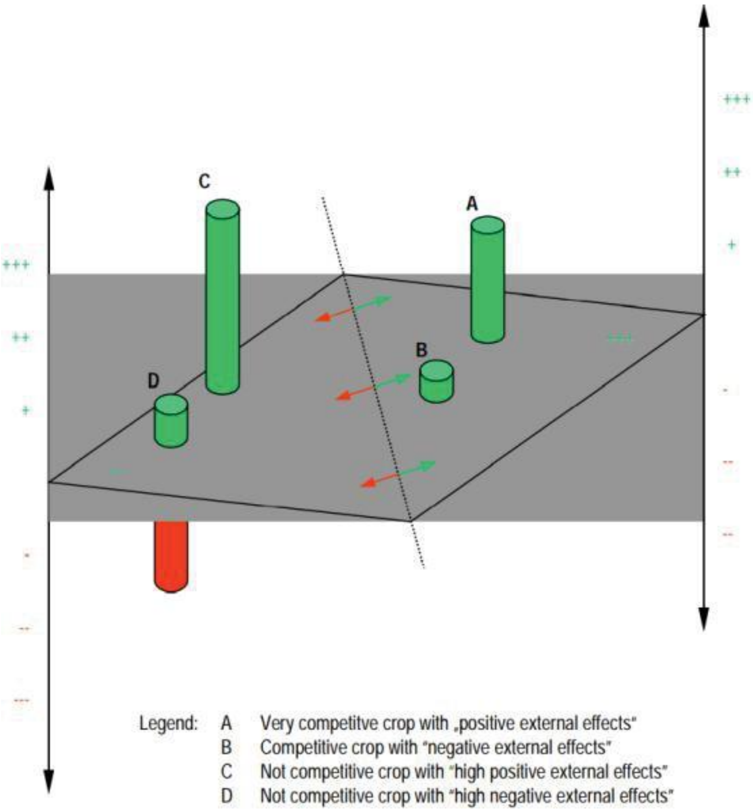


Figure 19: The extended portfolio effects for agriculture

As seen in Figure, there are four possible ways to deal with externalities:

i. Crop A: The synergy market has a surplus of "positive external effects" (PEE), which makes it very competitive.
ii. Crop B: Competitive with an excess of "negative externalities" (NEE) => trade-off market-“NEE. Strategy: change technology or downsizing.
iii. Crop C: An uncompetitive market because of "huge positive externalities," "high PEE," and the need to make trade-offs. Strategy: improve competitiveness without reduction of “high PEE” (technology?).
iv. Crop D: Not competitive with a surplus of “large negative externalities” (high NEE) => synergy between market and “high NEE”. Strategy: downsizing, suppression.

The most important responsibilities of policy are

Policies have a critical role in both guiding and supporting the actions of farmers who are reacting rather than initiating change. It's possible to distinguish between the following four policies:

1. Crop A: More than enough "positive external impacts" to keep things competitive (PEE). Synergy between "PEE" and the market.
   Policy: monitoring
2. Crop B: It's a trade-off between the market and "negative external effects" (NEE).

   Policy: polluter pays principle
3. Crop C: Competitiveness isn't possible with high PEE because of the trade-off between the market and PEE.
   Policy: incentives
4. Crop D: Negative external effects (NEE) (excessive) make it difficult to compete, therefore the market and "high NEE" work in tandem.

2.15 Water Saving and Yield Enhancing Micro-irrigation Technologies in India: When and Where Can They Become Best Bet Technologies?

Introduction

Efforts to improve agricultural water productivity are vital to the overall system for developing agricultural water demand, as it increases the ability of organizations to distribute the "saved" water to more cost-effective domestic and industrial use areas.

Enhancing the physical productivity of water being used in irrigated agriculture can be accomplished in two ways:

1. The quantity of water used or depleted to produce a certain amount of biomass on the same amount of land is lowered.
2. Without altering the amount of water consumed or drained per unit of land, the products produced for a specific crop are increased.

Agronomic, hydrologic, location-specific, and geochemical factors all have a factor in shaping the "depletion" percent.Water productivity increases as the depleted fraction are reduced and yields are increased.

Water conservation in irrigation can be achieved by a variety of technologies and methods:

1. Irrigation with large beds or small borders
2. Enhanced irrigation in furrows (surge, cutback, proper management)
3. Field leveling with a laser
4. Tunnels and plastic mulches
5. Enhanced water retention in the soil and subsurface obstacles
6. Rice alternative wetting and drying
7. Rice intensification system
8. Rice seeding directly
9. Rice that is aerobic
10. Storage on the farm
11. Surface irrigation (micro-irrigation, sprinklers, and its derivatives) can be better controlled and timed.

The final purpose of the study is to determine under what conditions micro-irrigation systems are the most effective. It aims to find the possible benefits of using MI systems by assessing conditions that are appropriate or inappropriate for MI systems, the influence of MI systems on water use at the field and bulk levels, and the production and economic benefits of MI system adoption.

Available Water Saving and Yield Improving Technologies in Indian Agriculture and its Potentials

India's water-saving and yield-enhancing irrigation systems are:

- Pressurized drip systems (inline and on-line drippers, drip tape)
- Overhead (movable) sprinklers (including rain guns)
- Micro sprinklers
- Plastic mulching
- Greenhouses
- Microtube drips

With the available water-saving technologies, the biggest increase in water productivity would be attainable with a greenhouse, which minimizes water consumption while significantly increasing production.

2.16 Contribution of Micro-Irrigation Technologies in Indian Agriculture

Present Spread of Micro-irrigation Technologies in Indian Agriculture

Cotton, sugarcane, banana, orange, grapes, pomegranate, lemon, citrus, mangoes, flowers, and coconut are among the major crops for which drip irrigation is currently used.

According to the most recent data, drip irrigation is used on roughly 1.3 million hectares of irrigated land in India. Sprinkler systems are in demand in places where conditions are unsuitable for traditional irrigation methods, such as loose sandy soils and heavily uneven fields, while specific state-level data on the expansion of sprinkler systems is not available.

Potential Contribution of Micro-irrigation Technologies in India

Micro-irrigation technologies' physical impact on crop productivity water demand

Three significant considerations must be made when analyzing the possible influence of MI systems on the collective demand for water in crop production.

The first is the amount of coverage that can be obtained in the implementation of MI systems at the country level taking into consideration a variety of physical, socioeconomic, and institutional factors that impose significant barriers to the adoption of these technologies. The second question is how much real water can be saved by using MI systems in the field with the fact that real water savings achieved through MI adoption may be much lower than applied water savings.

The third topic is what farmers do with the water saved by MI systems, as well as the cropping system modifications that come with their adoption. Farmers may adjust their agricultural practices as a result of the adoption of MI systems, including expanding their irrigated land.

Physical limitations and potential for MI System adoption

There are two primary prerequisites for lowering the region's overall water consumption in agriculture. They're lowering the amount of non-beneficial evapotranspiration on farmland and keeping the area irrigated.

MI systems require a consistent daily water supply. However, surface sources such as canals and tanks supply almost 41.24 % of the country's net irrigated land. Farmers would need intermediate storage solutions if they wanted to use water from surface systems to run MIs.

Second, pumps are required to lift water from storage tanks and run the MI systems.As a result, the adoption of MI in the present situation would be mostly limited to areas watered by wells. However, an increasing number of farmers in groundwater irrigated areas control their water resources through water purchasing. These farmers find it tough to embrace any MI devices. In over-exploited groundwater basins, well ownership is generally held by communities rather than individual farmers. In addition, a huge number of farmers must rely on water purchases.

Farmers who buy water or share wells can store it in small enclosures and lift it to small heights to provide the necessary head for running subsurface drip systems or micro tube systems. The bad quality of groundwater is another significant stumbling block. This needs to be cleaned regularly with moderate acids like hydrochloric acid. This is a substantial maintenance task, and farmers are unwilling to take on the responsibility of performing it regularly.

Aside from places irrigated by groundwater, there are hilly areas where farmers use hose lines to collect water from streams and connect it to sprinkler systems. In well-irrigated locations, the geological background has a significant impact on MI adoption. Farmers in hard rock areas will have a strong incentive to use MI systems because the rate at which water is pushed decreases when pressurized irrigation devices (drips, sprinklers) are employed.

Adoption of MI is constrained by socioeconomic and institutional factors

The typical farming pattern in water-scarce locations is another key impediment to the adoption of traditional MI technology. From an economic standpoint, MI systems are the most flexible for horticulture crops. Farmers' agricultural practices must change dramatically for this water- saving technology to be adopted.

Crop shifts become more socioeconomically viable as the size of a farmer's operational holding grows. Given that small and marginal farmers make up a considerable percentage of India's operational holdings, farmers in these areas are unlikely to choose horticulture crops.

Another barrier is the market. A large-scale switch to fruit crops could result in a significant drop in the market price of these fruits. When traditional labor-intensive crops like paddy are replaced by orchards, labor absorption becomes a serious issue. Orchards require less labor, are seasonal, and have more opportunities for mechanization.

Another key barrier to MI adoption is poor rural infrastructure, particularly power connections to agricultural wells and the reliability of power supply. The existing water and energy pricing rules in most states also diminish the financial incentives for MI adoption. The water- and energy- saving benefits of MI systems are not transformed into private benefits as a result of these policies. The governance of MI device subsidies also acts against MI system development.

Impacts of MI Systems in the Field on Water Saving and Productivity

MI implementation can result in actual water savings at the field level in locations where the water table is deep and falling. The depth of the groundwater table varies between 20 and 135 m. In places where groundwater levels are still less than 20 m below ground level, the applicable water savings achieved by MI devices would mostly result in pumping cost savings, with no real water savings from the system.

Under semi-arid and arid climatic conditions, the actual water savings achieved by the MI system would be significant. Because of the high temperature, wind speed, and low humidity, the non- beneficial evaporation of moisture from the exposed soil could be high in such a condition.

Row crops, such as orchards, cotton, fennel, castor, and many vegetables, would save the most water because the spacing between plants is so vast.

The reason for this is that the area exposed to solar radiation and wind between plants would be huge, and hence non-beneficial evaporation would account for a large portion of the total water drained when using typical irrigation methods. Water might be applied directly to plants via drip irrigation, reducing this loss.

Effect of MI systems on water use for crop cultivation in the aggregate

If power supply constraints prevent farmers from pumping groundwater, the use of traditional WSTs is unlikely to help farmers expand their irrigation area. Farmers will be able to simply irrigate the current command using the MI system because the available power source is fully exploited during the winter and summer seasons. With the introduction of the MI system, the power required to pump out and supply a unit amount of groundwater increases. Another factor is the scarcity of additional arable land for cultivation. This is appropriate to locations with a high level of land usage and irrigation intensity.

However, farmers may still use water-saving technologies to enhance yields in income crops or to increase the profitability of newly added high-valued crops. As a result, adoption would lead to a reduction in aggregate water consumption in such instances.

If the available water in wells is less than what the available power supply can extract, farmers are likely to enlarge the irrigated area by using micro-irrigation systems.Other than production enhancement, farmers have a substantial economic benefit from using MI devices.

The crops chosen are the third factor. Orchard crops are the most chosen crops in all sections of the country where drip irrigation methods have become more popular. Farmers can intercrop some vegetables and watermelon to lower the cost of developing orchards. Small and marginal farmers can use MI systems because of this adaptability. Access to loans and subsidies encourages small and marginal farmersto use MI.

MI Systems and its Economic Impact

Given the wide range of physical, socioeconomic, and financial variables that influence the costs and returns from crops irrigated by MI systems, it's critical to conduct comprehensive analyses that account for all of them, especially in cases where the physical and socio-economic conditions change.

In many regions, well owners are not presented with the economic cost of wasting water when it comes to water conservation. As a result, conserving water has no private benefits. Water is likewise offered at a high price in these locations, as is the opportunity cost of consuming it. As a result, the amount of water saved will result in financial savings for the adopters.

In terms of energy-saving benefits, they apply to some MI devices, particularly low-pressure and gravity systems like drip tapes, tiny tube drips, and simple drips. In terms of cost, capital costs might vary significantly depending on the crop. Due to the low density of laterals and drippers, the cost of widely spread crops (mango, sapota, orange, and gooseberry) might be relatively low.

Costs for tightly spaced crops including pomegranate, lemon, papaya, and grapes could rise. Costs would rise much more for commodities including castor, cotton, fennel, and vegetables, as denser laterals and drippers would be required.

Potential Future Benefits from Micro-Irrigation Technologies

The circumstances in which a micro-irrigation system is the best bet as technology are:

1. Crops that respond well to micro-irrigation

Tree crops and orchards, row crops, plantation crops, field crops, vegetables, and cash crops are all examples.

2. Water-scarce Micro-irrigation Technologies in River Basins

MI devices have the potential to improve a wide range of river basins. Large portions of Haryana, Uttar Pradesh, and Punjab, which are primarily covered by canal systems, have no possibility for scaling up micro-irrigation systems. Owing to the presence of tree and fruit crops and plantation crops such as coconut, arecanut, coffee, tea, mango, and banana, the western Ghat areas in Kerala, Karnataka, Maharashtra, and Goa present a conducive environment for the use of micro-irrigation systems.

Due to limited groundwater resources, the primacy of well irrigation, and the dominance of tree crops, fruit crops, cash crops, row crops, and vegetables, the semi-arid, hard rock areas of Tamil Nadu, Karnataka, Andhra Pradesh, Maharashtra, and most parts of Gujarat provide a hospitable environment for the adoption of MI systems. At the same time, the dropping groundwater table in these areas would result in significant water savings.

3. Areas in which MI Technologies can be implemented in major Indian states

According to empirical research, Uttar Pradesh has the biggest area of crops susceptible to WSTs (1.884 million ha). Gujarat comes in second with 1.327 million ha, followed by Maharashtra with 1.012 million ha.

4. Basins and Cropped Area Conducive to Adoption of Micro-irrigation Technologies

The following cropped regions will benefit from the MI system:

i. All east-flowing rivers of peninsular India.
ii. Basins of west-flowing rivers north of Tapi in Gujarat and Rajasthan.
iii. Mahanadi some portions of the Indus basin covering south-western Punjab and west- flowing rivers of South India.
iv. The total cultivated area would be 5.844 m ha (79.30-20.86).

5. Quantification of the Impact of MI Systems on Water Requirements in the Future

The implementation of drip irrigation systems was predicted to save 44.46 BCM in crop water requirements. It can also be shown that the usage of drips in sugarcane saves the most water, followed by cotton. This is the maximum area that can be covered by the crops listed in well-irrigated locations, assuming that all adoption barriers are removed through proper institutional and regulatory contexts.

Institutional and Policy Alternatives for Spreading Micro-Irrigation Technologies Pro-rata power pricing is the most optimal policy environment for promoting MI technology in well-irrigated areas. Farmers that are ready to reduce their electricity consumption could be given cash incentives or a large subsidy for MI devices. Improving the quality and duration of power is critical for increasing the usage of pressurized MI devices in many places.

Water delivery systems must be designed so that farmers can stay connected to their distribution system from the source. Increases in the price of irrigation water can boost economic incentives for MI implementation in canal commands. High irrigation water prices raise costs and lead to water conservation. Alternatively, by properly designing subsidies, the cost of constructing intermediate storage systems can be minimized.

Chapter-3: Methodology of Research

3.1 Geographical Location of Study

This study was done in the Pune district of Maharashtra, which is in India. According to this, the average annual rainfall in the district ranges from approximately 468 mm to 4659 mm on average. The minimum rainfall occurs in the eastern half of the district, in the vicinity of Daund (468 mm), Baramati (486 mm), and Jejuri (494 mm). In the western ghat, this increases as one travels westward and reaches a maximum around Khandala (4659 mm) in the west.

3.2 Research Design

The population of Pune District:

Taluka	Population	Area (km2)	Pop. Density	Sex-ratio
Pune City	3304888	286.42	11539	943
Haveli	2435581	1163.55	2093	850
Khed	450116	1369.06	329	892
Baramati	429600	1372.68	313	943
Junnar	399302	1383.32	289	973
Shirur	385414	1560.26	247	916
Indapur	383183	1470.62	261	927
Daund	380496	1307.85	291	939
Mawal	377559	1129.80	334	902
Ambegaon	235972	1039.37	227	979
Purandhar	235659	1101.65	214	965
Bhor	186116	860.09	216	977
Mulshi	171006	1029.20	166	899
Velhe	54516	569.13	96	982

Table 13: Pune population of taluka wise distribution

According to the 2011 census by the government of India, the above table suggests a population of 94 lakhs 29 thousand and four hundred and eight.

Selection of Study Participants

The researcher has used the geographical topology where the Pune district is having different tehsils or talukas to classify the study participants; this is where the farmers are using precision irrigation, aka micro-irrigation systems. For this purpose, 14 blocks have been chosen, which are given below:

Pune City	Mawal	Ambegaon	Haveli	Velha	Shirur	Mulshi
Purandar	Daund	Indapur	Khed	Bhor	Baramati	Junnar

From these blocks, the farmers were selected who are using precision irrigation systems for agriculture purposes. Those who have used or using these systems are considered only for this research study.

Sample Size

To calculate the sample size for the current research study the following sample size formula has been used:

The Cochran formula is:

$n_0 = Z^2pq / e^2$

Where: e denotes the desired level of precision (also known as the margin of error), p denotes the (estimated) fraction of the population that possesses the attribute in question, and q denotes the difference between 1 and p.

z=1.96 p=0.5 q=0.5 e=0.06

This gave us a sample size of 267. Finally, the researcher had collected 350 samples.

Sampling Element:

The sampling element in the current research study is the farmer using the precision irrigation systems in the block mentioned above locations.

Sampling Unit:

The sampling unit in a current research study is 14 locations or taluka's where the farmers reside and do farming with these irrigation systems.

Sampling Frame:

The sampling frame has been devised with the help of gram panchayats in the tehsil or talukas.

Sampling Method

In the current research study, a two-stage cluster sampling method has been used. The objective of choosing this is mentioned below:

When choosing cluster samples in the first stage, one can select a sample of every sampled cluster, which is called two-stage cluster sampling. Imagine that there are N populations altogether, each of which contains K clusters. N clusters are selected using a conventional cluster sampling method in the first stage.

The second stage of random sampling almost always uses simple random sampling. Each cluster uses the number of items selected from that cluster, but the number of elements selected from the other clusters will vary.

The survey designer must predetermine the overall number of clusters, the number of clusters picked, and the number of elements from the selected clusters. The two-stage cluster sampling strategy seeks to lower the survey's cost while also keeping uncertainty in mind.

In the current research study, fourteen clusters have been chosen, and from each cluster, twenty- five sample elements have been selected to collect the data.

Survey Instrument

The questionnaire was devised to collect the responses from the farmers with ease. The first focus of the survey is to understand the farmer's demographic information like asking about their age, education, income, family size and landholding. The questionnaire also investigates the water situation and the costs, benefits, and soil health that have resulted from the use of precision irrigation systems.

The questionnaire was designed to help participants better understand the factors that influence the adoption and non-adoption of precision irrigation systems and the problems associated with employing those systems. The questionnaire also sought to understand better the function of subsidies in the provision of irrigation systems.

The total numbers of items in a questionnaire were 65 which have covered all the necessary aspects of the research study. To understand whether the questionnaire was reliable and valid the researcher has used reliability testing method.

Reliability Test	
Cronbach's Alpha	Number of Items
.856	59

Table 14: Reliability statistics of survey instrument

The above reliability statistics indicate that the questionnaire was very reliable to capture the data required for the study. The alpha value of 0.856 suggests strong reliability, and it consists of 59 items, whereas the rest six items form the basis for demographic questions, which were not part of the reliability test.

To understand the validity researcher has adopted translational validity, which includes two types of validity which are mentioned below:

1. Face Validity:

Does the test "appear" to be a measure of the construct under consideration? Respondents can use "context" to help interpret questions and deliver more relevant and accurate replies if they know what information we are searching for in the responses.

2. Content Validity:

If the test contains items from the specified "content domain," then the test is successful. The validity of the content is not "checked for." Instead, it is "guaranteed" by the expert item selections made by domain experts knowledgeable in their field.

Pilot Testing

Before the final data collection, testing the instrument with 20 individuals with farming backgrounds who utilize precision irrigation systems took place. Another essential feature of this survey is that respondents had to give replies on how comprehensible and grammatically correct the questions were, and they were also asked to offer suggestions for additional improvements. Fortunately, no such improvements were suggested, and no questions or items were dropped because of poor reliability. The questionnaire had a Likert scale rating in some cases and some dichotomous or MCQ type questions.

3.3 Ethical Considerations in Research Study

In the case of this particular research study, ethical considerations are of high importance because of the following:

1. Study participants belonged to different education strata, and hence informing them about research and its usage is significant since it can impact the outcome of the research study.
2. The identity of the respondents will not be revealed so that without any bias, they can share their perception is taken care of.
3. The study participants were assured that this was an academic survey and no government or political intervention was there while answering the survey.
4. The researcher has ensured that his subject knowledge should not influence the responding farmers while answering the survey.
5. The anonymity and confidentiality of the respondents and their responses will be taken care of with integrity.

3.4 Limitations of Study

Some limitations apply to this study, and these limitations must be identified and discussed in detail.

1. The design of this study imposes a significant limitation on its findings. The survey was conducted to gather information about farmers perceptions. Perception data can only be analyzed to a limited extent because of its nature. The use of perceptual data makes it more challenging to establish a causal relationship between two events.

2. This is one of the few studies on precision irrigation that has collected data from throughout the district's many zones, making it a unique study. The generalizability of this study is greater than that of the majority of earlier studies on precision irrigation. Although the information is gathered from fourteen zones, the generalizability of the findings across all Maharashtra districts will be limited as a result of this limitation.

3. The survey instrument had another constraint, in that it could only be conducted in Marathi language other than the one in which it was initially developed. This was mitigated to some extent by selecting survey administrators who were knowledgeable about farming as well as familiar with the local rural environment, allowing them to ask the appropriate questions. The surveyors were also given instruction on how to use the instrument and administer it prior to administering the survey.

3.5 Objectives of Research Study

1. To understand the adoption factors for using precision irrigation systems.

1.1 To understand the factors creating hurdles in adoption of using precision irrigation systems.

1.2 To understand the challenges of operating and maintaining the precision irrigation systems.

2. To understand whether benefits perceived got change because of farmers' educational qualification.

3. To understand whether the income and subsidy availing option has any association.

3.1 To understand whether the water situation and cost involved into precision irrigation has any relation.

4. To understand how precision irrigation systems are related to soil health, water and pest management.

3.6 Hypothesis

H1.

Null (H0): There is no variation in the adoption factors among the farmers regarding precision irrigation systems.

Alternate (HA): There is a variation in the adoption factors among the farmers regarding precision irrigation systems.

H1.1

Null (H0): There is no variation in the factors that create a hurdle in adopting precision irrigation systems amongst the farmers.

Alternate (HA): There is a variation in the factors that create a hurdle in adopting precision irrigation systems amongst the farmers.

H1.2

Null (H0): There is no variation in the factors creating challenges in operating and maintaining the precision irrigation systems.

Alternate (HA): There is a variation in the factors creating challenges in operating and maintaining the precision irrigation systems.

H2.

Null (H0): According to the qualification groups, there is no difference in the perceived benefits of using precision irrigation systems for farming. (Group means are equal).

Alternate (HA): According to the qualification groups, there is a difference in the perceived benefits of using precision irrigation systems for farming. (Group means are not equal).

H3.

Null (H0): There is no association between the annual income of the farmers and availing the subsidy for precision irrigation system by the farmers.

Alternate (HA): There is an association between the annual income of the farmers and availing the subsidy for precision irrigation system by the farmers.

H3.1

Null (H0): There is no correlation between cost involved into using precision irrigation systems and water situation due to precision irrigation system.

Alternate (HA): There is a correlation between cost involved into using precision irrigation systems and water situation due to precision irrigation system.

H4.

Null (H0): There is no correlation between soil health, water management and pest management due to the installation of precision irrigation systems.

Alternate (HA): There is a correlation between soil health, water management and pest management due to the installation of precision irrigation systems.

Chapter-4: Data Analysis

This chapter deals with coding of data, labeling of data, analyzing the data and testing the claimed hypotheses by the researcher. The below section will have analysis of each variable involved into the study:

4.1 Descriptive Analysis

1. Age group you belong to

Choice Parameters	Frequency	Cumulative Percent	Mean	Std. Dev	Var
<30 years	92	26.3	2.29	1.105	1.221
30-40 years	129	63.1			
40-50 years	84	87.1			
50-60 years	25	94.3			
60+ years old	20	100.0			
Total	350				

Table 15: Descriptive statistics for age group

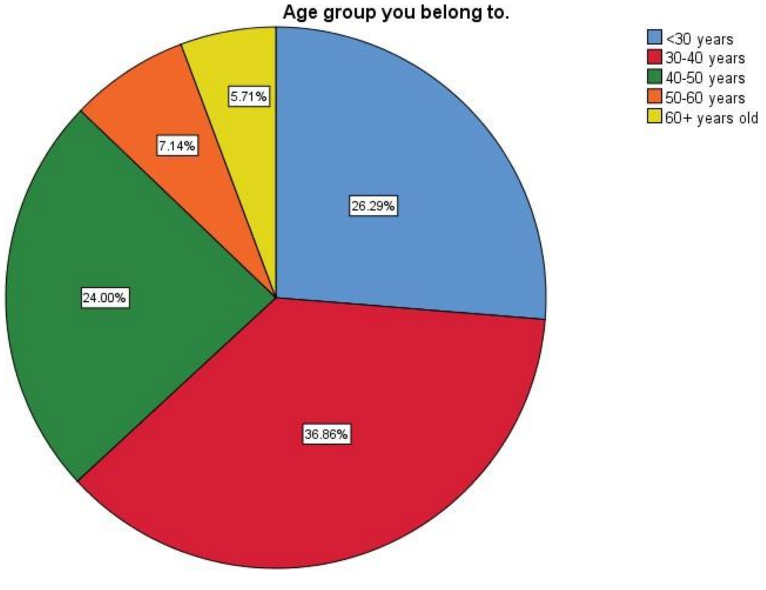


Figure 20: Distribution of age group

Findings: The above pie chart and statistics table suggests that maximum farmers are in the age group of 30-40 years (36.9%) followed to that are from less than 30 years of age groups (26.3%), the least were from 60+ years age groups (5.7%).

The measure of dispersion and CT are mean=2.29, std. dev. = 1.105 and CO Var= 1.221.

2. Qualification of study participants

Choice Parameters	Frequency	Cumulative Percent	Mean	Std. Dev	Var
Illiterate	26	7.4	4.45	1.090	1.188
High School	8	9.7			
Undergraduate	74	30.9			
Graduate and above	242	100.0			
Total	350				

Table 16: Descriptive statistics for qualification of participants

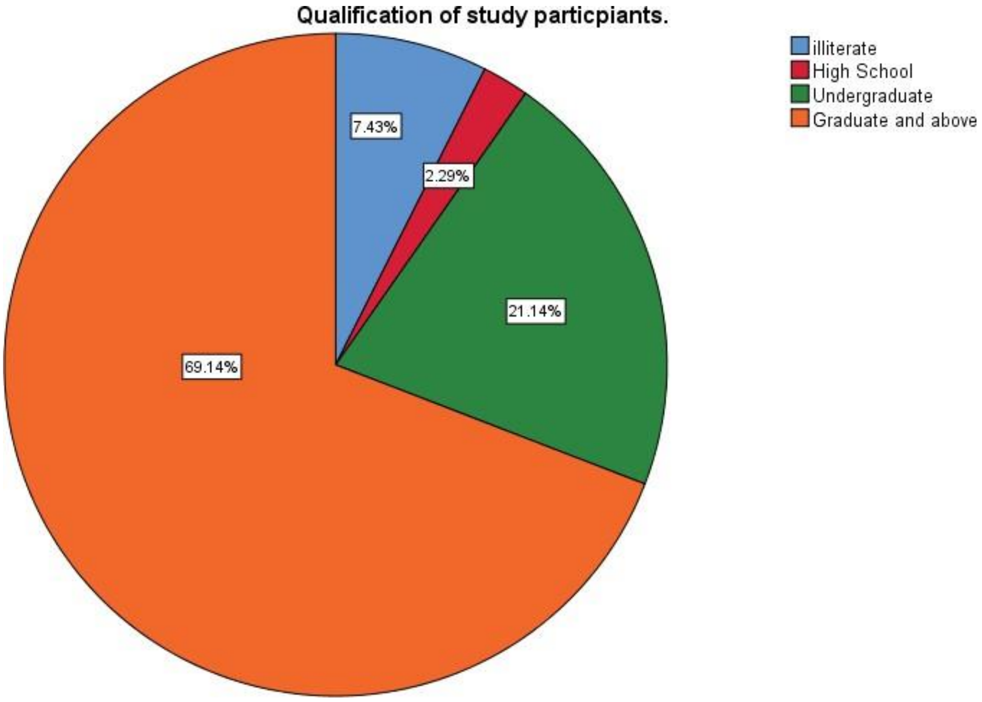


Figure 21: Distribution of qualification of participants

Findings: The above pie chart and statistics table suggests that maximum farmers are qualified enough because maximum of them are having their graduation (69.1%) followed to that were from undergraduate qualification constituting (21.1%), around 7.4% of the farmers were illiterate and high school (2.3%).

The measure of dispersion and CT are mean= 4.45, std. dev. = 1.090 and Var= 1.188.

3. Size of the family (number of members in family)

Choice Parameters	Frequency	Cumulative Percent	Mean	Std. Dev	Var
<5 Members	156	44.6	1.77	0.780	0.608
5-10 Members	119	78.6			
More than 10 Members	75	100.0			
Total	350				

Table 17: Descriptive statistics for size of the family

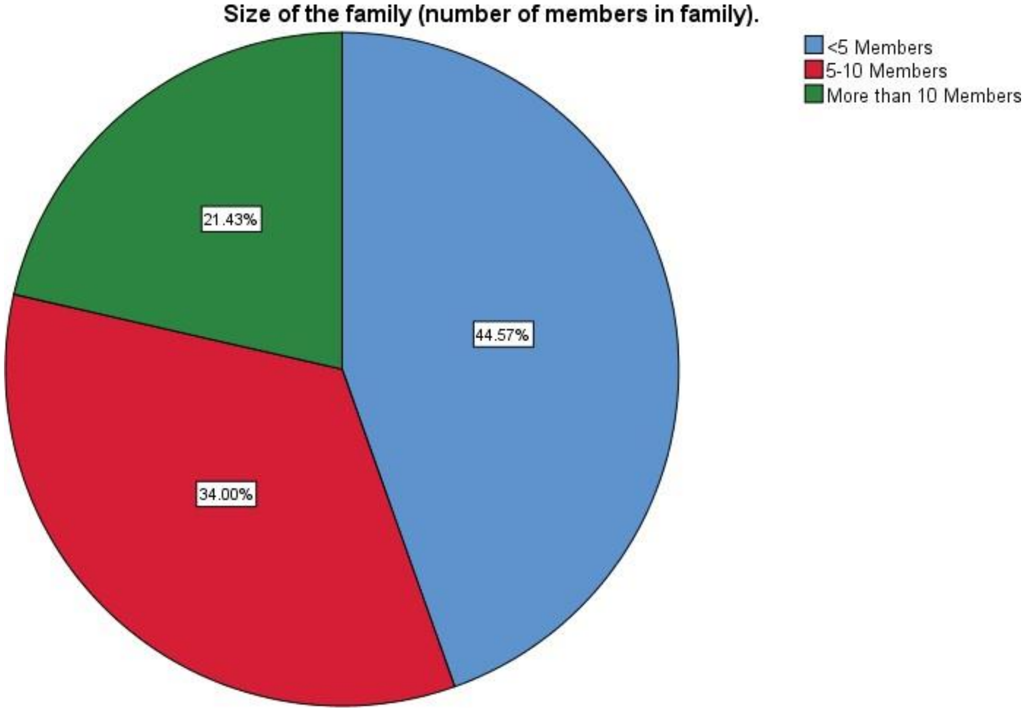


Figure 22: Distribution of size of the family

Findings: The above pie chart and statistics table suggests that around 45% farmers from the total samples were having less than five family members followed to that 34% farmers having 5- 10 family members. Only 21% farmers are there who are having more than 10 family members.

The measure of dispersion and CT are mean=1.77, std. dev. = 0.780 and Var= 0.608.

4. The land holding size in hectares.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
<1.0 ha	129	36.9	2.01	1.027	1.054
1-2 ha	133	74.9			
2-5 ha	56	90.9			
5-10 ha	21	96.9			
10+ ha	11	100.0			
Total	350				

Table 18: Descriptive statistics for land holding size in hectares

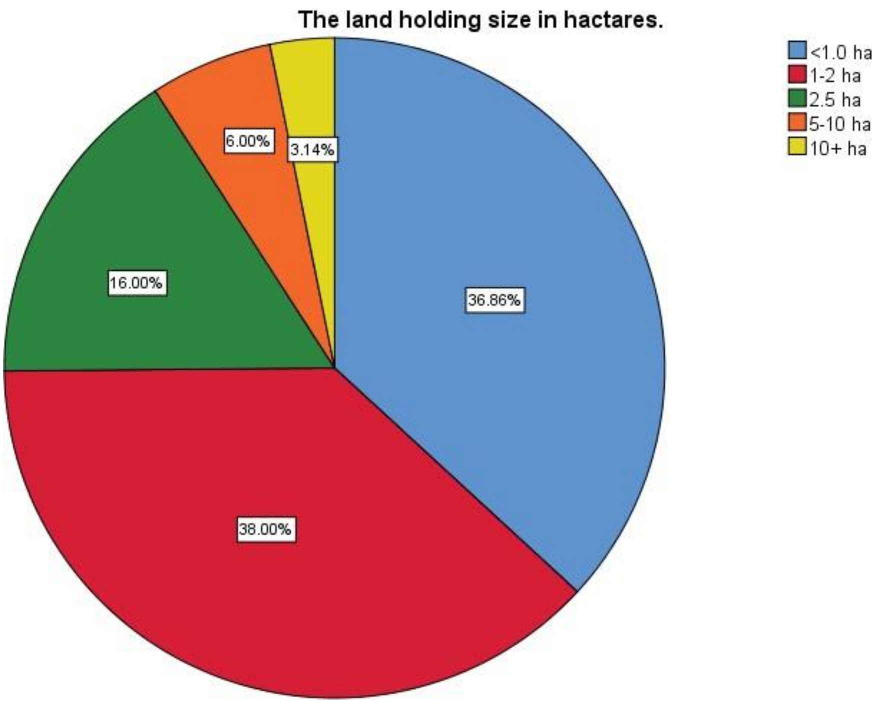


Figure 23: Distribution of land holding size in hectares

Findings: The above pie chart and statistics table suggests that 385 farmers are having land holding between 1-2 hectares followed to that around 37% farmers having less than 1 hectares land holding, 16% were between 2-5 hectares, 6% are having 5-10 hec and only 3% are having land holding above 10 hec.

The measure of dispersion and CT are mean=2.01, std. dev. = 1.027 and Var= 1.054.

5. The annual income of the study participants

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
<50 Thousand	184	52.6	2.08	1.451	2.105
<1 Lakh	71	72.9			
<3 Lakh	29	81.1			
<5 Lakh	14	85.1			
<10 Lakh	52	100.0			
Total	350				

Table 19: Descriptive statistics for annual income of the participants

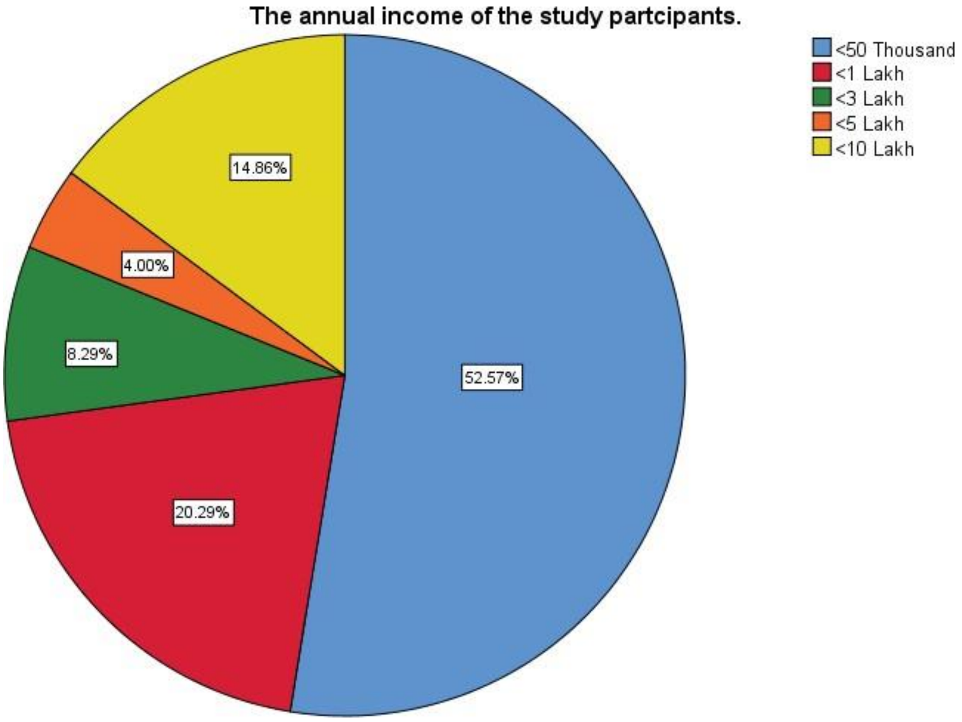


Figure 24: Distribution of annual income of the participants

Findings: The above pie chart and statistics table suggests that around 53% of the total farmers are having income less that 50 thousand followed by 20% having less than 1 Lac, 15% having annual income 5-10 Lacs.

The measure of dispersion and CT are mean=2.08, std. dev. = 1.451 and Var= 2.105.

6. What is the source of water for Precision Irrigation Systems?

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
From Tanks	4	1.1	4.55	0.715	0.512
From Canal	22	7.4			
From Open Well	97	35.1			
From Tube Well	227	100.0			
Total	350				

Table 20: Descriptive statistics for source of water for precision irrigation systems

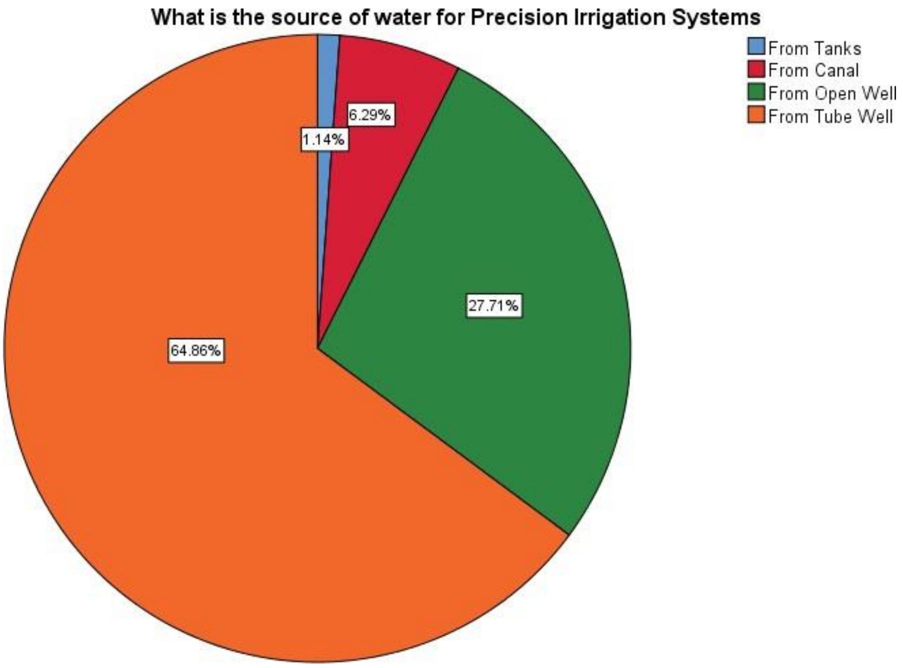


Figure 25: Distribution of source of water for precision irrigation systems

Findings: The above pie chart and statistics table suggests that around 65% farmers are using tube well water, 28% are using open well water and 7% are using canal water, only 1% farmers are using water from tanks.

The measure of dispersion and CT are mean=1.24, std. dev. = 0.715 and Var= 0.512.

7. The willingness of the farmer to invest in adoption of precision irrigation technologies from his available potential resources.

a. To earn a profit, a farmer must prioritise higher yields.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Disagree	12	3.4	4.59	0.743	0.552
Not sure	18	8.6			
Agree	72	29.1			
Strongly Agree	248	100.0			
Disagree	350				

Table 21: To earn a profit, a farmer must prioritise higher yields

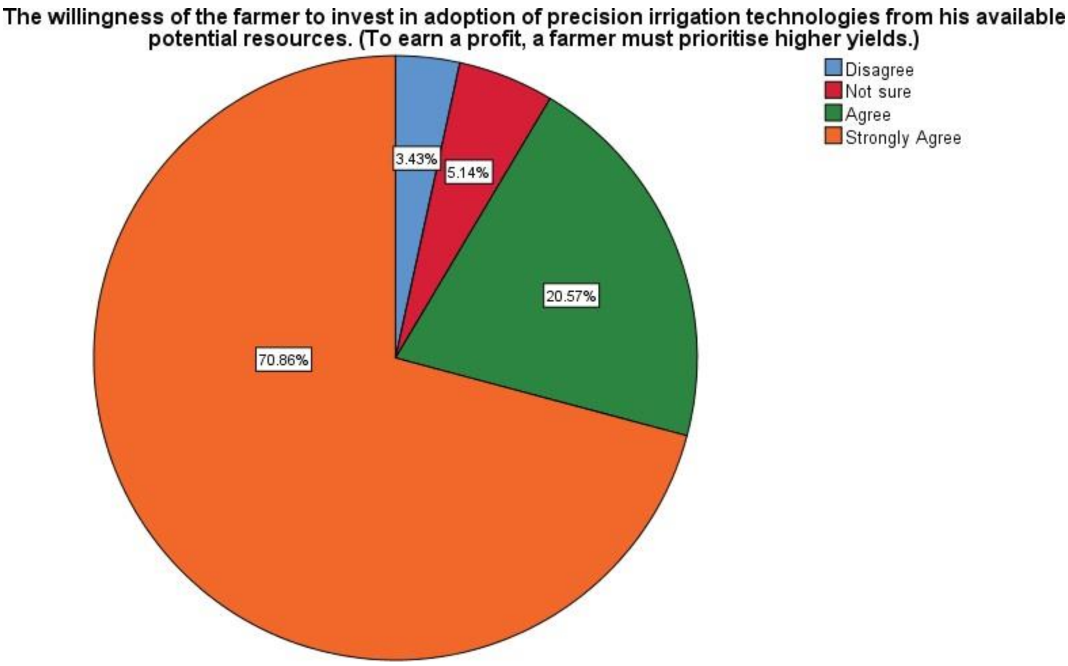


Figure 26: Distribution of to earn a profit, a farmer must prioritise higher yields

Findings: The above pie chart and statistics table suggests that around 91% farmers think that prioritizing higher yields are important a farmer has to make a profit.

The measure of dispersion and CT are mean=4.59, std. dev. = 0.743 and Var= 0.552.

b. A farmer must make his living, yet economic definition cannot determine the most important thing in life.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Strongly Disagree	11	3.1	4.52	0.879	0.772
Disagree	5	4.6			
Not sure	10	7.4			
Agree	89	32.9			
Strongly Agree	235	100.0			
Total	350				

Table 22: Descriptive statistics for farmer must make his living, yet economic definition cannot determine the most important thing in life

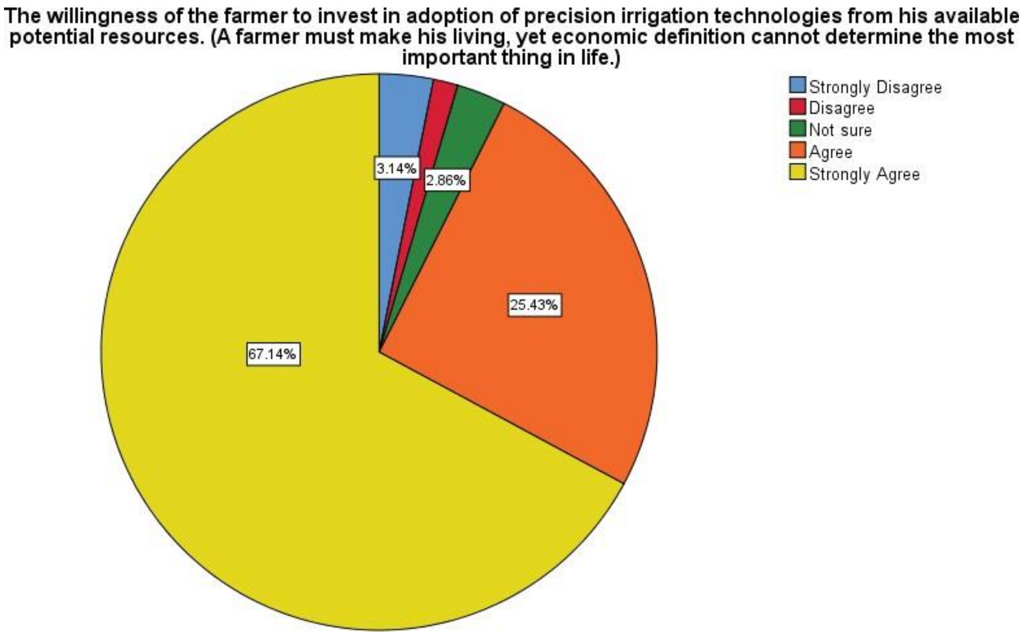


Figure 27: Distribution of farmer must make his living, yet economic definition cannot determine the most important thing in life

Findings: The above pie chart and statistics table suggests that 93% farmers believe that earning is important to live the life but this is not the only things which are important for them. That means they have important things in life instead of just to make the money.

The measure of dispersion and CT are mean= 4.52, std. dev. = 0.879 and Var= 0.772.

c. Farmers should cultivate cash crops in order to increase monetary profit compared to the production of domestic food crops.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Strongly Disagree	1	0.3	4.70	0.530	0.281
Not sure	6	2.0			
Agree	90	27.7			
Strongly Agree	253	100.0			
Total	350				

Table 23: Descriptive statistics for farmers should cultivate cash crops in order to increase monetary profit compared to the production of domestic food crops

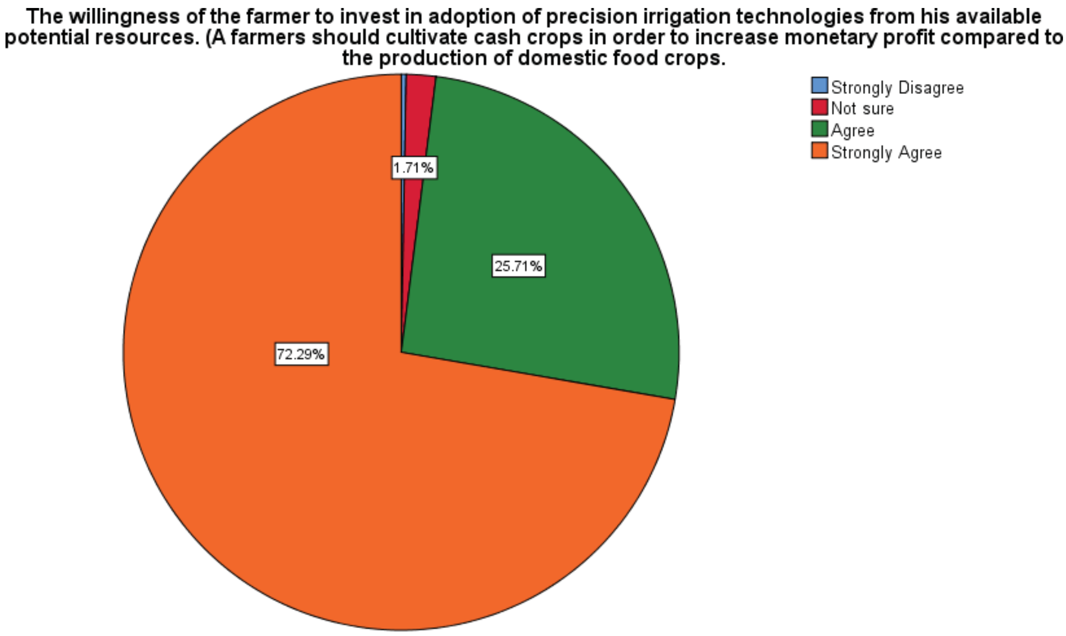


Figure 28: Distribution of willingness of farmers should cultivate cash crops in order to increase monetary profit compared to the production of domestic food crops

Findings: The above pie chart and statistics table suggests that around 98% farmers believes that if they have to raise their profits, they must focus on farming those crops gives them more money instead of traditional routine crops.

The measure of dispersion and CT are mean=4.70, std. dev. = 0.530 and Var = 0.281.

d. The farmer should try any new farming idea which may earn him more money.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Strongly Disagree	2	0.6	4.58	0.748	0.560
Disagree	8	2.9			
Not sure	19	8.3			
Agree	78	30.6			
Strongly Agree	243	100.0			
Total	350				

Table 24: Descriptive statistics for the farmer should try any new farming idea which may earn him more money

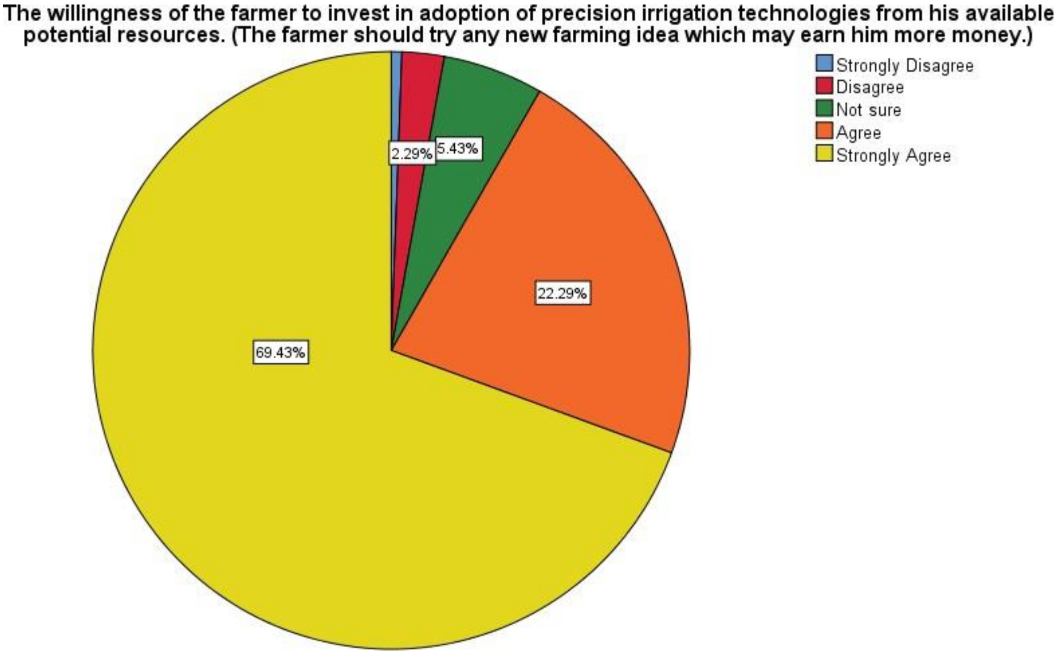


Figure 29: Distribution of the farmer should try any new farming idea which may earn him more money

Findings: The above pie chart and statistics table suggests that around 92% farmers are open to experiment with new ideas which can help them to earn more by cultivating crops based on those experiments.

The measure of dispersion and CT are mean= 4.58, std. dev. = 0.748 and Var = 0.560.

8. The level of risk and uncertainty a study participant is willing to accept while embracing new ideas in farming.

a. A farmer can minimize risk by planting many crops in order to avoid having a single crop fail.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Strongly Disagree	34	9.7	4.26	1.326	1.757
Disagree	19	15.1			
Not sure	12	18.6			
Agree	42	30.6			
Strongly Agree	243	100.0			
Total	350				

Table 25: Descriptive statistics for a farmer can minimize risk by planting many crops in order to avoid having a single crop fail

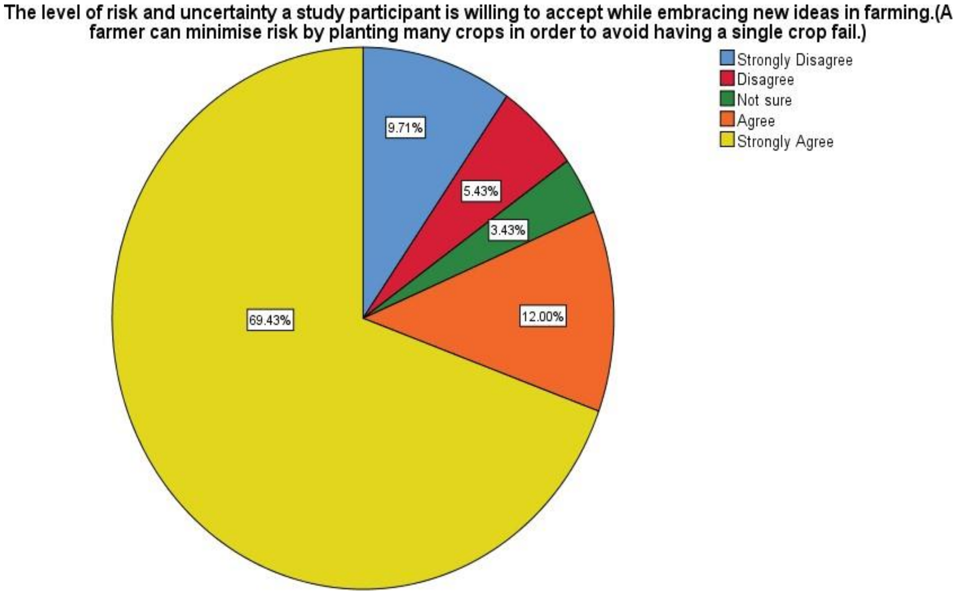


Figure 30: Distribution of a farmer can minimize risk by planting many crops in order to avoid having a single crop fail

Findings: The above pie chart and statistics table suggests that around 81% farmers believes that to escape from the single crop failure one must use multicrop idea because the risk associated with one single crop will get minimized, 19% of the farmers are of the opinion that no one should go ahead with single crop only even if their risk associated with it.

The measure of dispersion and CT are mean=4.26, std. dev. = 1.326 and Var = 1.757.

b. Generally, a farmer who takes extra risks will end up better off financially.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Strongly Disagree	1	0.3	4.76	0.520	0.270
Not sure	9	2.9			
Agree	63	20.9			
Strongly Agree	277	100.0			
Total	350				

Table 26: Descriptive statistics for a farmer who takes extra risks will end up better off financially

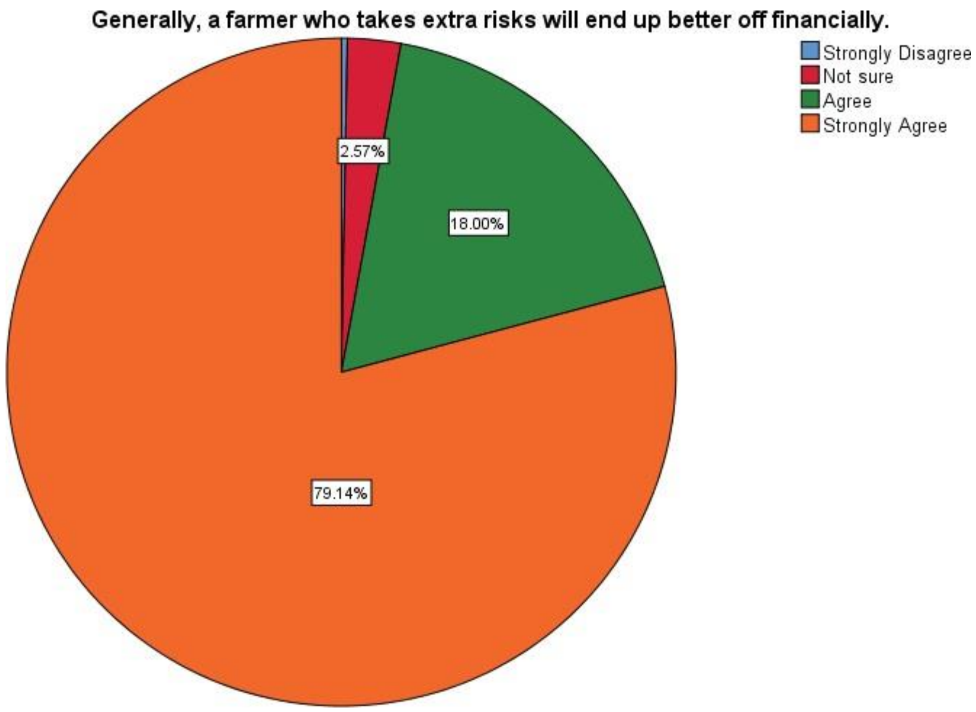


Figure 31: Distribution of a farmer who takes extra risks will end up better off financially

Findings: The above pie chart and statistics table suggests that around 97% of the farmers have seen personally and experienced it that's why they believe it that the farmer who is willing to take extra risks they earn significantly much more then the farmers who are doing their routine work.

The measure of dispersion and CT are mean=4.76, std. dev. = 0.520 and Var = 0.270.

c. New farming ideas should only be attempted if they've proven successful in practice.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Strongly Disagree	5	1.4	4.65	0.697	0.486
Not sure	15	5.7			
Agree	73	26.6			
Strongly Agree	257	100.0			
Total	350				

Table 27: Descriptive statistics for a new farming idea should only be attempted if they've proven successful in practice

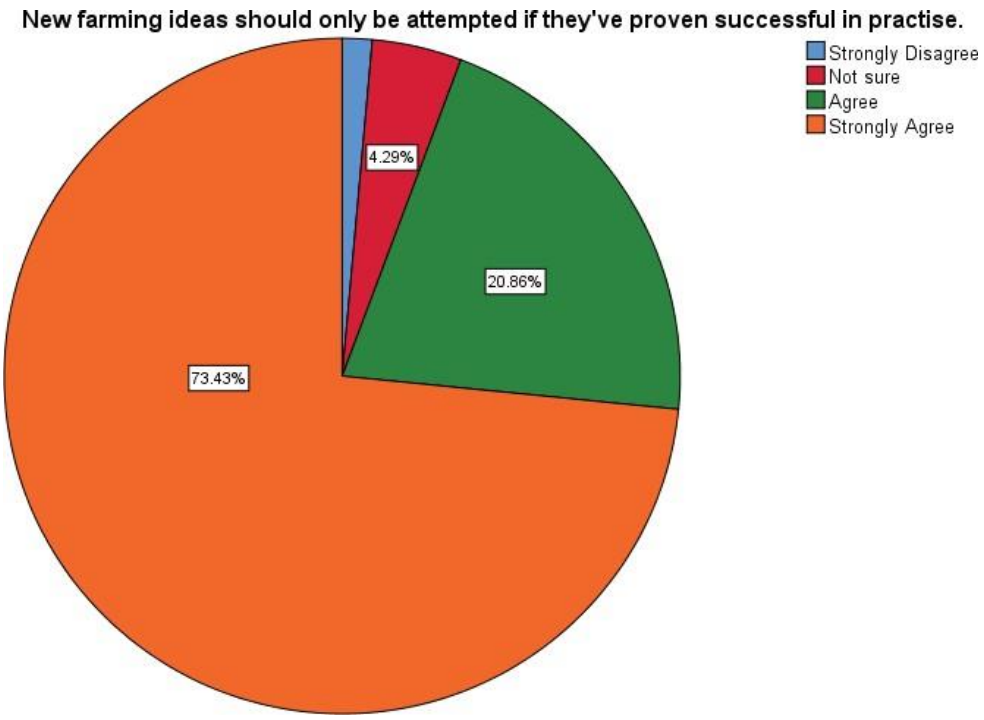


Figure 32: Distribution of a new farming idea should only be attempted if they've proven successful in practice

Findings: The above pie chart and statistics table suggests that around 94% farmers believes that farmers see the success stories of crops, yields, income of other farmers who have done something different in their farms then only they will learn and try to practice it themselves.

The measure of dispersion and CT are mean= 4.65, std. dev. = 0.697 and Var = 0.486.

d. A farmer attempting a whole new farming approach is taking a risk, but the results are worth it.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std dev	Var
Strongly Disagree	1	.3	4.72	0.594	0.352
Disagree	4	1.4			
Not sure	8	3.7			
Agree	67	22.9			
Strongly Agree	270	100.0			
Total	350				

Table 28: Descriptive statistics for a farmer attempting a whole new farming approach is taking a risk, but the results are worth it

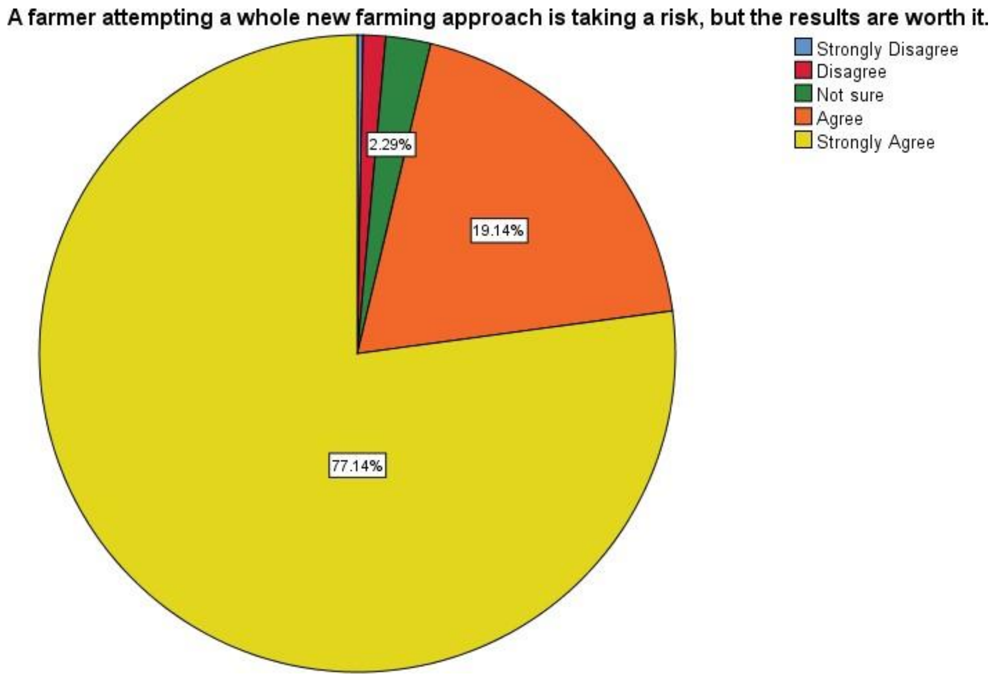


Figure 33: Distribution of a farmer attempting a whole new farming approach is taking a risk, but the results are worth it

Findings: The above pie chart and statistics table suggests that around 96% of the farmers believe that even if someone is taking new farming approach which involves risk is fine because the outcome of that process is worth waiting for it will pay financially of to the farmers.

The measure of dispersion and CT are mean= 4.72, std. dev. = 0.594 and Var = 0.352.

9. Perception of farmers about the factors affecting adoption of precision irrigation systems.

a. Mass media's influence

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Not Sure	1	0.3	4.72	0.536	0.287
Less Important	12	3.7			
Important	70	23.7			
Very Important	267	100.0			
Total	350				

Table 29: Descriptive statistics for mass media's influence

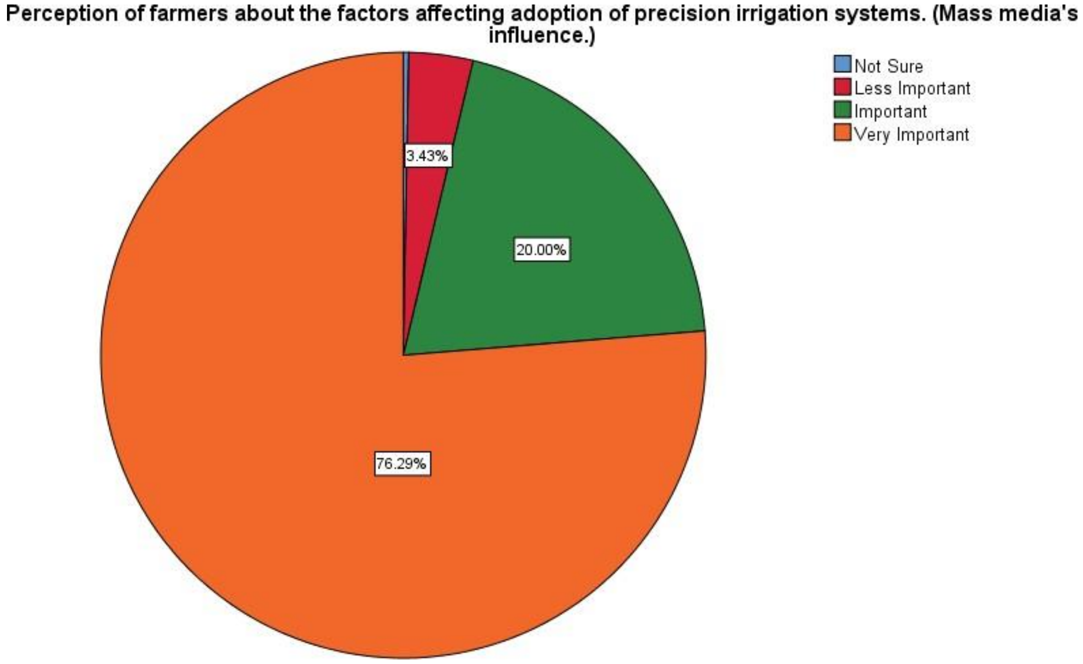


Figure 34: Distribution of mass media's influence

Findings: The above pie chart and statistics table suggests that around 96% farmers believe that the decision of using precision irrigation system is measurably get influence because of TV, newspapers, radio, social media.

The measure of dispersion and CT are mean= 4.72, std. dev. = 0.536 and Var = 0.287.

b. Researchers' influence

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Not Important at All	1	0.3	4.81	0.457	0.209
Less Important	3	1.1			
Important	58	17.7			
Very Important	288	100.0			
Total	350				

Table 30: Descriptive statistics for researchers' influence

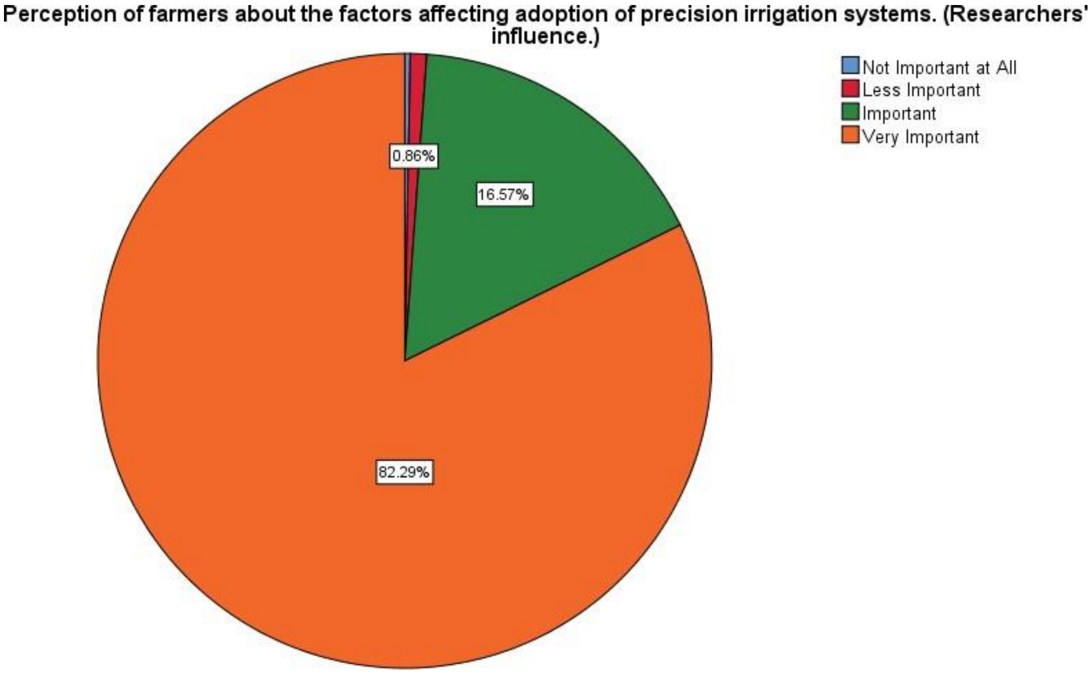


Figure 35: Distribution of a researchers' influence

Findings: The above pie chart and statistics table suggests that around 99% farmers are of the opinion that information shared by some researches through different medium about the usage of precision irrigation system and its benefits does influence farmers.

The measure of dispersion and CT are mean= 4.81, std. dev. = 0.457 and Var = 0.209.

c. The irrigation equipment dealer's influence

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Not Important at All	17	4.9	4.63	0.950	0.903
Not Sure	3	5.7			
Less Important	6	7.4			
Important	39	18.6			
Very Important	285	100.0			
Total	350				

Table 31: Descriptive statistics for an irrigation equipment dealer's influence

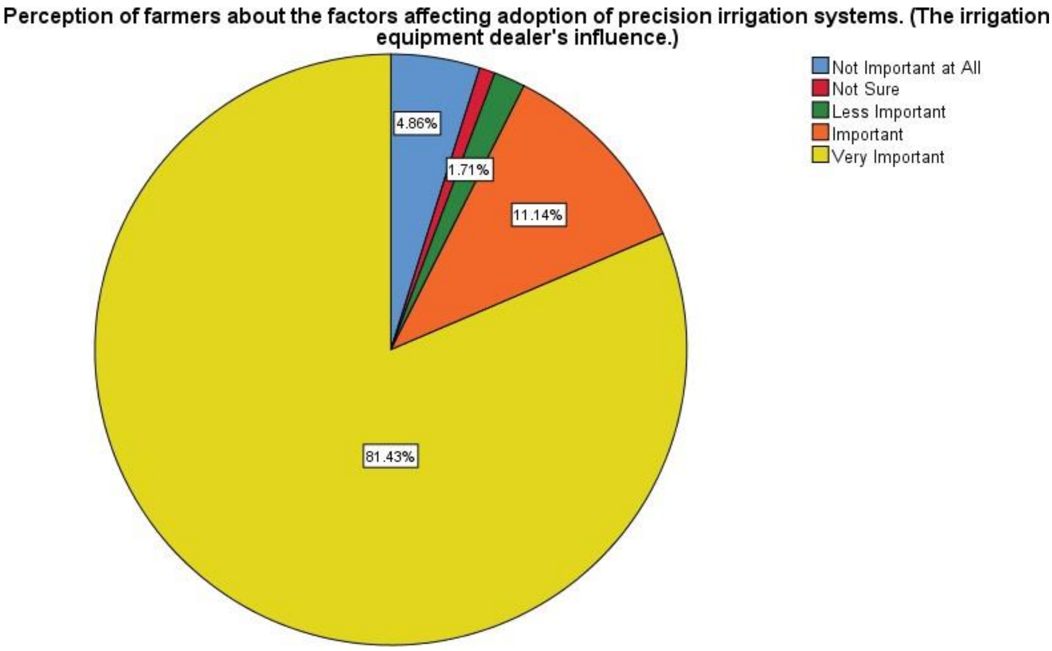


Figure 36: Distribution of an irrigation equipment dealer's influence

Findings: The above pie chart and statistics table suggests that around 93% farmers are of the opinion that they get influence because of the dealers who are selling precision irrigation system.

The measure of dispersion and CT are mean= 4.63, std. dev. =0.950 and Var = 0.903.

d. Influence of friends and family

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Not Important at All	16	4.6	4.48	0.980	0.961
Not Sure	2	5.1			
Less Important	22	11.4			
Important	68	30.9			
Very Important	242	100.0			
Total	350				

Table 32: Distribution of an influence of friends and family

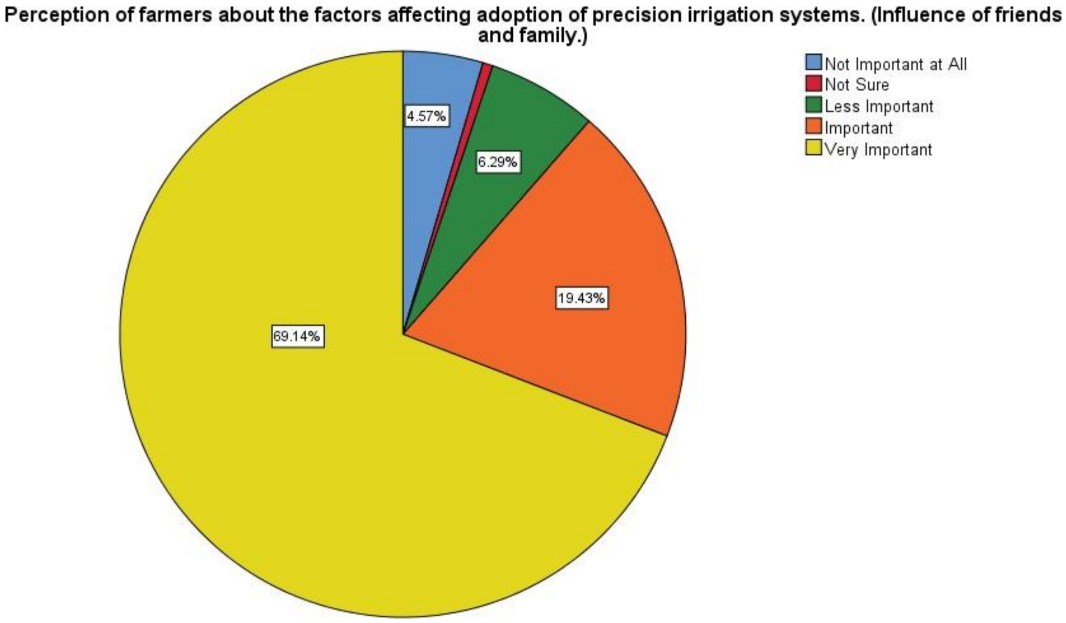


Figure 37: Descriptive statistics for an influence of friends and family

Findings: The above pie chart and statistics table suggests that around 89% of the farmers said that friends and family's decision also influence them to use precision irrigation system for farming.

The measure of dispersion and CT are mean=1.24, std. dev. = 0.980 and Var = 0.961.

e. Self-interest.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Not Important at All	15	4.3	4.58	1.000	1.000
Not Sure	9	6.9			
Less Important	15	11.1			
Important	29	19.4			
Very Important	282	100.0			
Total	350				

Table 33: Descriptive statistics for a self-interest

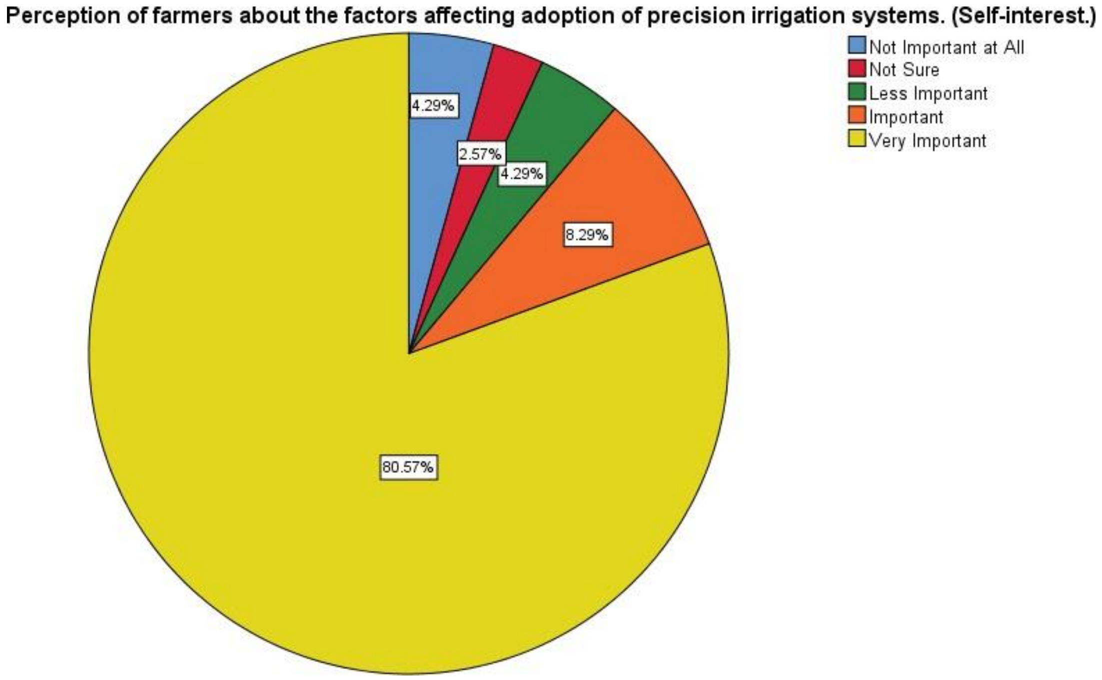


Figure 38: Distribution of self-interest

Findings: The above pie chart and statistics table suggests that around 89% farmers use precision irrigation system because they have their own vested interest.

The measure of dispersion and CT are mean=4.58, std. dev. = 1.000 and Var = 1.000.

f. Getting public attention due to the installation of precision irrigation systems

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Not Important at All	7	2.0	4.66	0.754	0.569
Not Sure	3	2.9			
Less Important	9	5.4			
Important	64	23.7			
Very Important	267	100.0			
Total	350				

Table 34: Descriptive statistics for a getting public attention due to the installation of precision irrigation systems

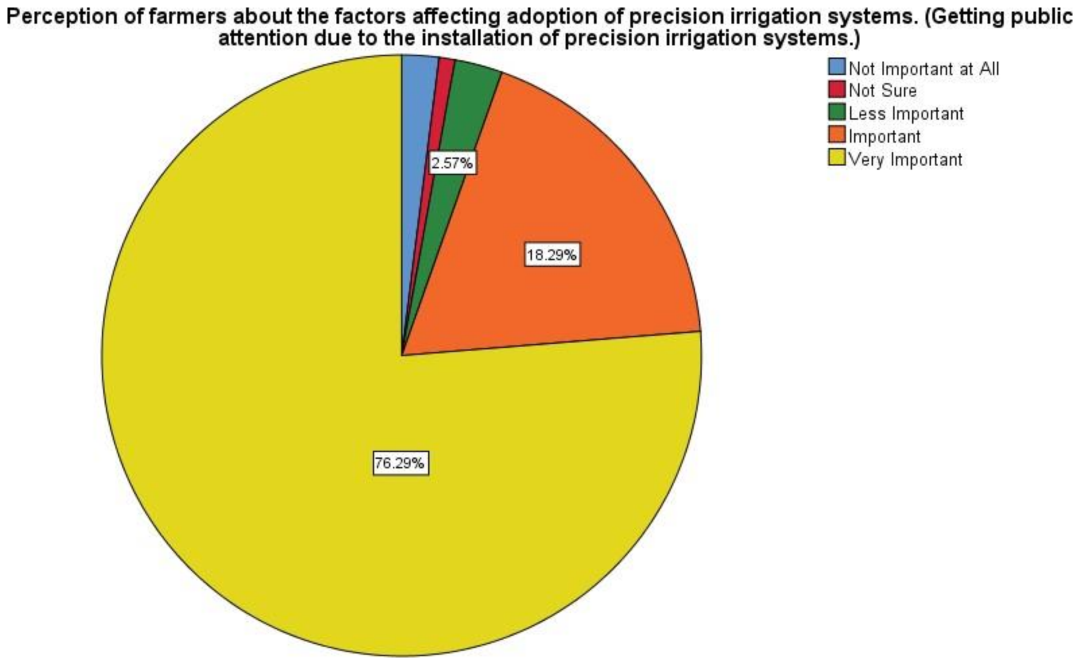


Figure 39: Distribution of a getting public attention due to the installation of precision irrigation systems

Findings: The above pie chart and statistics table suggests that around 95% farmers say that they got public attention if they use precision irrigation system is one of the influencing factors for them.

The measure of dispersion and CT are mean=4.66, std. dev. = 0.754 and Var = 0.569.

g. Need for achievement.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Not Important at All	3	0.9	4.63	0.663	0.439
Less Important	18	6.0			
Important	80	28.9			
Very Important	249	100.0			
Total	350				

Table 35: Descriptive statistics for a need for achievement

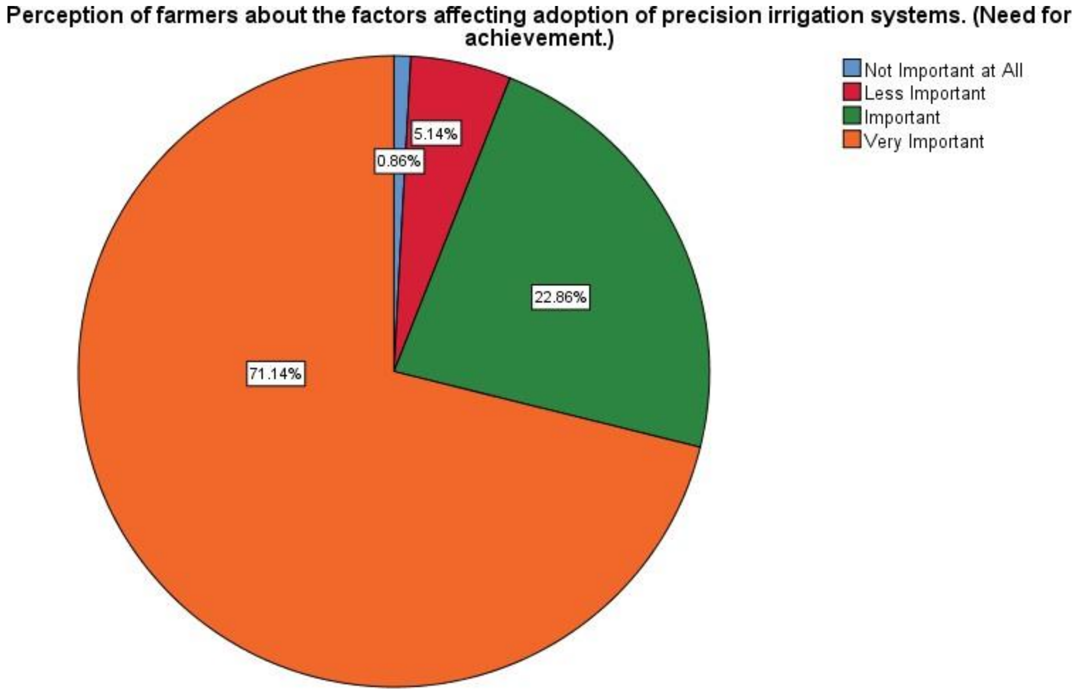


Figure 40: Distribution of a need for achievement

Findings: The above pie chart and statistics table suggests that around 94% farmers believes that precision irrigation system will helps them to achieve what they are expecting for and hence they will adopt the systems.

The measure of dispersion and CT are mean=4.63, std. dev. = 0.663 and Var = 0.439.

h. When summer arrives, water is low in supply.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Not Important at All	5	1.4	4.66	0.750	0.563
Not Sure	4	2.6			
Less Important	17	7.4			
Important	53	22.6			
Very Important	271	100.0			
Total	350				

Table 36: Descriptive statistics for when summer arrives, water is low in supply

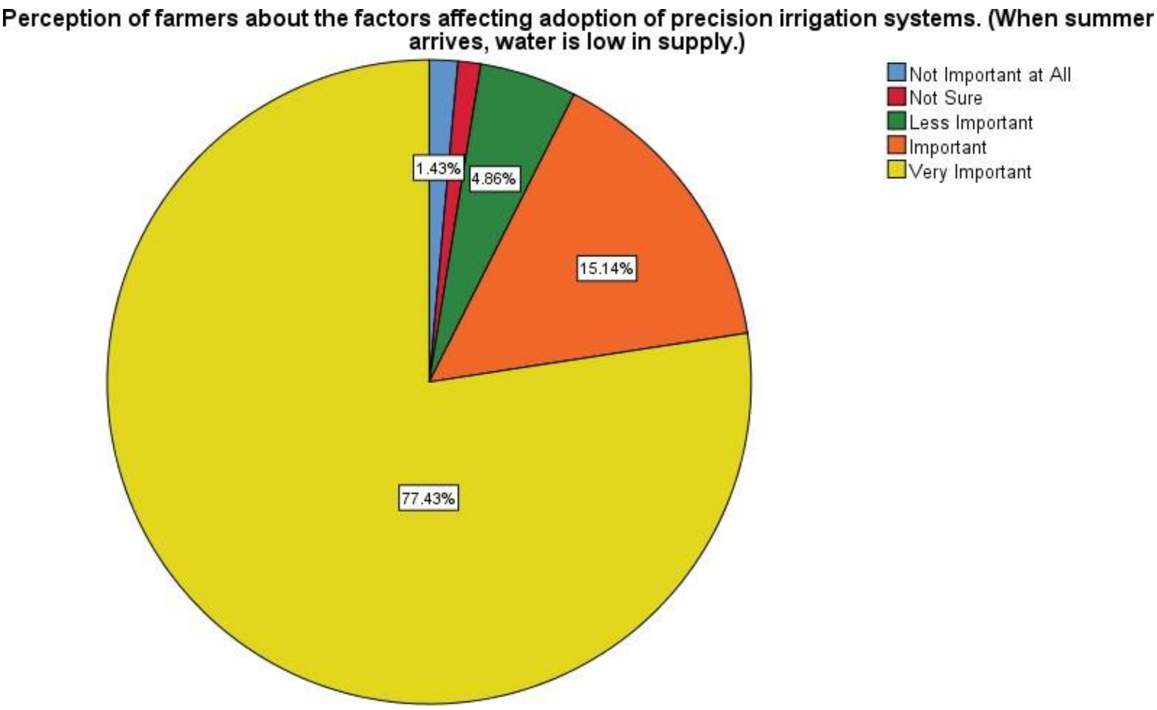


Figure 41: Distribution of a perception of when summer arrives, water is low in supply

Findings: The above pie chart and statistics table suggests that around 93% farmers said that shortage of water in summers is one of the factors why they adopt precision irrigation system.

The measure of dispersion and CT are mean=4.66, std. dev. = 0.750 and Var = 0.563.

i. Subsidy availability

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Not Important at All	32	9.1	4.28	1.216	1.479
Not Sure	4	10.3			
Less Important	19	15.7			
Important	75	37.1			
Very Important	220	100.0			
Total	350				

Table 37: Descriptive statistics for a subsidy availability

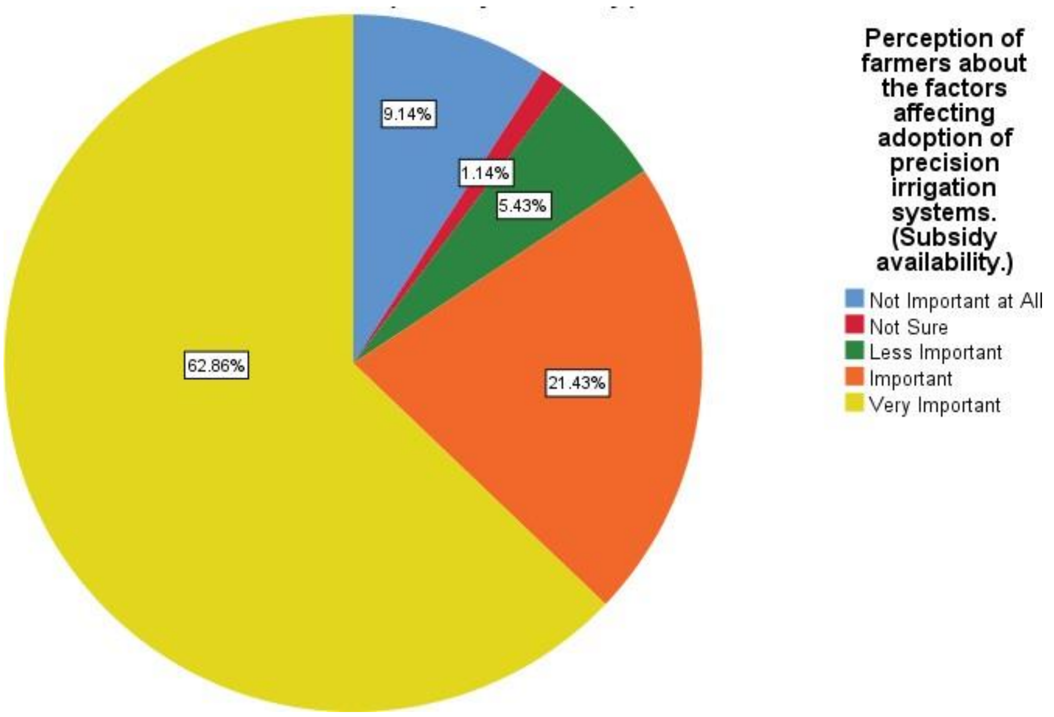


Figure 42: Distribution of a subsidy availability

Findings: The above pie chart and statistics table suggests that around 84% farmers believes that if subsidy is available to install precision irrigation system it will serve as a crucial factor in the adoption of the system.

The measure of dispersion and CT are mean= 4.28, std. dev. = 1.216 and Var = 1.479.

j. Difficulty in finding workers having knowledge of irrigation systems

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Not Important at All	3	0.9	4.61	0.663	0.440
Less Important	17	5.7			
Important	92	32.0			
Very Important	238	100.0			
Total	350				

Table 38: Descriptive statistics for a difficulty in finding workers having knowledge of irrigation systems

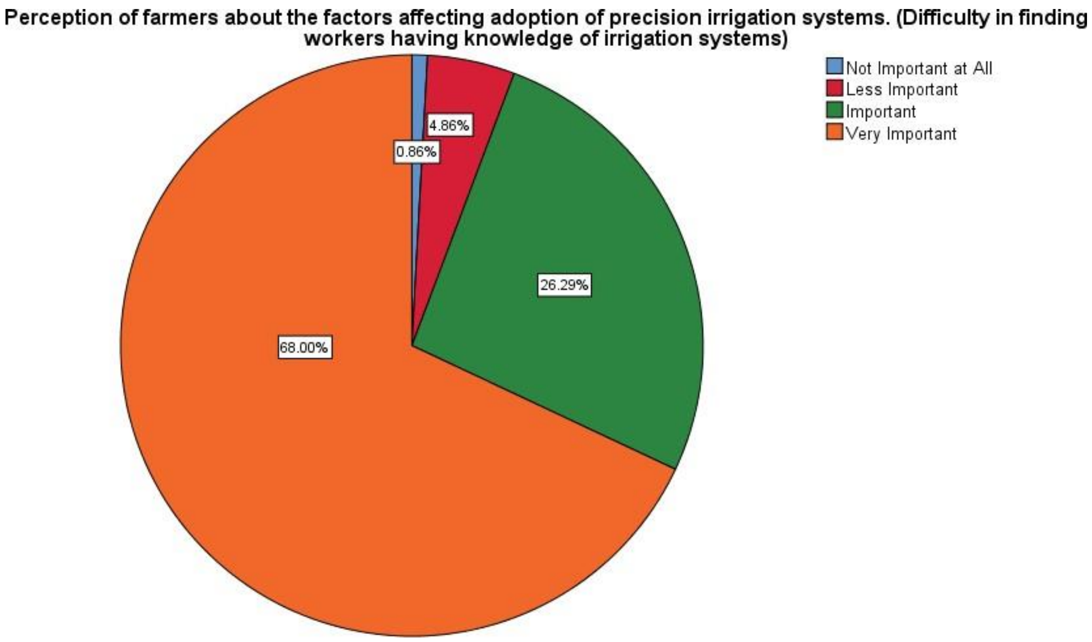


Figure 43: Distribution of a difficulty in finding workers having knowledge of irrigation systems

Findings: The above pie chart and statistics table suggests that around 94% farmers are of the opinion that it's difficult to find the labourers/workers who have working knowledge of precision irrigation system.

The measure of dispersion and CT are mean= 4.61, std. dev. = 0.663 and Var = 0.440.

10. Perception of farmers about the reasons which creates hurdles for adoption of precision irrigation systems.

a. Lack of water for irrigation leads to water availability sufficient just for household use.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Not Important at All	9	2.6	4.54	0.923	0.851
Not Sure	10	5.4			
Less Important	21	11.4			
Important	54	26.9			
Very Important	256	100.0			
Total	350				

Table 39: Descriptive statistics for a lack of water for irrigation leads to water availability sufficient just for household use

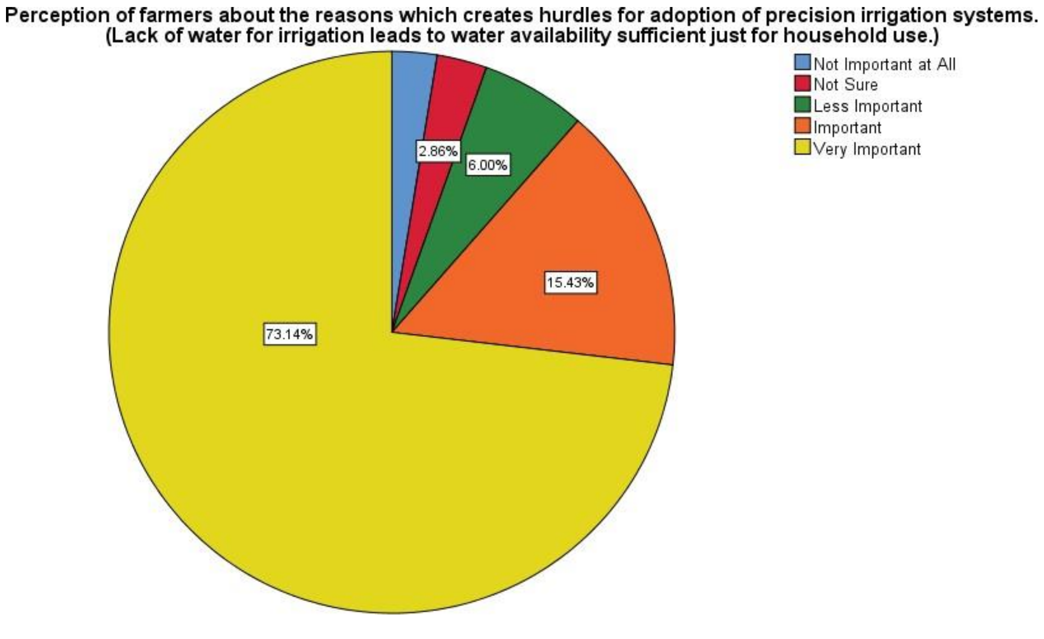


Figure 44: Distribution of lack of water for irrigation leads to water availability sufficient just for household use

Findings: The above pie chart and statistics table suggests that around 89% farmers said that those who don't adopt precision irrigation system availability of the water is the issue because these farmers just have the quantity of water for their household use and left with no choice for using water for precision irrigation.

The measure of dispersion and CT are mean=4.54, std. dev.= 0.923 and Var = 0.851.

b. The initial expenditure is high.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Not Important at All	14	4.0	4.38	0.965	0.930
Not Sure	6	5.7			
Less Important	19	11.1			
Important	104	40.9			
Very Important	207	100.0			
Total	350				

Table 40: Descriptive statistics for the initial expenditure is high

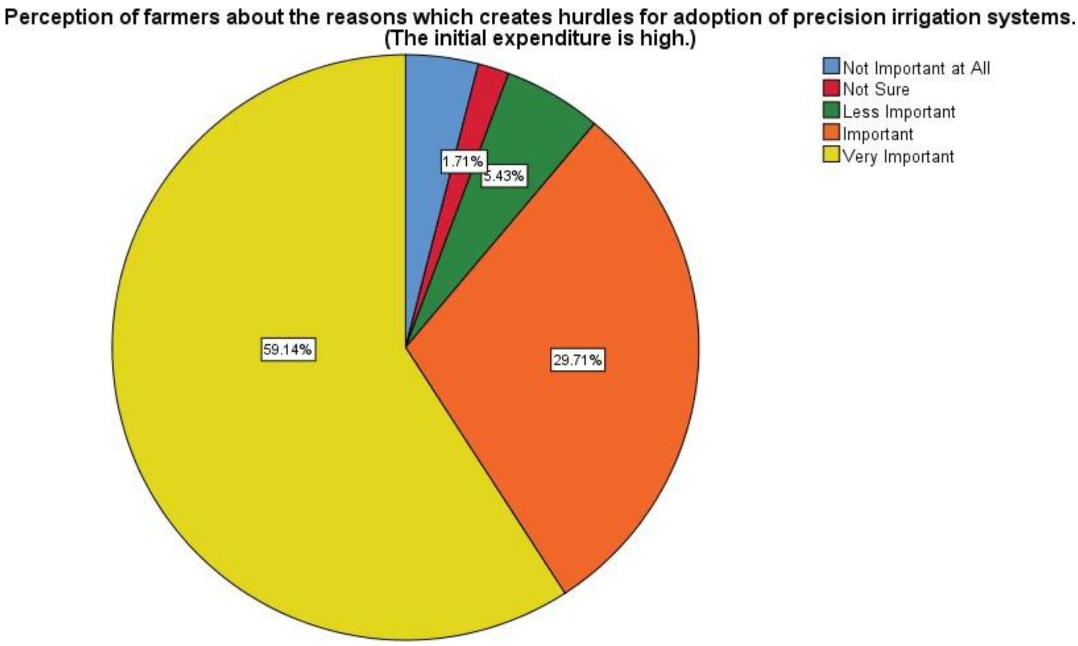


Figure 45: Distribution of the initial expenditure is high

Findings: The above pie chart and statistics table suggests that around 89% farmers said that initial investment is high if someone wants to install precision irrigation system most of the time this turn off the farmers from adopting the precision irrigation system.

The measure of dispersion and CT are mean= 4.38, std. dev. = 0.965 and Var = 0.930.

c. In regions where there is enough of water, farmers are happy with conventional irrigation methods.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Not Important at All	3	.9	4.73	0.635	0.403
Not Sure	2	1.4			
Less Important	12	4.9			
Important	52	19.7			
Very Important	281	100.0			
Total	350				

Table 41: Descriptive statistics for in regions where there is enough of water, farmers are happy with conventional irrigation methods

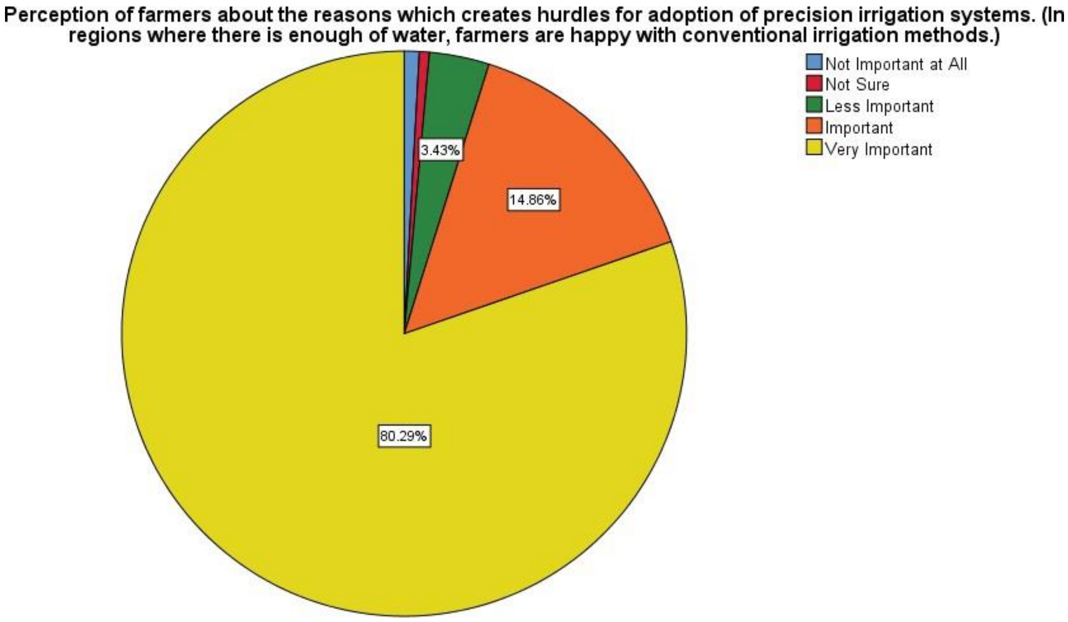


Figure 46: Distribution in regions where there is enough of water, farmers are happy with conventional irrigation methods

Findings: The above pie chart and statistics table suggests that around 95% farmers said that the farmers who are having abundances of water supply those farmers do traditional irrigation to their farms instead of using precision irrigation system.

The measure of dispersion and CT are mean=4.73, std. dev. = 0.635 and Var = 0.403.

d. Water that is of poor quality may block a drip system.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Not Sure	2	0.6	4.60	0.586	0.344
Less Important	12	4.0			
Important	110	35.4			
Very Important	226	100.0			
Total	350				

Table 42: Descriptive statistics for water that is of poor quality may block a drip system

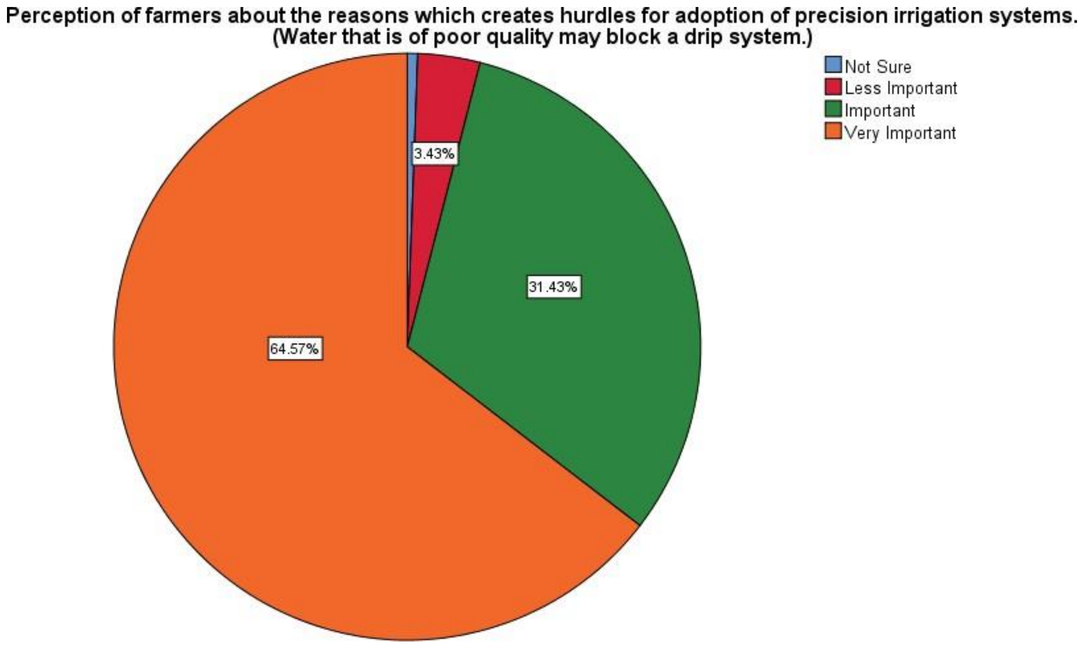


Figure 47: Distribution of water that is of poor quality may block a drip system

Findings: The above pie chart and statistics table suggests that around 96% farmers say that most of the times farmers don’t think of using precision irrigation system because the quality of water available to them is not as good as it involves dust, mud or foreign particles which may block and damage the irrigation system.

The measure of dispersion and CT are mean=4.60, std. dev. = 0.586 and Var = 0.344.

e. Lack of information and awareness of drip irrigation.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std dev	Var
Not Sure	2	0.6	4.62	0.682	0.466
Less Important	34	10.3			
Important	59	27.1			
Very Important	255	100.0			
Total	350				

Table 43: Descriptive statistics for lack of information and awareness of drip irrigation

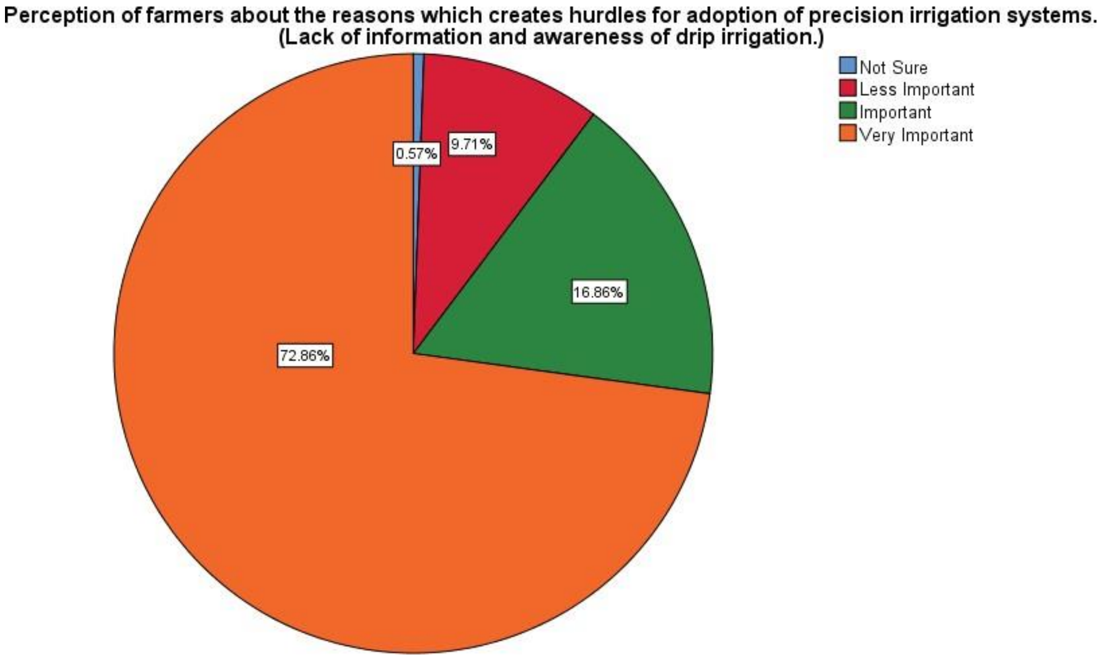


Figure 48: Distribution of lack of information and awareness of drip irrigation

Findings: The above pie chart and statistics table suggests that around 89% of the farmers are of the opinion that the farmers who lacks awareness about installing and using precision irrigation system stay away from adopting it.

The measure of dispersion and CT are mean=4.62, std. dev. = 0.682 and Var = 0.466.

f. The water delivered by the drip method is insufficient for proper crop growth, so it is believed.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Not Sure	12	3.4	4.59	0.743	0.552
Less Important	18	8.6			
Important	72	29.1			
Very Important	248	100.0			
Total	350				

Table 44: Descriptive statistics for the water delivered by the drip method is insufficient for proper crop growth, so it is believed

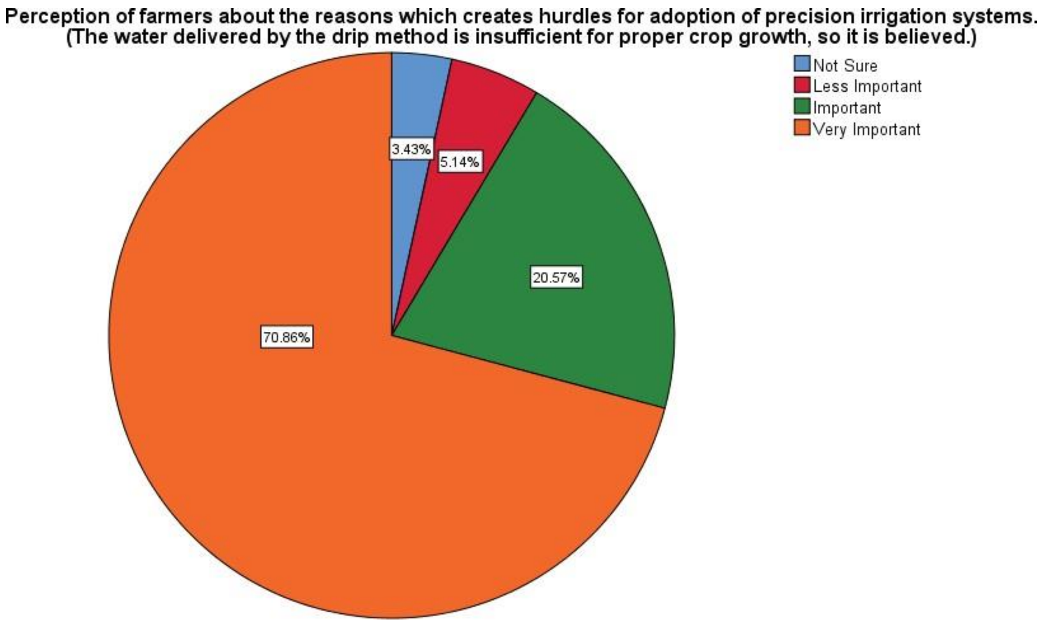


Figure 49: Distribution of the water delivered by the drip method is insufficient for proper crop growth, so it is believed

Findings: The above pie chart and statistics table suggests that around 91% farmers are of the opinion that there is a miss conception among the farmers that precision irrigation systems are not in a position to deliver appropriate amount of water to the crops hence they don't want to adopt the systems.

The measure of dispersion and CT are mean=4.59, std. dev. =0.743 and Var = 0.552.

g. A lot of people have quit using the technology.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Not Sure	7	2.0	4.67	0.679	0.461
Less Important	21	8.0			
Important	51	22.6			
Very Important	271	100.0			
Total	350				

Table 45: Descriptive statistics for a lot of people have quit using the technology

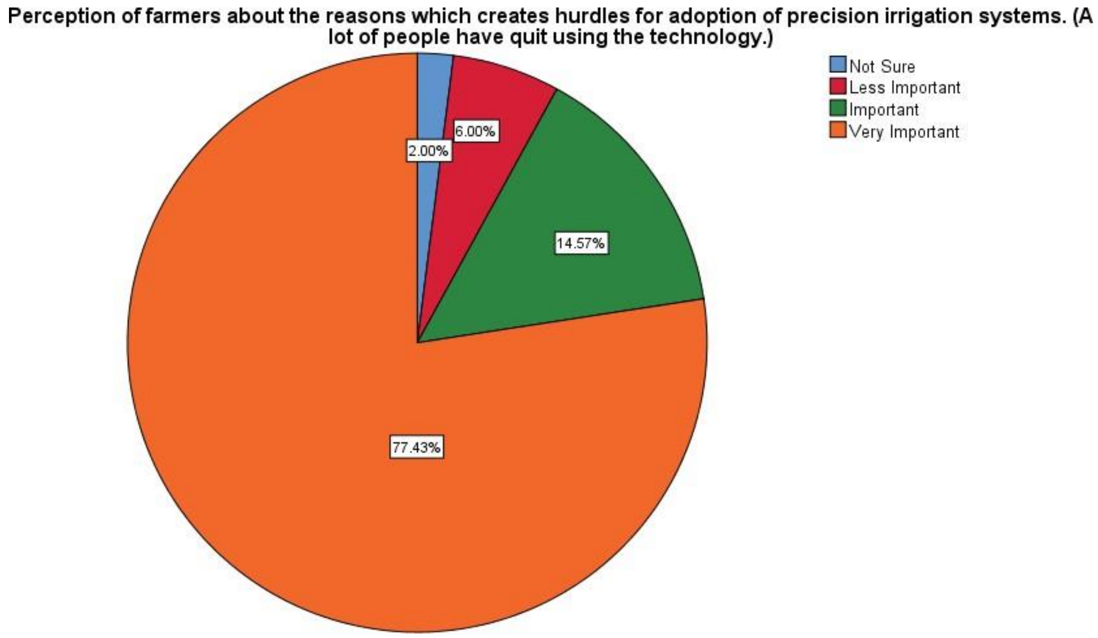


Figure 50: Distribution of a lot of people have quit using the technology

Findings: The above pie chart and statistics table suggests that around 92% farmers said that lot of farmers have surrendered using precision irrigation system by taking the example from these other farmers don't want to adopt it.

The measure of dispersion and CT are mean=4.67, std. dev. = 0.679 and Var = 0.461.

h. Power shortages.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Not Important at All	1	.3	4.80	0.460	0.212
Less Important	3	1.1			
Important	60	18.3			
Very Important	286	100.0			
Total	350				

Table 46: Descriptive statistics for power shortage

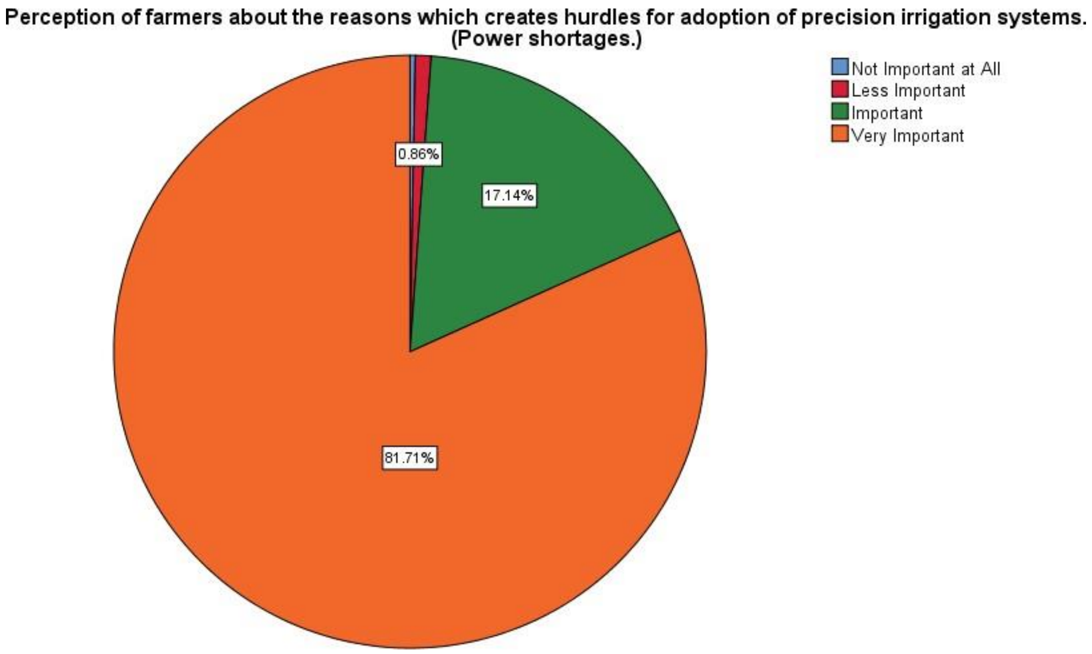


Figure 51: Distribution of a power shortages

Findings: The above pie chart and statistics table suggests that around 99% farmers are of the opinion that the farmers who don't adopt precision irrigation system because they don't have consistent power supply available to them.

The measure of dispersion and CT are mean=4.80, std. dev. = 0.460 and Var = 0.212.

i. Voltage malfunctions.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Not Important at All	1	.3	4.81	0.487	0.238
Less Important	9	2.9			
Important	43	15.1			
Very Important	297	100.0			
Total	350				

Table 47: Descriptive statistics for voltage malfunction

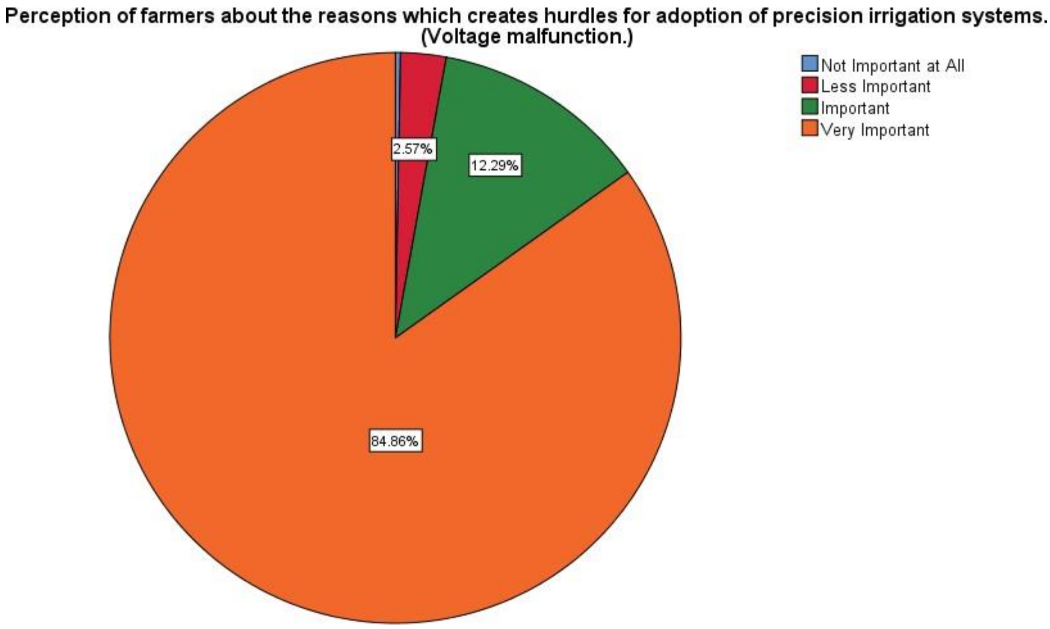


Figure 52: Distribution of voltage malfunction

Findings: The above pie chart and statistics table suggests that around 97% farmers are of the opinion that lot of time voltage fluctuations may damage the irrigation system hence the farmers who are having such situation of fluctuation of voltage in their villages stay away from using the system.

The measure of dispersion and CT are mean=4.81, std. dev. = 0.487 and Var = 0.238.

11. Perception of farmers about the challenges in operating and maintaining precision irrigation system

a. A system clog from contaminants in irrigation water.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Less Important	8	2.3	4.74	0.489	0.239
Important	75	23.7			
Very Important	267	100.0			
Total	350				

Table 48: Descriptive statistics for a system clog from contaminants in irrigation water

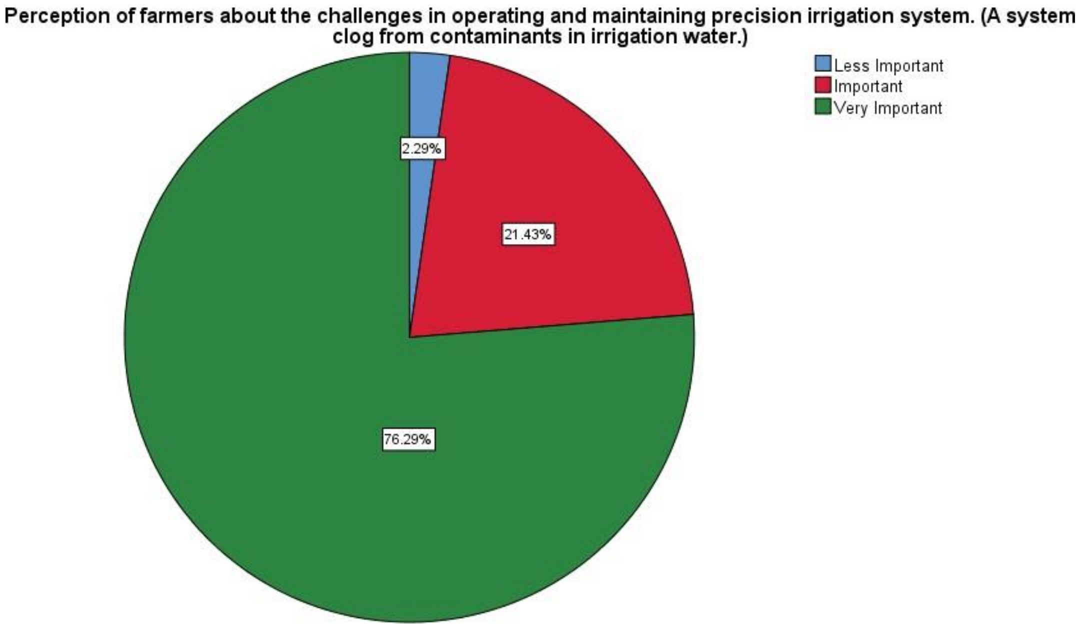


Figure 53: Distribution of a system clog from contaminants in irrigation water

Findings: The above pie chart and statistics table suggests that around 97% of the farmers are of the opinion that irrigation systems clog most of the time and damage the systems hence to maintain them is no feasible hence it's a big challenge for them. The measure of dispersion and CT are mean=4.74, std. dev. =0.489 and Var = 0.239.

b. Poor power supply.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Less Important	8	2.3	4.82	0.442	0.196
Important	48	16.0			
Very Important	294	100.0			
Total	350				

Table 49: Descriptive statistics for poor power supply

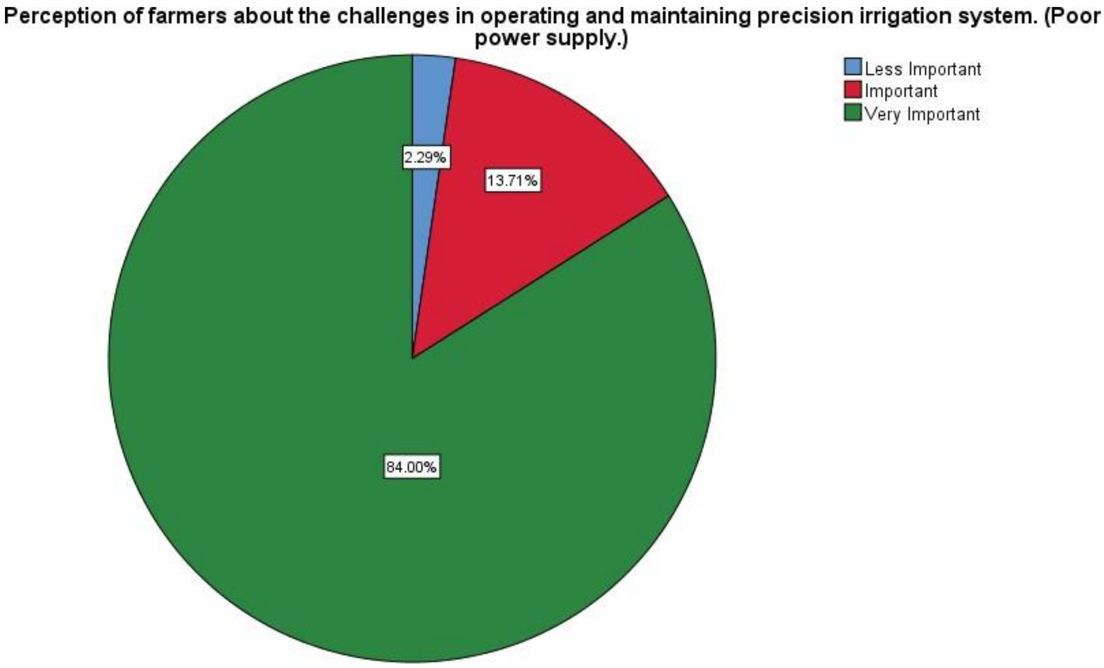


Figure 54: Distribution of poor power supply

Findings: The above pie chart and statistics table suggests that around 97% farmers of the opinion that poor power supply is the main reason which creates a big hurdle in running these irrigation systems.

The measure of dispersion and CT are mean= 4.82, std. dev. = 0.442 and Var = 0.196.

c. Voltage malfunction

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Less Important	18	5.1	4.70	0.560	0.314
Important	69	24.9			
Very Important	263	100.0			
Total	350				

Table 50: Descriptive statistics for voltage variation

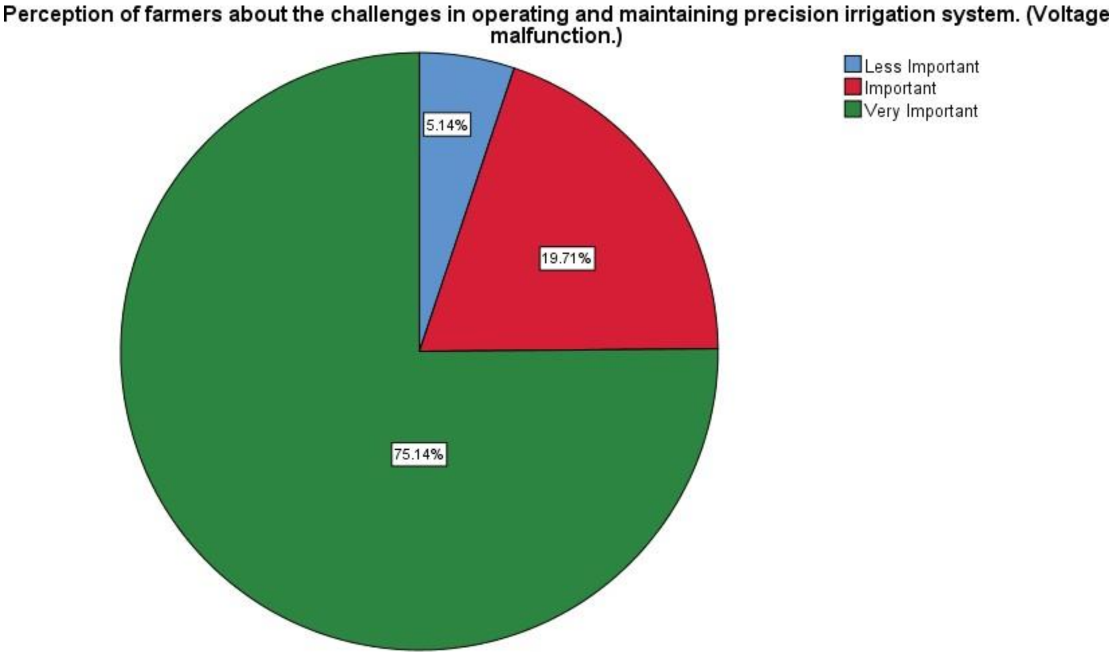


Figure 55: Distribution of voltage variation

Findings: The above pie chart and statistics table suggests that around 95% farmers of the opinion that the inconsistent voltage damages the systems or put system on trip (power is off) because of this the maintenance cost of the irrigation systems goes high.

The measure of dispersion and CT are mean=4.70, std. dev. = 0.560 and Var = 0.314.

d. Pipeline and dripper damage from rats

Choice Parameters	Frequency	Cumulative Percent	Mean	Std dev	Var
Not Important at All	1	0.3	4.82	0.520	0.270
Not Sure	2	0.9			
Less Important	9	3.4			
Important	36	13.7			
Very Important	302	100.0			
Total	350				

Table 51: Descriptive statistics for pipeline and dripper damage from rats

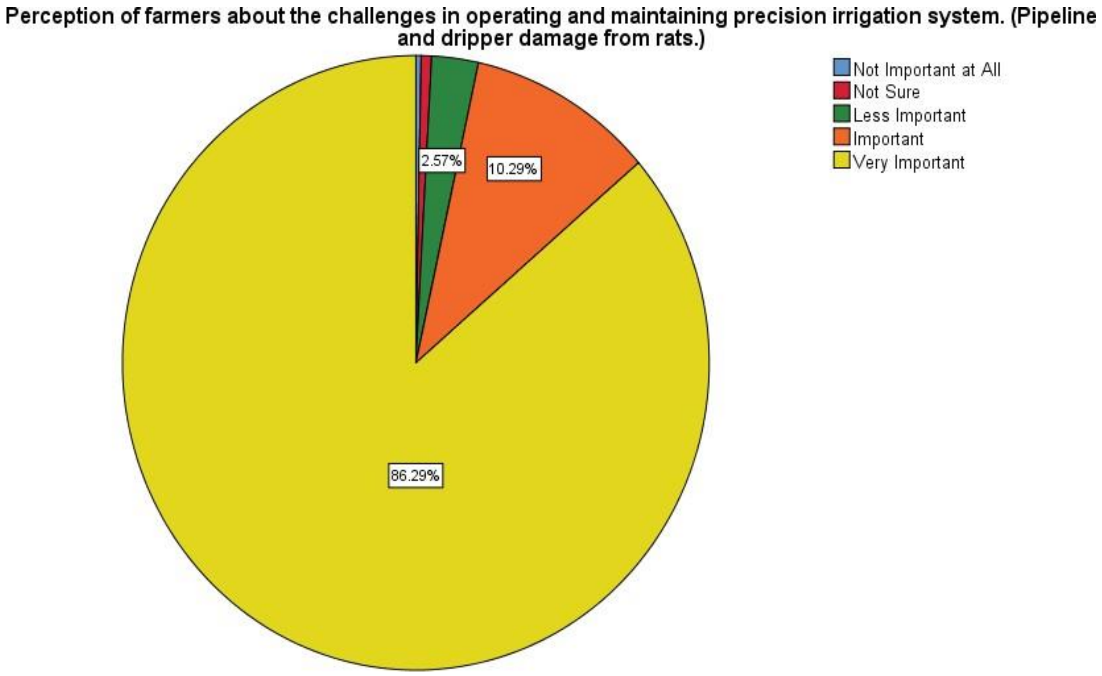


Figure 56: Distribution of pipeline and dripper damage from rats

Findings: The above pie chart and statistics table suggests that around 95% of the farmers that rodent is a big problem for them to maintain a drip or sprinklers pipelines. If the rodent tears out the system there will be a power failure or wastage of water hence it becomes a costly affair for them to maintain it.

The measure of dispersion and CT are mean=4.82, std. dev. = 0.520 and Var = 0.270.

e. Pipelines and drippers are prone to damage by wild animals

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Less Important	6	1.7	4.85	0.406	0.165
Important	42	13.7			
Very Important	302	100.0			
Total	350				

Table 52: Descriptive statistics for pipelines and drippers are prone to damage by wild animals

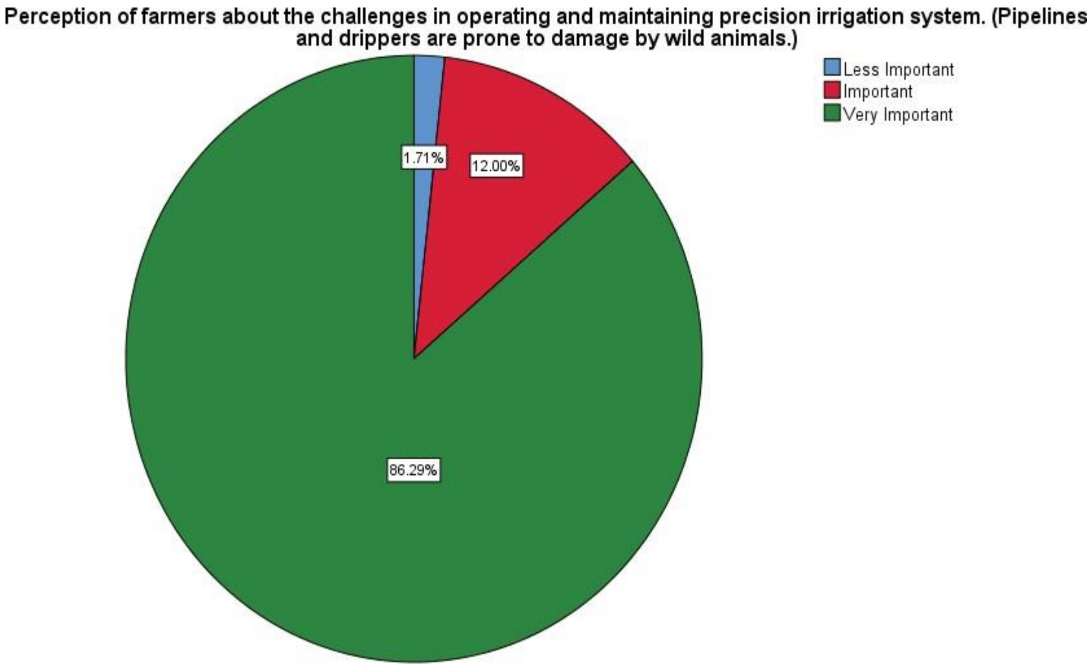


Figure 57: distribution of pipelines and drippers are prone to damage by wild animals

Findings: The above pie chart and statistics table suggests that around 98% of farmers of the opinion that wild animal (who are domesticated by farmers) such as dogs, cats spoil the irrigation systems.

The measure of dispersion and CT are mean=4.85, std. dev. = 0.406 and Var = 0.165.

f. A lack of understanding about utility, operations, and maintenance

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Not Important at All	2	0.6	4.69	0.597	0.356
Less Important	13	4.3			
Important	73	25.1			
Very Important	262	100.0			
Total	350				

Table 53: Descriptive statistics for a lack of understanding about utility, operations, and maintenance

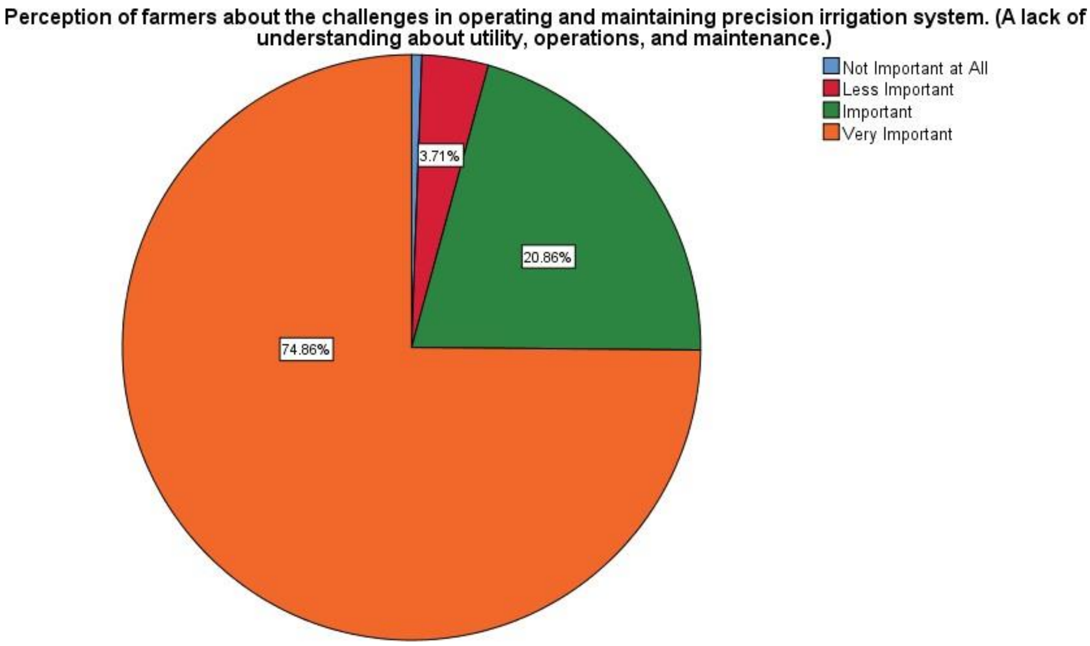


Figure 58: Distribution of a lack of understanding about utility, operations, and maintenance

Findings: The above pie chart and statistics table suggests that around 95% farmers are of the opinion that they don't have complete awareness about the utility, operations and how to maintain these systems effectively.

The measure of dispersion and CT are mean=4.69, std. dev. = 0.597 and Var = 0.356.

g. Substandard post-sales service

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Not Important at All	2	0.6	4.70	0.631	0.399
Not Sure	2	1.1			
Less Important	15	5.4			
Important	60	22.6			
Very Important	271	100.0			
Total	350				

Table 54: Descriptive statistics for substandard post-sales service

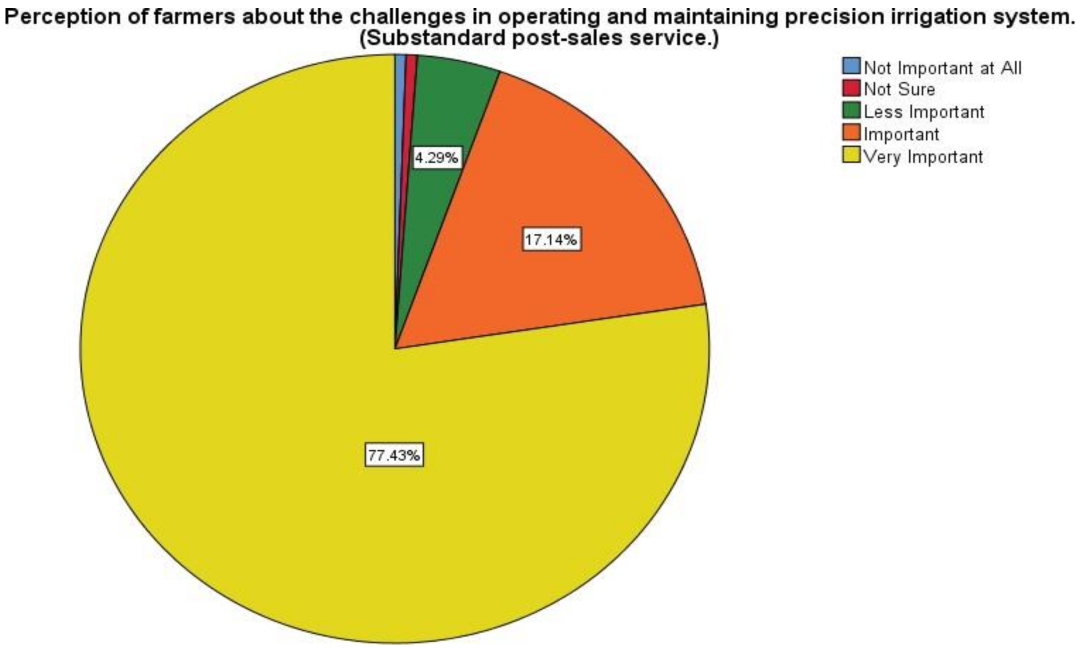


Figure 59: Distribution of substandard post-sales service

Findings: The above pie chart and statistics table suggests that around 93% of the farmers are of opinion that the after sales service provided by the dealers is not up to the mark this creates a big hurdle for the farmers to chase them in case of failure of the irrigation systems.

The measure of dispersion and CT are mean=4.70, std. dev. = 0.631 and Var = 0.399.

h. Technical guidance received too late from the dealer's technicians

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Not Sure	1	0.3	4.64	0.592	0.351
Less Important	18	5.4			
Important	86	30.0			
Very Important	245	100.0			
Total	350				

Table 55: Descriptive statistics for technical guidance received too late from the dealer's technicians

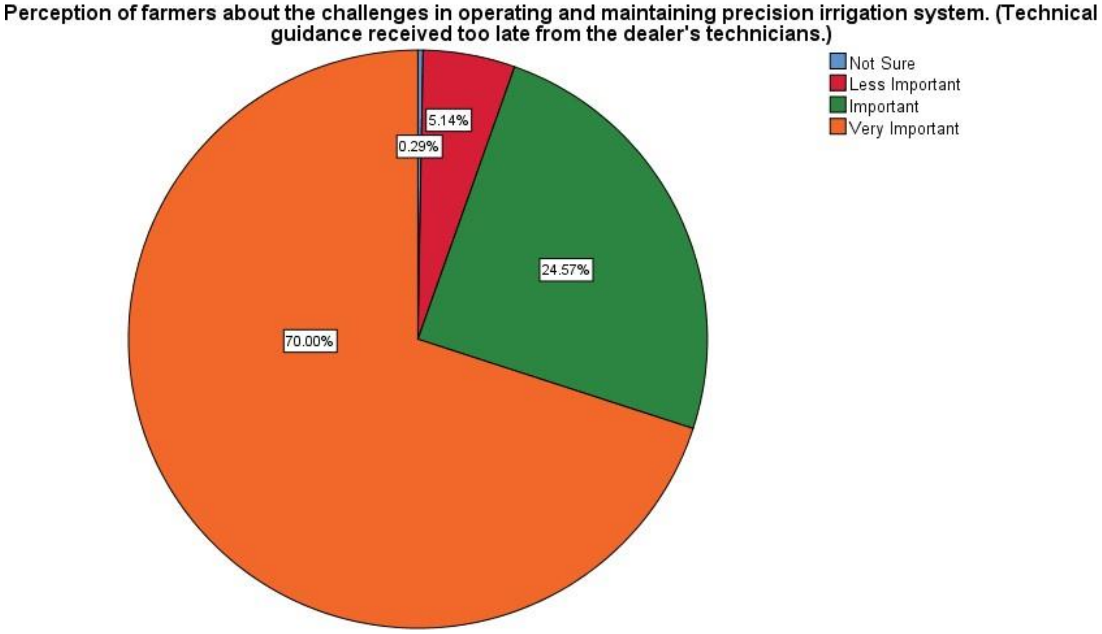


Figure 60: Distribution of technical guidance received too late from the dealer's technicians

Findings: The above pie chart and statistics table suggests that around 94% farmers of the opinion that the technicians of the dealers don't respond on time or they get delayed response hence maintaining and operating the precision irrigation systems is a tough job.

The measure of dispersion and CT are mean=4.64, std. dev. = 0.592 and Var = 0.351.

i. Ground-level weed concentration

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Less Important	20	5.7	4.67	0.579	0.335
Important	74	26.9			
Very Important	256	100.0			
Total	350				

Table 56: Descriptive statistics for ground-level weed concentration

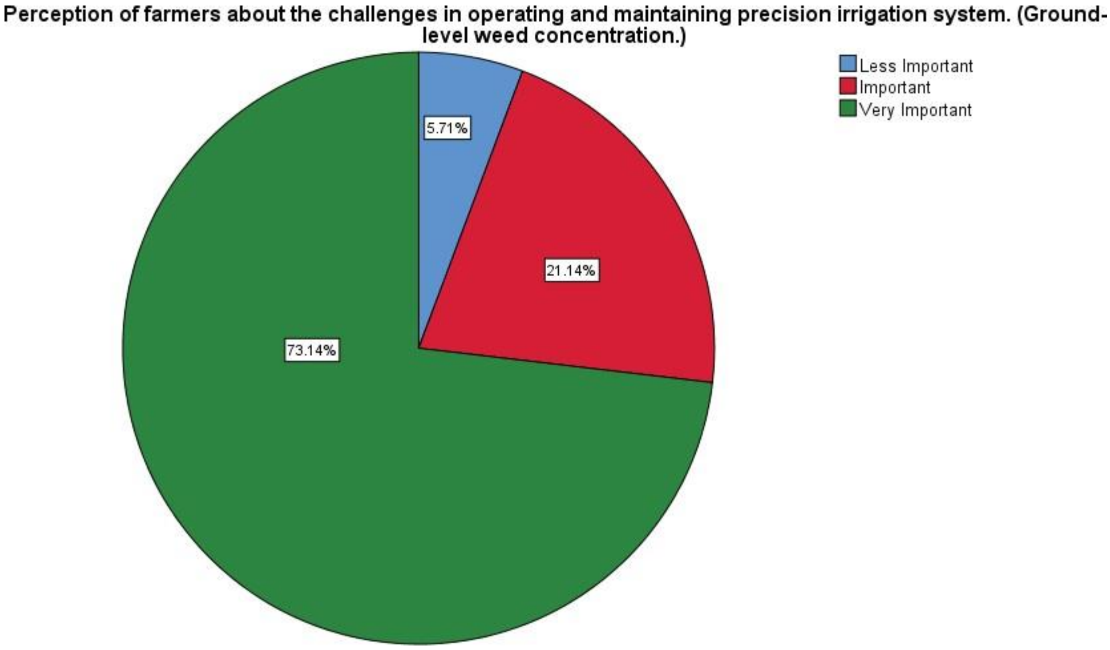


Figure 61: Distribution of ground-level weed concentration

Findings: The above pie chart and statistics table suggests that around 94% farmers are of the opinion that the unwanted plant which doesn't have a botanical importance these creates a problem to maintain the pipelines of irrigation systems.

The measure of dispersion and CT are mean=4.67, std. dev. = 0.579 and Var = 0.335.

12. Irrigation systems have effectively served a variety of irrigation demands

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Highly Unsatisfied	4	1.1	4.68	0.660	0.436
Unsatisfied	2	1.7			
Not sure	8	4.0			
Satisfied	74	25.1			
Highly Satisfied	262	100.0			
Total	350				

Table 57: Descriptive statistics for irrigation systems has effectively served a variety of irrigation demands

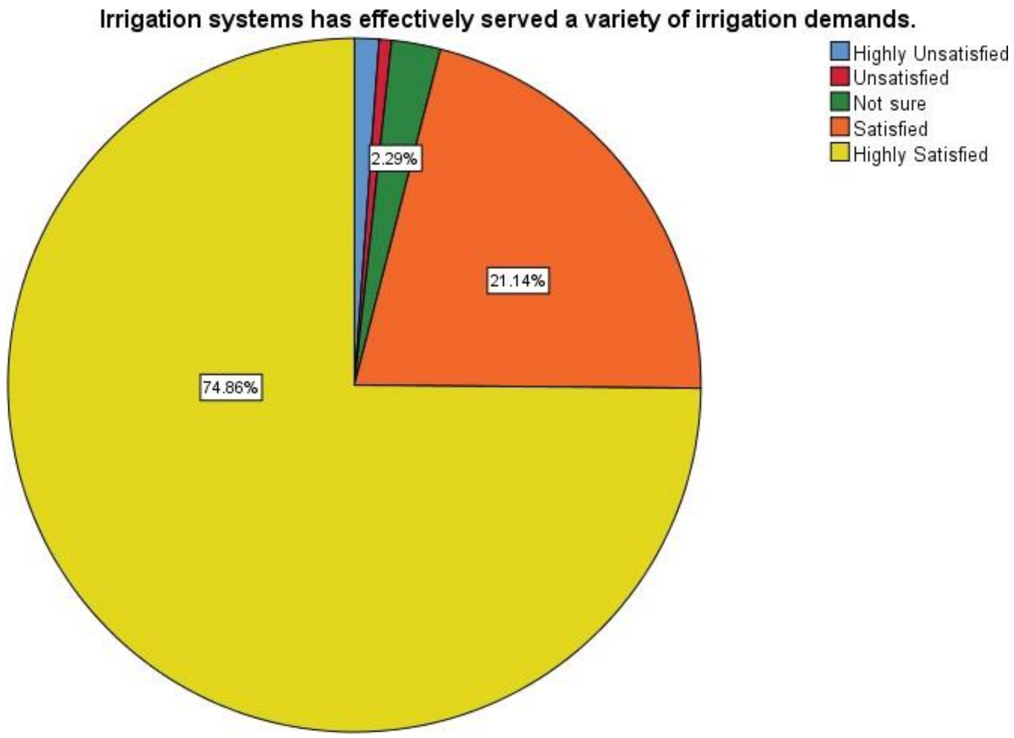


Figure 62: Distribution of irrigation systems has effectively served a variety of irrigation demands

Findings: The above pie chart and statistics table suggests that around 96% farmers said that most of their needs or demands related to the irrigation of farms got fulfilled because of precision irrigation system.

The measure of dispersion and CT are mean=4.68, std. dev. = 0.660 and Var = 0.436.

13. Reduction in the amount of electricity consumed to irrigate the fields

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Unsatisfied	1	.3	4.83	0.449	0.202
Not sure	8	2.6			
Satisfied	39	13.7			
Highly Satisfied	302	100.0			
Total	350				

Table 58: Descriptive statistics for reduction in the amount of electricity consumed to irrigate the fields

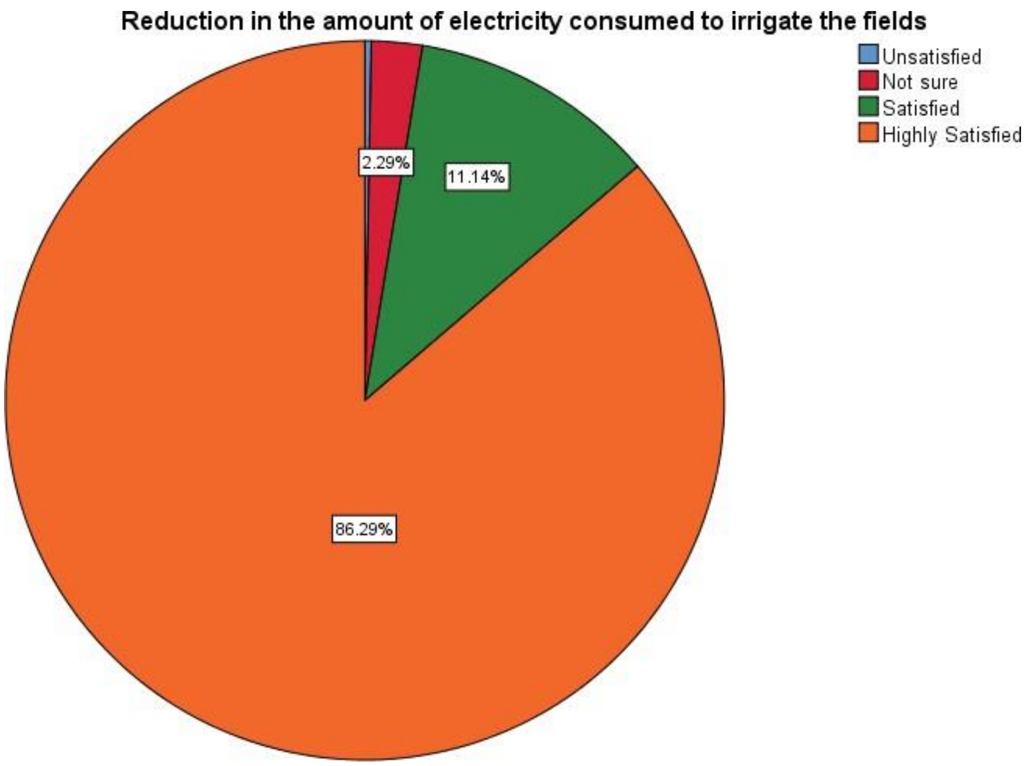


Figure 63: Distribution of reduction in the amount of electricity consumed to irrigate the fields

Findings: The above pie chart and statistics table suggests that around 97% farmers are of the opinion that after stated using the precision irrigation system the consumption of electric power has substantially reduced.

The measure of dispersion and CT are mean=4.83, std. dev. = 0.449 and Var = 0.202.

14. Your income has increased as a result of the use of irrigation systems

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Highly Unsatisfied	34	9.7	4.26	1.326	1.757
Unsatisfied	19	15.1			
Not sure	12	18.6			
Satisfied	42	30.6			
Highly Satisfied	243	100.0			
Total	350				

Table 59: Descriptive statistics for your income has increased as a result of the use of irrigation systems

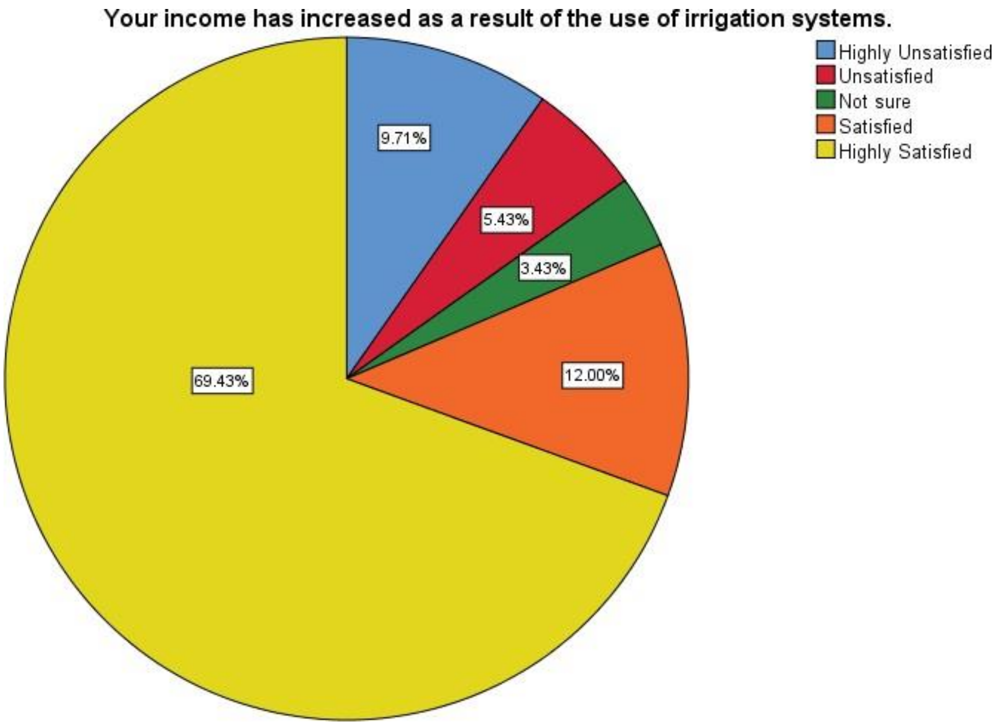


Figure 64: Distribution of income has increased as a result of the use of irrigation systems

Findings: The above pie chart and statistics table suggests that around 81% farmers are of the opinion that their income has been increase because of the crop cultivation based on precision irrigation system.

The measure of dispersion and CT are mean=4.26, std. dev. = 1.326 and Var = 1.757.

15. Did you take advantage of subsidy available for micro irrigation systems?

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Yes	184	52.6	1.47	0.500	0.250
No	166	100.0			
Total	350				

Table 60: Descriptive statistics for advantage of subsidy available for micro irrigation systems

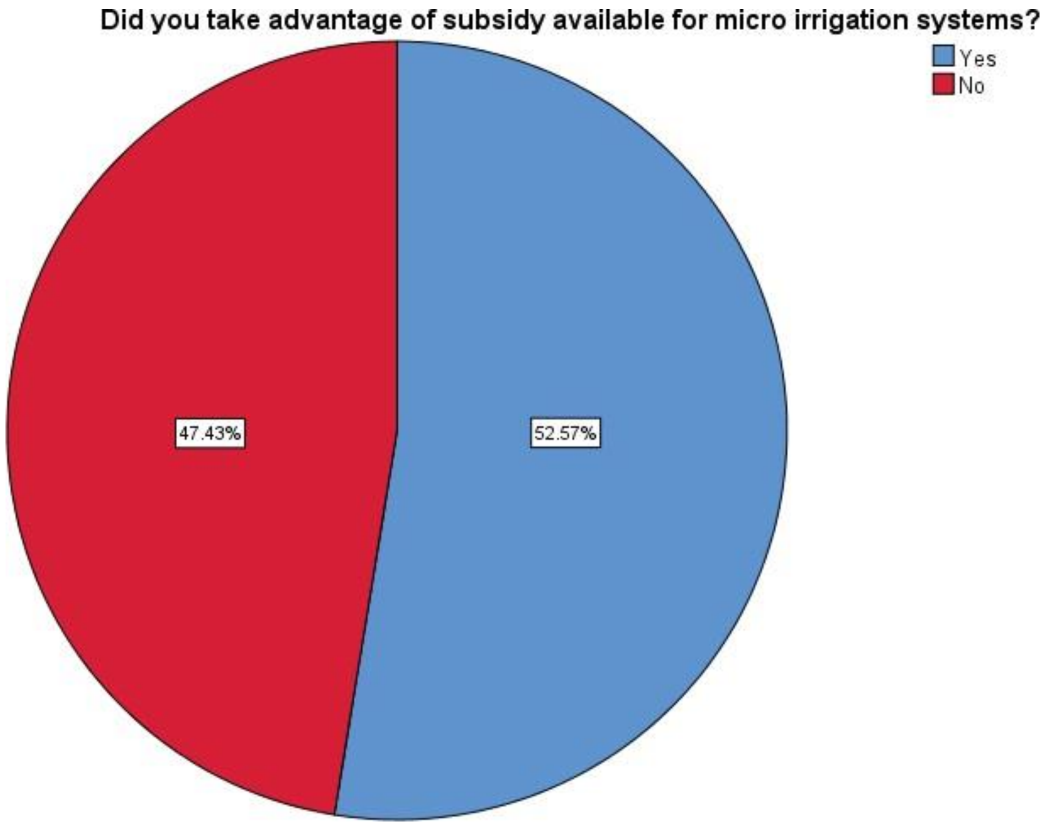


Figure 65: Distribution of advantage of subsidy available for micro irrigation systems

Findings: The above pie chart and statistics table suggests that around 52% of the farmer have availed subsidy to install precision irrigation system.

The measure of dispersion and CT are mean=1.47, std. dev. = 0.500 and Var = 0.250.

16. The amount of the subsidy is sufficient

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Very Bad	19	5.4	4.50	0.998	0.996
Okay	16	10.0			
Good	66	28.9			
Very Good	249	100.0			
Total	350				

Table 61: Descriptive statistics for the amount of the subsidy is sufficient

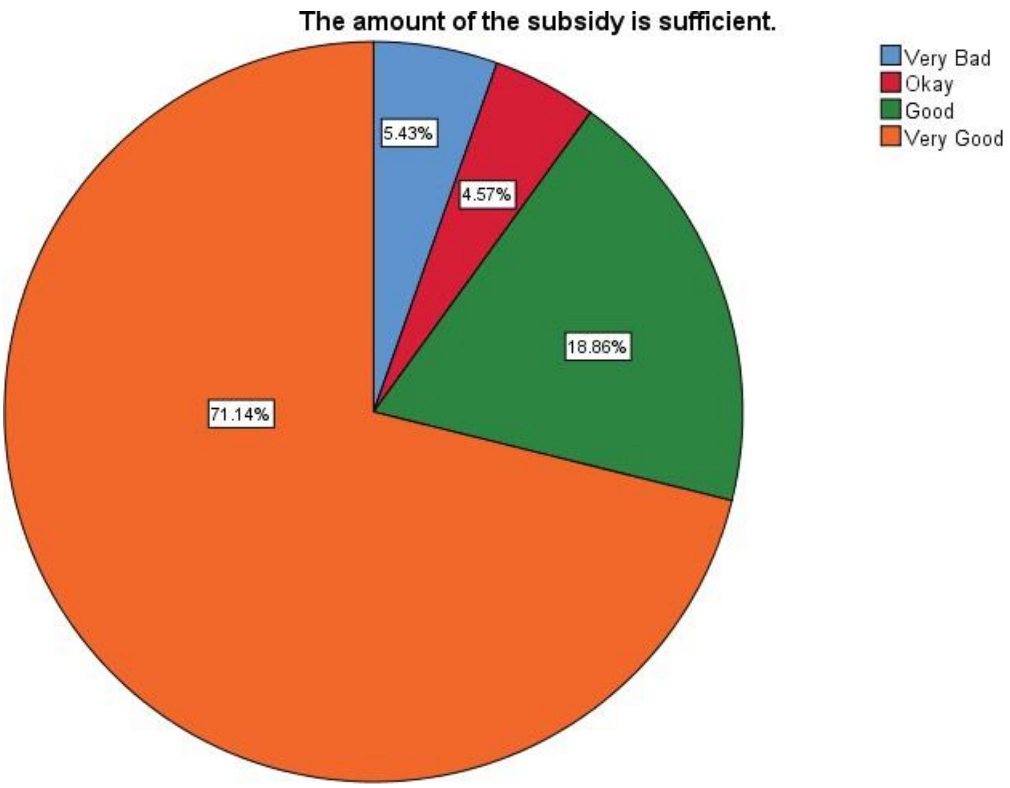


Figure 66: Distribution of the amount of the subsidy is sufficient

Findings: The above pie chart and statistics table suggests that around 90% farmers said that the amount of the subsidy they are availing is good enough for them to purchase precision irrigation.

The measure of dispersion and CT are mean=4.50, std. dev. = 0.998 and Var = 0.996.

17. The ease with which the subsidy procedure can be completed.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Co Var
Very Bad	35	10.0	4.20	1.264	1.597
Bad	5	11.4			
Okay	26	18.9			
Good	74	40.0			
Very Good	210	100.0			
Total	350				

Table 62: Descriptive statistics for the ease with which the subsidy procedure can be completed

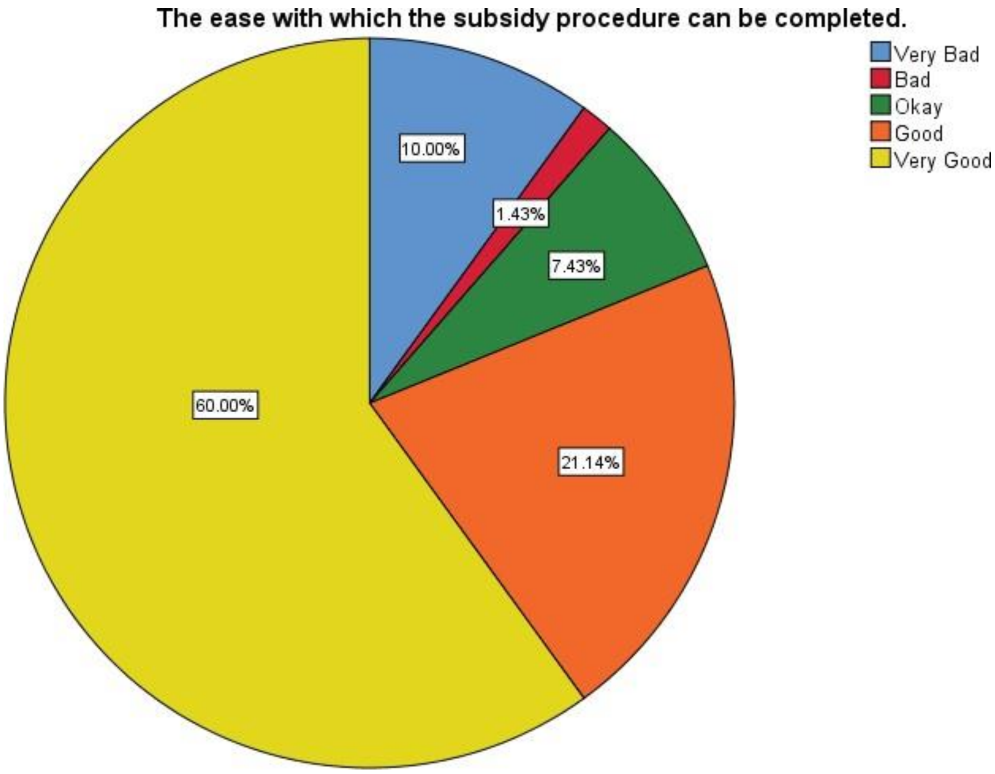


Figure 67: Distribution of the ease with which the subsidy procedure can be completed

Findings: The above pie chart and statistics table suggests that around 81% farmers are of the opinion that to make the application for availing the subsidy is not a tough task, anyone can make the application easily.

The measure of dispersion and CT are mean=4.20, std. dev. = 1.264 and Var = 1.597.

18. The actions and attitudes of the officials and agencies involved

Choice Parameters	Frequency	Cumulative Percent	Mean	Std dev	Var
Very Bad	210	60.0	1.87	1.321	1.744
Bad	63	8.0			
Okay	26	85.4			
Good	16	90.0			
Very Good	35	100.0			
Total	350				

Table 63: Descriptive statistics for the actions and attitudes of the officials and agencies involved

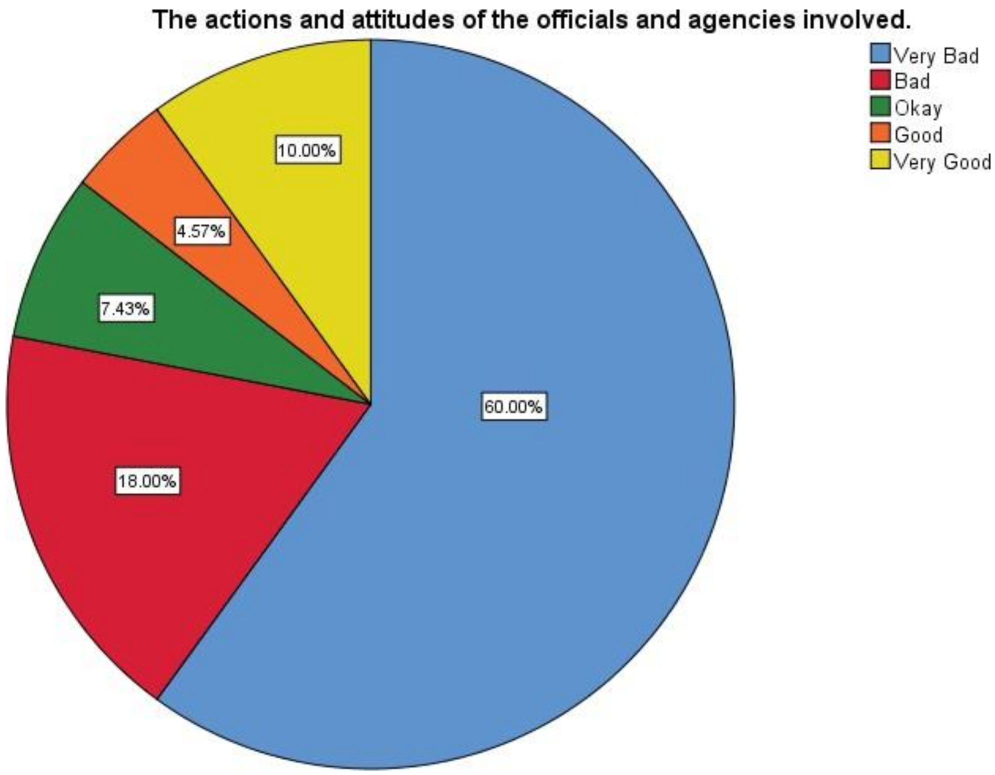


Figure 68: distribution of the actions and attitudes of the officials and agencies involved

Findings: The above pie chart and statistics table suggests that around 78% farmers are of the opinion that the officials who are involved in the process of subsidy are not having very positive outlook towards the applicants, their behaviour is something which is not acceptable to the farmers.

The measure of dispersion and CT are mean=1.87, std. dev. = 1.321 and Var = 1.744.

19. Time required to avail subsidy was appropriate.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std dev	Var
Very Bad	94	26.9	2.42	1.321	1.745
Bad	143	67.7			
Okay	27	75.4			
Good	45	88.3			
Very Good	41	100.0			
Total	350				

Table 64: Descriptive statistics for time required to avail subsidy was appropriate

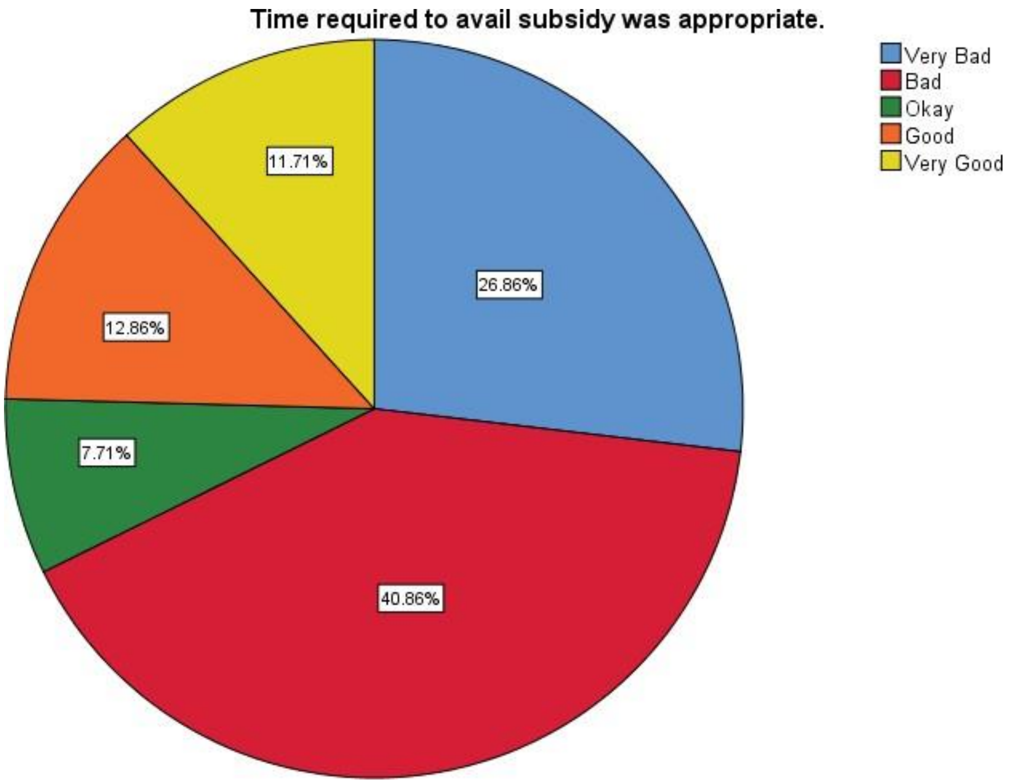


Figure 69: Distribution of time required to avail subsidy was appropriate

Findings: The above pie chart and statistics table suggests that around 67% farmers are of the opinion that time required to receive the subsidy is something which is really patience testing of the farmers, it took so long that sometimes farmer gives up. The measure of dispersion and CT are mean=2.42, std. dev. = 1.321 and Var = 1.745.

20. Transparency in the application process to avail for a subsidy

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Bad	216	61.7	2.49	0.701	0.491
Okay	104	91.4			
Good	24	98.3			
Very Good	6	100.0			
Total	350				

Table 65: Descriptive statistics for transparency in the application process to avail for a subsidy

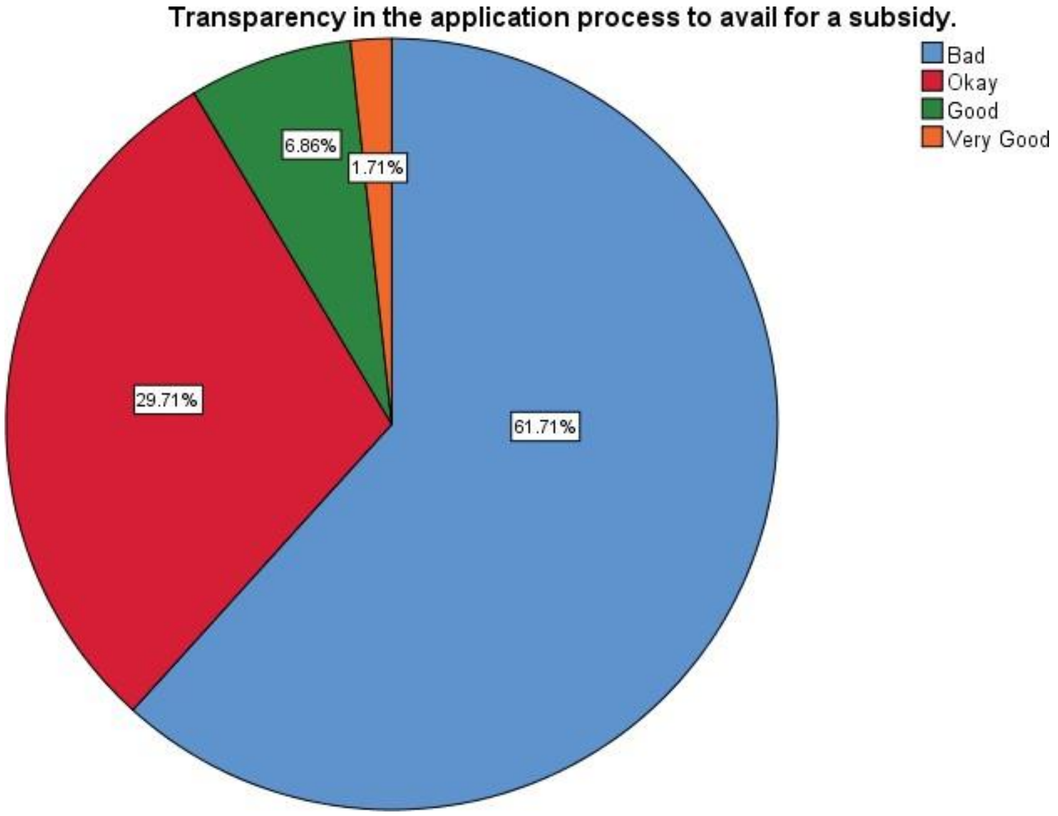


Figure 70: Distribution of transparency in the application process to avail for a subsidy

Findings: The above pie chart and statistics table suggests that around 91% farmers are of the opinion that the application process is very shady business where they believe that officers doesn't work transparently in scrutinizing and approving the applications of the farmers.

The measure of dispersion and CT are mean=2.49, std. dev. = 0.701 and Var = 0.491.

21. Because of the widespread use of micro irrigation systems, the soil quality on the farm has improved over time.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
No Change	11	3.1	4.70	0.522	0.272
Improved	82	26.6			
Highly Improved	257	100.0			
Total	350				

Table 66: Descriptive statistics for the widespread use of precision irrigation systems, the soil quality on the farm has improved over time

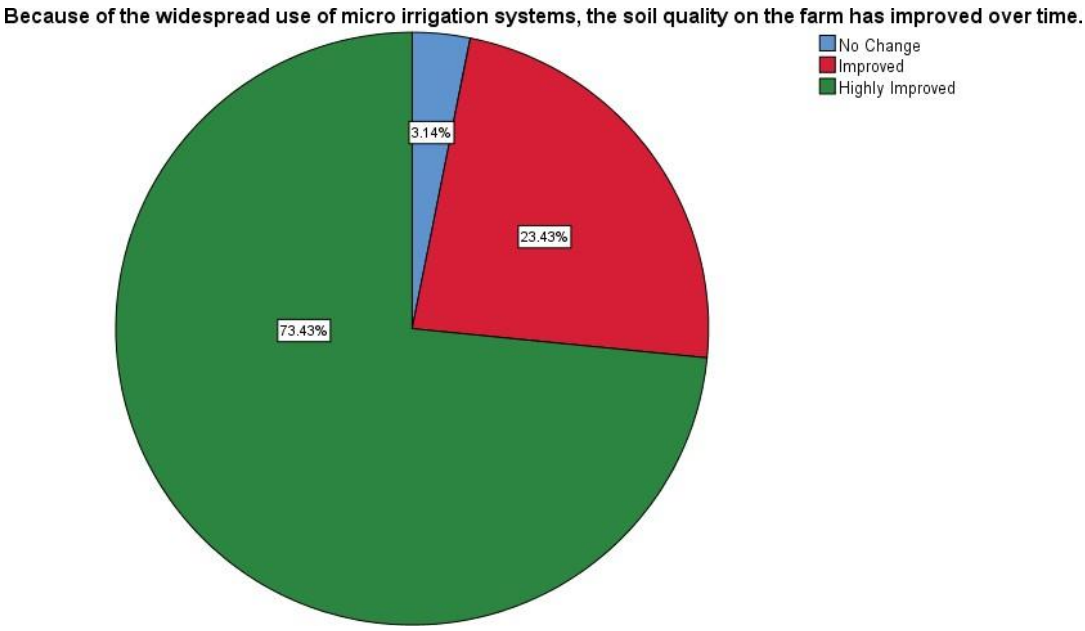


Figure 71: Distribution of the widespread use of precision irrigation systems, the soil quality on the farm has improved over time

Findings: The above pie chart and statistics table suggests that around 97% farmers said that due to the usage of this irrigation system has improved the quality of the soil of their farms over the period of time.

The measure of dispersion and CT are mean=4.70, std. dev. =0.522 and Var = 0.272.

22. A variety of terrains can be accommodated by precision irrigation systems.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Medium	12	3.4	4.76	0.503	0.253
High	61	20.9			
Very High	277	100.0			
Total	350				

Table 67: Descriptive statistics for a variety of terrains can be accommodated by precision irrigation systems

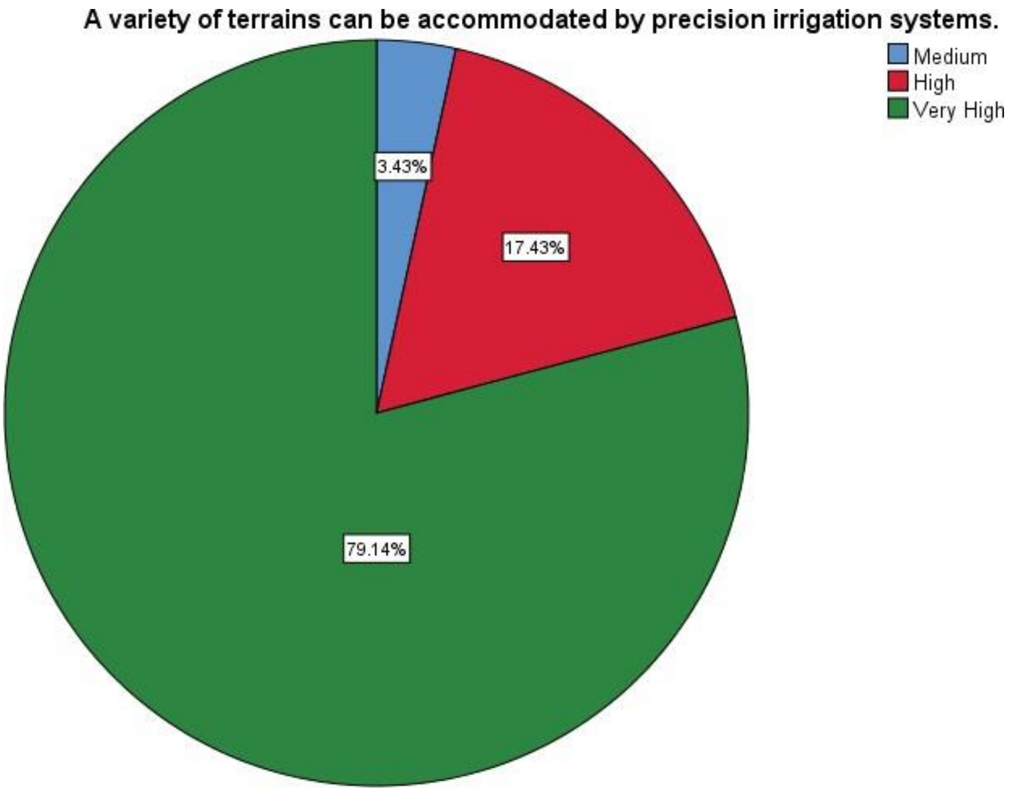


Figure 72: Distribution of a variety of terrains can be accommodated by precision irrigation systems

Findings: The above pie chart and statistics table suggests that around 96% farmers are of the opinion that precision irrigation system has help them to cultivate different types of lands and have maximum area under the cultivation.

The measure of dispersion and CT are mean=4.76, std. dev. = 0.503 and Var = 0.253.

23. Water distribution can be done equally with precision irrigation systems.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
No Impact	24	6.9	4.64	0.608	0.369
Positive	79	29.4			
Highly Positive	247	100.0			
Total	350				

Table 68: Descriptive statistics for water distribution can be done equally with precision irrigation systems

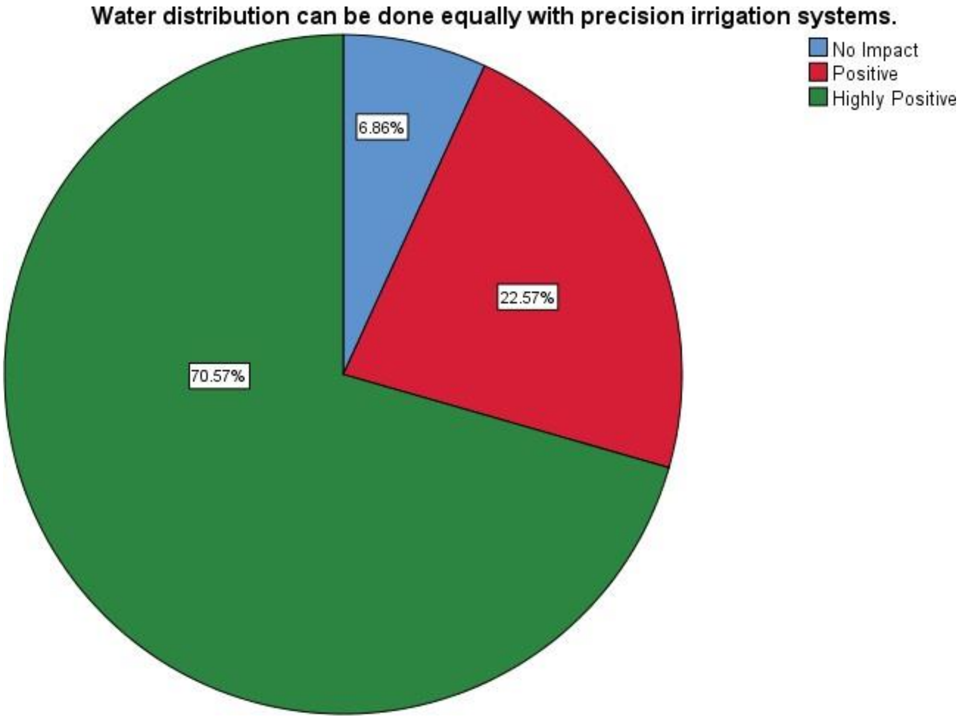


Figure 73: Distribution of water distribution can be done equally with precision irrigation systems

Findings: The above pie chart and statistics table suggests that around 93% farmers are of the opinion that with the help of precision irrigation system they can manage the water distribution in a well-defined manner and make sure that water gets equally over the land under the cultivation.

The measure of dispersion and CT are mean=4.64, std. dev. =0.608 and Var = 0.369.

24. The water wastage or misuse has drastically reduced due to the usage of precision irrigation systems.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Highly Negative	1	.3	4.77	0.571	0.326
Negative	3	1.1			
No Impact	11	4.3			
Positive	45	17.1			
Highly Positive	290	100.0			
Total	350				

Table 69: Descriptive statistics for the water wastage or misuse has drastically reduced due to the usage of micro irrigation systems

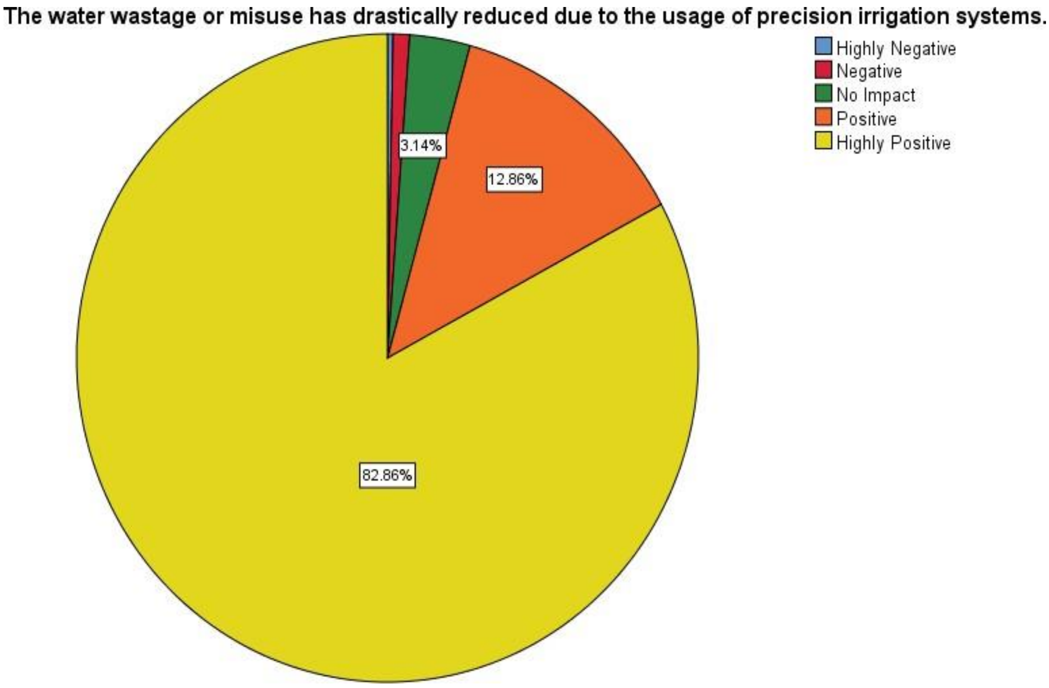


Figure 74: Distribution of the water wastage or misuse has drastically reduced due to the usage of precision irrigation systems

Findings: The above pie chart and statistics table suggests that around 95% farmers are of the opinion that mismanagement and wastage of water has been substantially reduced due to the usage of precision irrigation.

The measure of dispersion and CT are mean=4.77, std. dev. = 0.571 and Var = 0.326.

25. The water quality has been improved over the years due to the usage of precision irrigation systems.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
No Change	8	2.3	4.81	0.446	0.199
Improved	50	16.6			
Highly Improved	292	100.0			
Total	350				

Table 70: Descriptive statistics for the water quality has been improved over the years due to the usage of precision irrigation systems

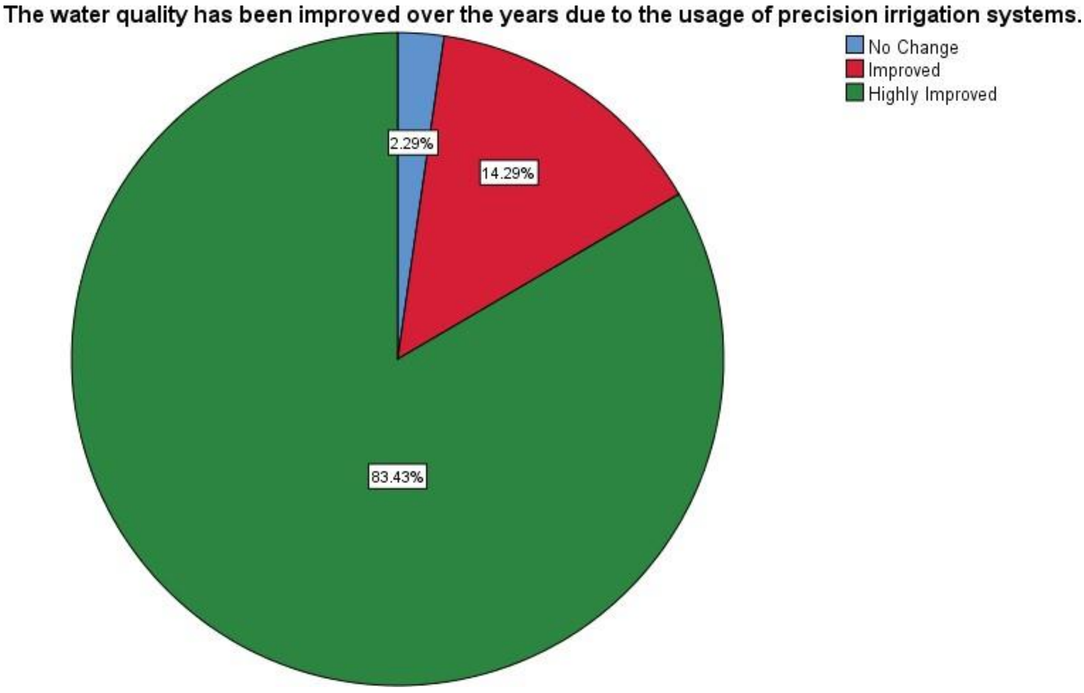


Figure 75: Distribution of the water quality has been improved over the years due to the usage of precision irrigation systems

Findings: The above pie chart and statistics table suggests that around 98% farmers believe that this irrigation system has improved the quality of water over the period of time.

The measure of dispersion and CT are mean=4.81, std. dev. = 0.446 and Var = 0.199.

26. Precision irrigation has reduced pest occurrences on crops.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Very Low	2	0.6	4.64	0.634	0.402
Medium	18	5.7			
High	81	28.9			
Very High	249	100.0			
Total	350				

Table 71: Descriptive statistics for precision irrigation has reduced pest occurrences on crops

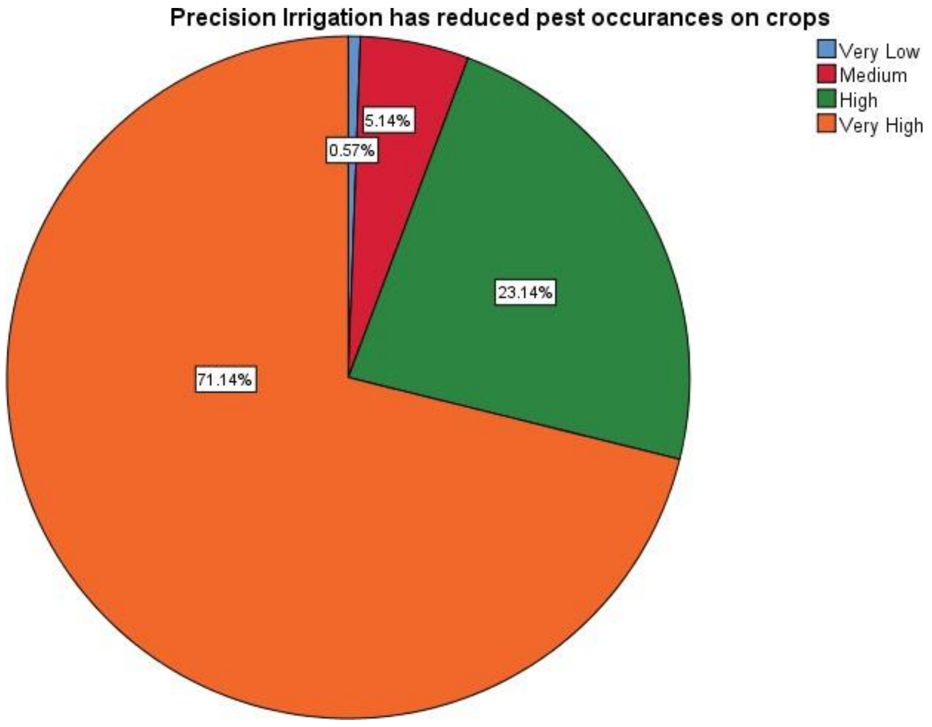


Figure 76: Distribution of precision irrigation has reduced pest occurrences on crops

Findings: The above pie chart and statistics table suggests that around 94% farmers said that they use sprays through the use of precision irrigation system with substantially reduced the pest occurrences on the crops.

The measure of dispersion and CT are mean=4.64, std. dev. = 0.634 and Var = 0.402.

27. Precision irrigation has helped in reducing the usage of pesticides.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Highly Negative	2	0.6	4.65	0.671	0.450
Negative	2	1.1			
No Impact	21	7.1			
Positive	65	25.7			
Highly Positive	260	100.0			
Total	350				

Table 72: Descriptive statistics for precision irrigation has helped in reducing the usage of pesticides

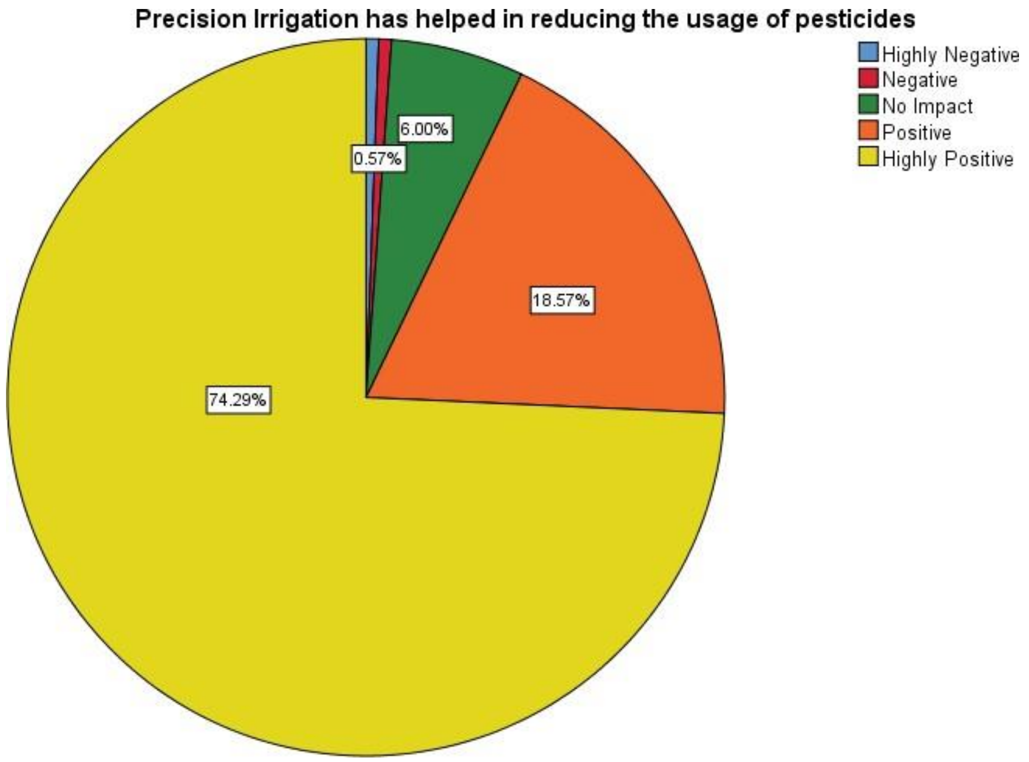


Figure 77: Distribution of precision irrigation has helped in reducing the usage of pesticides

Findings: The above pie chart and statistics table suggests that around 93% farmers said that these irrigation systems are useful in sprinkling pesticides with maximum land coverage hence the required pesticides are used low by the farmers.

The measure of dispersion and CT are mean=4.65, std. dev. =0.671 and Var = 0.450.

28. Precision irrigation has helped in reducing the cost of pesticides.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std dev	Var
Negative	1	0.3	4.58	0.631	0.399
No Impact	24	7.1			
Positive	95	34.3			
Highly Positive	230	100.0			
Total	350				

Table 73: Descriptive statistics for precision irrigation has helped in reducing the cost of pesticides

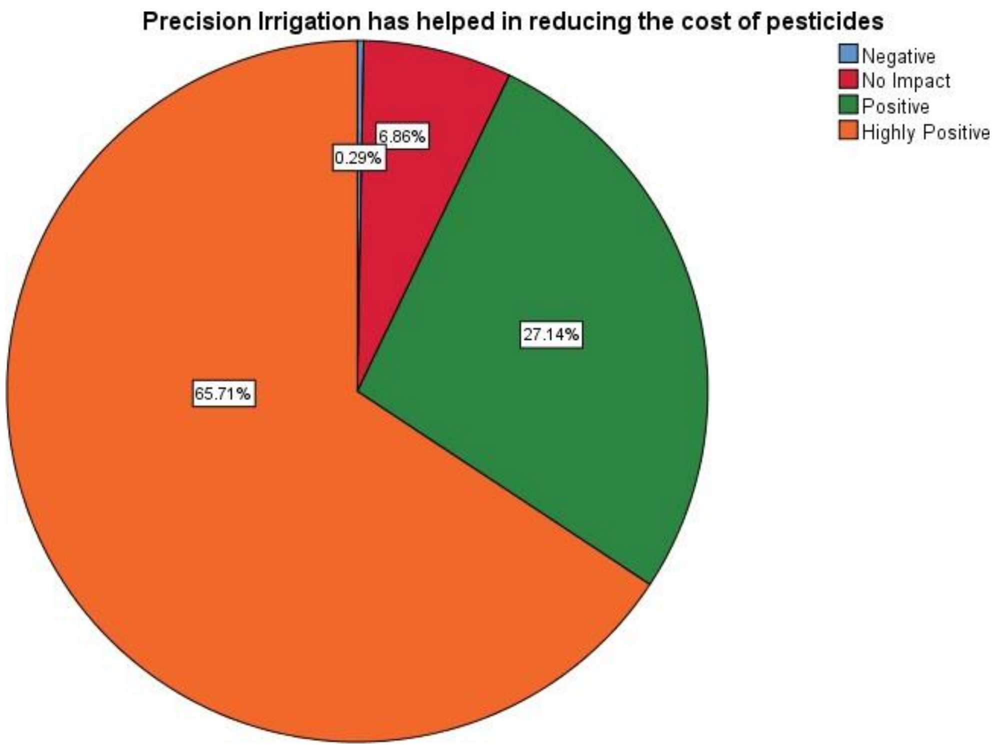


Figure 78: Distribution of precision irrigation has helped in reducing the cost of pesticides

Findings: The above pie chart and statistics table suggests that around 93% farmers are of the opinion that since the usage of pesticides is getting reduced this has helped them to cut down the cost because the required amount of pesticides got reduced.

The measure of dispersion and CT are mean=4.58, std. dev. = 0.631 and Var = 0.399.

29. Precision irrigation has helped in curbing disease outbreak.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Medium	28	8.0	4.60	0.633	0.401
High	84	32.0			
Very High	238	100.0			
Total	350				

Table 74: Descriptive statistics for precision irrigation has helped in curbing disease outbreak

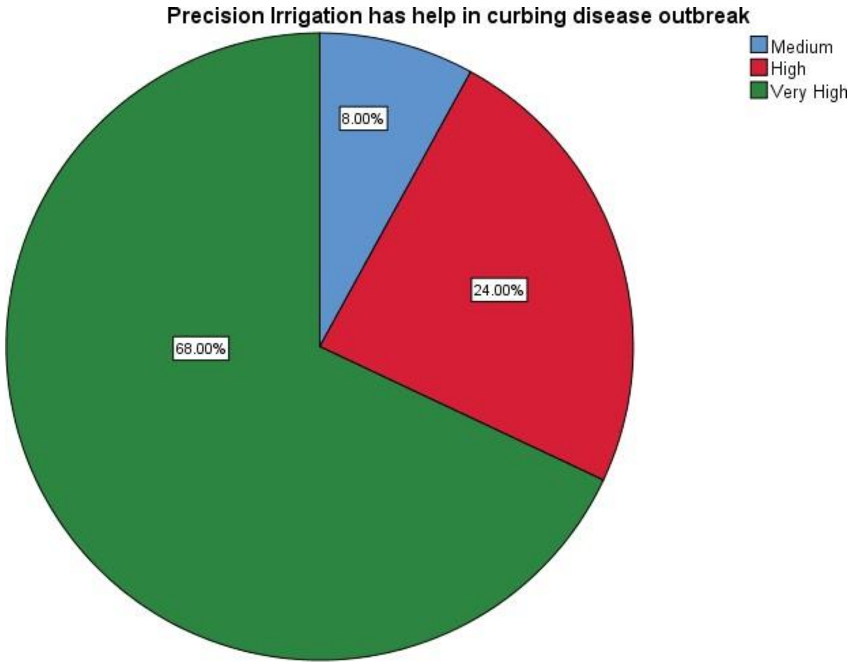


Figure 79: Distribution of precision irrigation has helped in curbing disease outbreak

Findings: The above pie chart and statistics table suggests that around 92% farmers believe that the wide area coverage of land with the precision irrigation systems has helped them to spray the pesticides quickly has helped to control the disease outbreak on a larger scale.

The measure of dispersion and CT are mean=4.60, std. dev. = 0.633 and Var = 0.401.

30. Precision irrigation has helped in the reduction of weeds.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Very Low	4	1.1	4.61	0.693	0.480
Low	2	1.7			
Medium	12	5.1			
High	92	31.4			
Very High	240	100.0			
Total	350				

Table 75: Descriptive statistics for precision irrigation has helped in the reduction of weeds

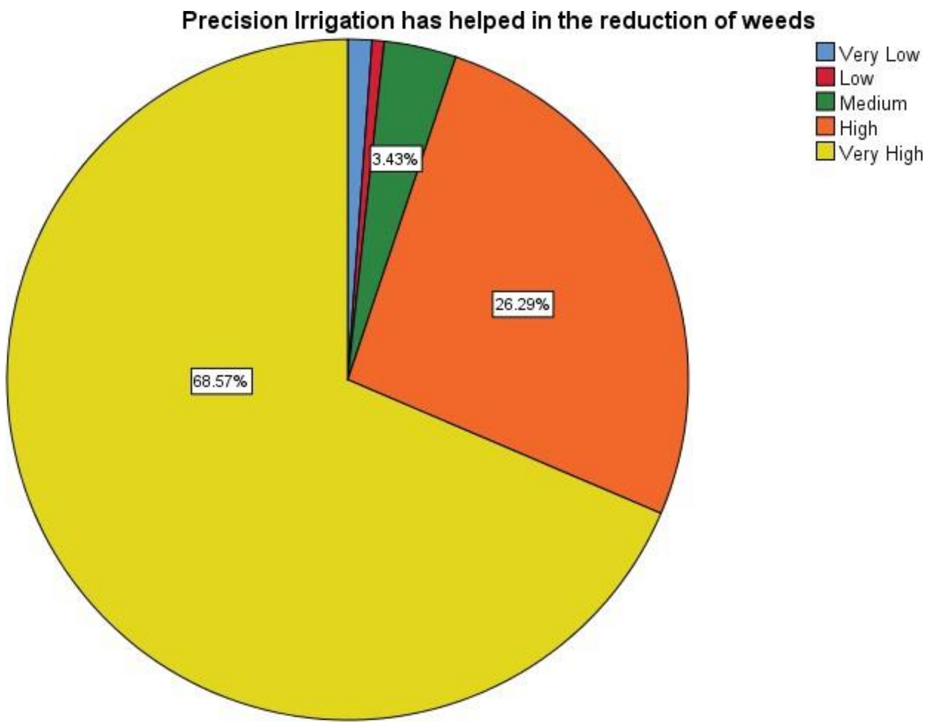


Figure 80: Distribution of precision irrigation has helped in the reduction of weeds

Findings: The above pie chart and statistics table suggests that around 95% farmers said that precision irrigation systems has helped them to control the water supply and reduce the supply of unwanted water this leads to the curb of weed growing in the farms.

The measure of dispersion and CT are mean=4.61, std. dev. = 0.693 and Var = 0.480.

31. Precision Irrigation has helped in reducing the cost of harvesting.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Negative	1	0.3	4.80	0.492	0.242
No Impact	11	3.4			
Positive	46	16.6			
Highly Positive	292	100.0			
Total	350				

Table 76: Descriptive statistics for precision irrigation has helped in reducing the cost of harvesting

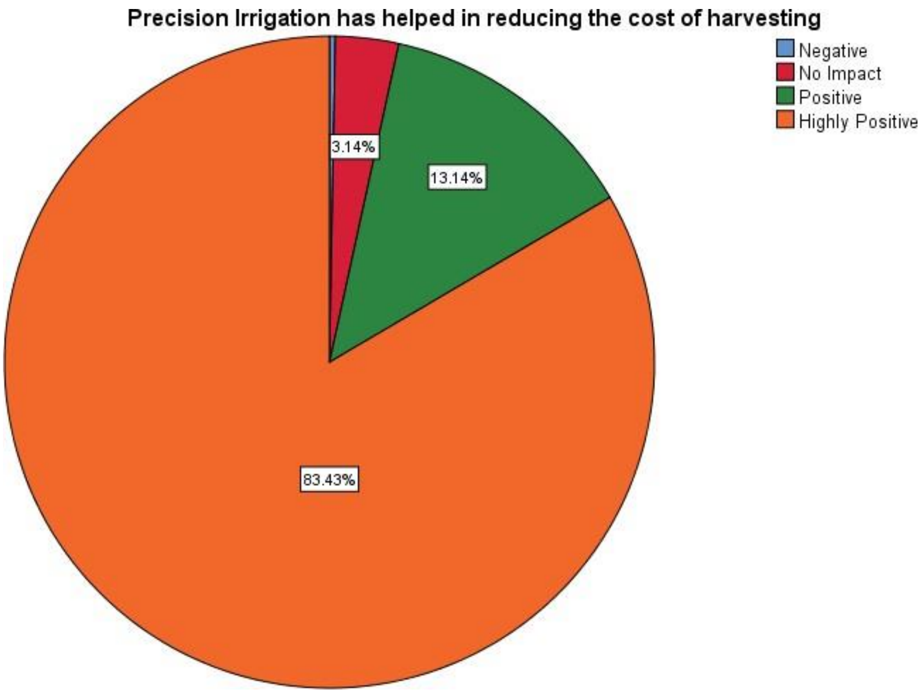


Figure 81: Distribution of precision irrigation has helped in reducing the cost of harvesting

Findings: The above pie chart and statistics table suggests that around 96% farmers said that since the unwanted weeds doesn't grow hence the cost of harvesting got low since to eliminate those weeds are not required that much now with the usage of precision irrigation systems.

The measure of dispersion and CT are mean=4.80, std. dev. =0.492 and Var = 0.242.

32. Precision irrigation has helped in reducing the labour requirement drastically.

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Very Low	38	10.9	4.13	1.377	1.897
Low	23	17.4			
Medium	14	21.4			
High	55	37.1			
Very High	220	100.0			
Total	350				

Table 77: Descriptive statistics for precision irrigation has helped in reducing the labour requirement drastically

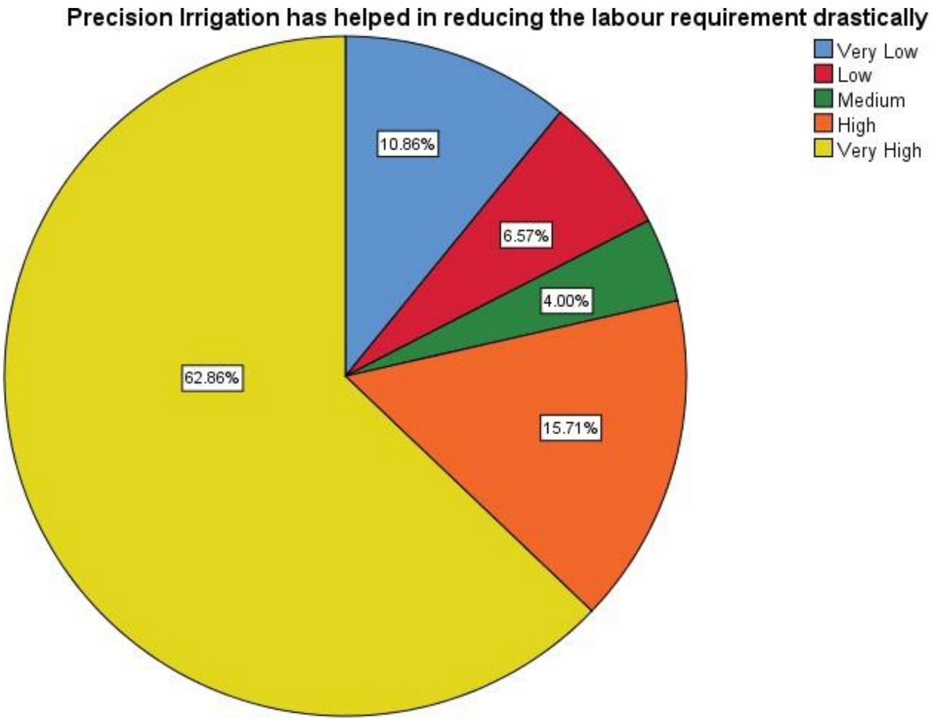


Figure 82: Distribution of precision irrigation has helped in reducing the labour requirement drastically

Findings: The above pie chart and statistics table suggests that around 82% farmers has opinion that the harvesting not required much hence the manpower required also gets reduced.

The measure of dispersion and CT are mean=4.13, std. dev. = 1.377 and Var = 1.897.

33. How is the overall water situation in your village due to the precision irrigation systems?

Choice Parameters	Frequency	Cumulative Percent	Mean	Std Dev	Var
Highly Negative	3	.9	4.64	0.686	0.471
Negative	4	2.0			
No Impact	12	5.4			
Positive	77	27.4			
Highly Positive	254	100.0			
Total	350				

Table 78: Descriptive statistics for how is the overall water situation in your village due to the precision irrigation systems

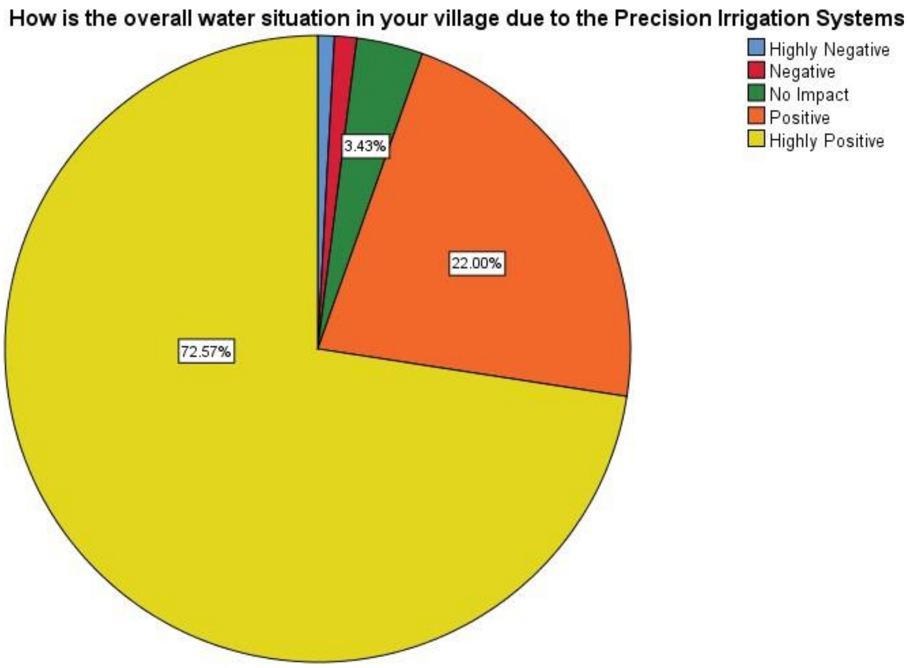


Figure 83: Distribution of how is the overall water situation in your village due to the precision irrigation systems

Findings: The above pie chart and statistics table suggests that around 95% farmers are of the opinion that the precision irrigation systems is saving water which has resulted into the betterment of water situation in the villages.

The measure of dispersion and CT are mean=4.64, std. dev. = 0.686 and Var = 0.471.

34. What happens to the saved water due to the Precision Irrigation Systems?

Choice Parameters	Frequency	Cumulative Percent	Mean	Std dev	Var
Used for other non-agricultural purposes	36	10.3	4.21	1.281	1.642
Used for other agriculture and related purposes	6	12.0			
Used for more irrigation to the same crops	23	18.6			
Used for expanding area under agriculture	67	37.7			
Used for irrigating more crops	218	100.0			
Total	350				

Table 79: Descriptive statistics for what happens to the saved water due to the precision irrigation systems

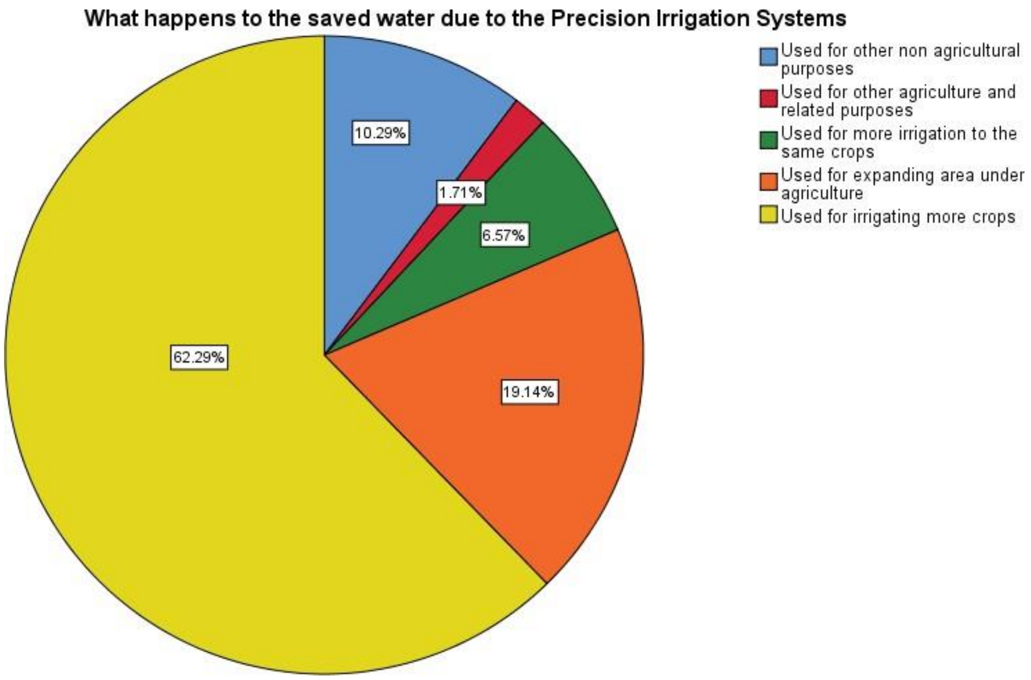


Figure 84: Distribution of what happens to the saved water due to the precision irrigation systems

Findings: The above pie chart and statistics table suggests that around 62% farmers said that the saved water is getting used into irrigating more crops while 19% farmers said that saved water has helped them to bring more land area under cultivation.

The measure of dispersion and CT are mean=4.21, std. dev. =1.281 and Var = 1.642.

4.2 Hypotheses Testing

Research Question-1:

Is there a variation in the adoption factors among the farmers regarding precision irrigation systems?

Statistical Test: Friedman Test

Hypothesis:

Null (H0): There is no variation in the adoption factors among the farmers regarding precision irrigation systems.

Alternate (HA): There is a variation in the adoption factors among the farmers regarding precision irrigation systems.

Test Statistics:

N	350
Chi-Square	87.623
df	9
p-value	.000

Observation:

z2(9) = 87.623, p<0.01.

There was a statistically significant variation in the adoption factors among the farmers regarding precision irrigation systems.

To understand the variation, we will have a look on the below mentioned ranks table:

Adoption Factors	Mean Rank
Researchers influence	5.92
The irrigation equipment dealer's influence	5.81
Self-interest	5.76
They are getting public attention due to the installation of precision irrigation systems	5.66
When summer arrives, water is low in supply	5.61
Mass media's influence	5.60
Need for achievement	5.40
Difficulty in finding workers knowing irrigation systems	5.27
Influence of friends and family	5.24
Subsidy availability	4.74

Table 80: Perception of farmers about the factors affecting adoption of precision irrigation systems

The above rank table suggests that influence due to researchers who write in newspapers or the influence of dealers who sell irrigation systems, the self-interest or public attention because of using precision irrigation system are the top four reasons why the farmers adopt the precision irrigation systems. Interesting to know that subsidy that plays a critical role in many cases for installation of precision irrigation systems has a lower rank than other factors.

Research Question-2:

Is there a variation in the factors that create a hurdle in adopting precision irrigation systems amongst the farmers?

Statistical Test: Friedman Test

Hypothesis:

Null (H0): There is no variation in the factors that create a hurdle in adopting precision irrigation systems amongst the farmers.

Alternate (HA): There is a variation in the factors that create a hurdle in adopting precision irrigation systems amongst the farmers.

Test Statistics:

N	350
Chi-Square	129.218
df	8
p-value	.000

Observation:

$z2(8) = 129.218$, $p<0.01$.

There was statistically significant variation in the factors that create a hurdle in adopting precision irrigation systems.

To understand the variation, we will have a look at the below- mentioned ranks table:

Factors Creating Hurdles in Adoption	Mean Rank
Voltage Fluctuations	5.53
Power shortages	5.44
In regions where there is enough water, farmers are happy with conventional irrigation methods	5.29
A lot of people have quit using the precision irrigation system	5.15
Lack of water for irrigation leads to water availability sufficient just for household use	4.89
Lack of information and awareness of drip/sprinkler irrigation	4.87
The water delivered by the drip method is insufficient for proper crop growth, so it is believed	4.84
Water that is of poor quality may block a drip/sprinkler system	4.68
The initial expenditure is high	4.30

Table 81: The variation in farmers' perception about the factors creating hurdles for the adoption of precision irrigation systems

The above rank table suggests that repeatedly farmers are facing variation in voltages and power dark out or abundance of water or has stopped using the precision irrigation systems are the top four factors that create a hurdle for farmers in adopting the precision irrigation systems. The exciting fact is that expenses to install the system or awareness about the systems or the water getting available with precision irrigation systems are at the lower rank, which suggests that farmers do not perceive much about these compared to other factors that create a hurdle in adopting to precision irrigation systems.

Research Question-3:

Is there a variation in the factors creating challenges in operating and maintaining the precision irrigation systems?

Statistical Test: Friedman Test

Hypothesis:

Null (H0): There is no variation in the factors creating challenges in operating and maintaining the precision irrigation systems.

Alternate (HA): There is a variation in the factors creating challenges in operating and maintaining the precision irrigation systems.

Test Statistics:

N	350
Chi-Square	73.032
df	8
p-value	.000

Observation:

$$\mathbf{z^2(8) = 73.032}, \; p<0.01.$$

There was statistically significant variation in the factors creating challenges in operating and maintaining the precision irrigation systems.

To understand the variation, we will have a look at the below-mentioned ranks table:

Challenges in operating and maintaining precision irrigation systems	Mean Rank
Pipelines and drippers are prone to damage by wild animals	5.39
Pipeline and dripper damage from rats	5.37
Poor power supply	5.28
A system clog from contaminants in irrigation water	4.95
Substandard post-sales service	4.92
A lack of understanding about utility, operations, and maintenance	4.86
Voltage malfunction	4.85
Ground-level weed concentration	4.75
Technical guidance received too late from the dealer's technicians	4.62

Table 82: The variation in perception of farmers about the challenges in operating and maintaining precision irrigation systems

The above rank table suggests that precision irrigation systems are generally prone to damage by wild animals as well as rats also there is a problem of poor power supply and clogging of system due to water are the top challenges farmers face while operating and maintaining precision irrigation systems.

Research Question-4

According to the qualification groups, is there any difference in the perceived benefits of using precision irrigation systems for farming?

Statistical Test: One-way ANOVA

Hypothesis:

Null (H0): According to the qualification groups, there is no difference in the perceived benefits of using precision irrigation systems for farming. (Group means are equal)

Alternate (HA): According to the qualification groups, there is a difference in the perceived benefits of using precision irrigation systems for farming. (Group means are not equal)

Test Statistics:

ANOVA					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	11.063	3	3.688	12.460	.000
Within Groups	102.401	346	.296		
Total	113.463	349			

Observation:

$$F\ (3,346) = 12.460,\ p<0.01$$

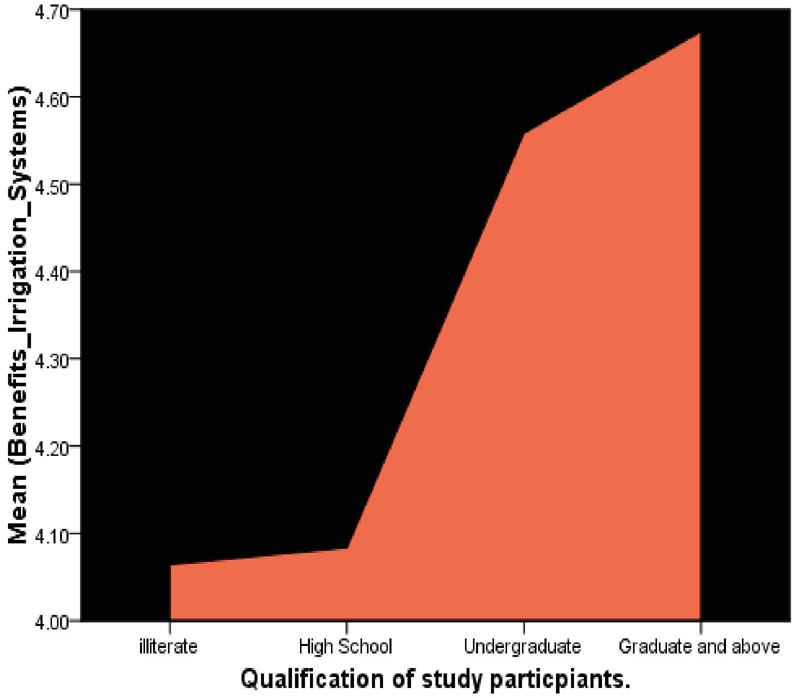
From the above ANOVA table, we can say that there is a difference in the benefits perceived by the farmers of using precision irrigation systems.

To understand the difference, we will have to look into posthoc test, particularly tukey, to see this, which has been mentioned below:

Multiple Comparisons						
Dependent Variable: Benefits_Irrigation_Systems						
Tukey HSD						
(I) Qualification of study participants.	(J) Qualification of study participants.	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
illiterate	High School	-.01923	.21995	1.000	-.5870	.5486
	Undergraduate	-.49446*	.12403	.000	-.8146	-.1743
	Graduate and above	-.61083*	.11228	.000	-.9007	-.3210
High School	illiterate	.01923	.21995	1.000	-.5486	.5870
	Undergraduate	-.47523	.20247	.090	-.9979	.0475
	Graduate and above	-.59160*	.19549	.014	-1.0963	-.0869
Undergraduate	illiterate	.49446*	.12403	.000	.1743	.8146
	High School	.47523	.20247	.090	-.0475	.9979
	Graduate and above	-.11637	.07227	.374	-.3029	.0702
Graduate and above	illiterate	.61083*	.11228	.000	.3210	.9007
	High School	.59160*	.19549	.014	.0869	1.0963
	Undergraduate	.11637	.07227	.374	-.0702	.3029
*. The mean difference is significant at the 0.05 level.						

A Tukey post hoc test revealed that the benefits perceived are more if the farmers belong to education group of undergraduate (4.5 ± .511 min, $p<0.01$) and graduate and above (4.67 ± .557 min, p<0.01 .034) as compared to the illiterate or high school schooling.

To understand the difference pictorially, we will follow the means plot given below:



From the above means plot, it is evident that the more the farmers are educated, the more they can understand the benefits of a precision irrigation system for farming.

Research Question-5

Is there any association between the annual income of the farmers and availing the subsidy for precision irrigation system by the farmers?

Statistical Test: Chi-square Test of Association

Hypothesis:

Null (H0): There is no association between the annual income of the farmers and availing the subsidy for precision irrigation system by the farmers.

Alternate (HA): There is an association between the annual income of the farmers and availing the subsidy for precision irrigation system by the farmers.

Test Statistics:

Chi-Square Tests			
	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	13.659	4	.008
Likelihood Ratio	15.589	4	.004
Linear-by-Linear Association	.417	1	.518
N of Valid Cases	350		

Observation:

z (4) = 13.659, p<0.01

Since the p value is less than 0.05 we reject the null and accept alternate which suggest that there is an association between the annual income of the farmers and availing the subsidy for precision irrigation system by the farmers.

To understand it visually we will follow a bar chart given below which depicts this association in more elaborative way.

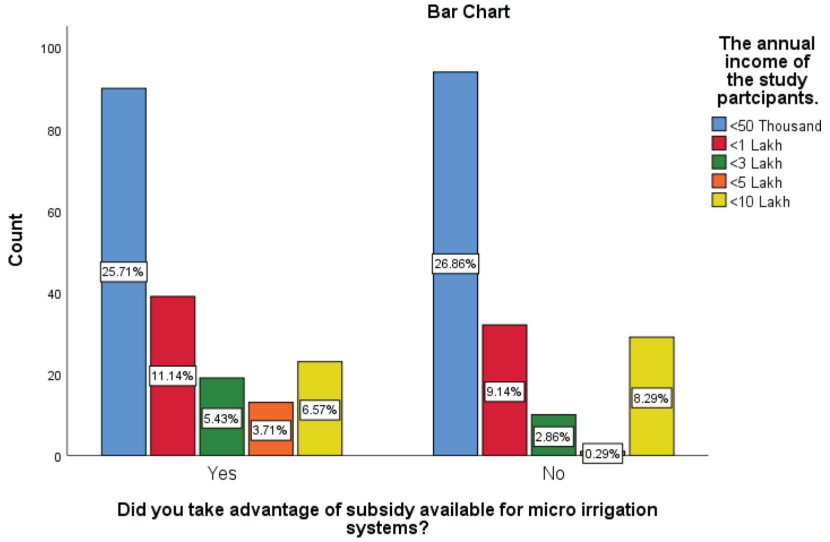


Figure 85: Advantage of subsidy on micro-irrigation

From the above table we can say that the farmers who avail the subsidy are more in the annual income group of having less than 50 thousand incomes.

The descriptive table will give more idea about the distribution which is given below:

Did you take advantage of subsidy available for micro irrigation systems? * The annual income of the study participants. Cross tabulation									
			The annual income of the study participants.					Total
			<50 Thousand	<1 Lakh	<3 Lakh	<5 Lakh	<10 Lakh	
Did you take advantage of subsidy available for micro irrigation systems.	Yes	Count	90	39	19	13	23	184
		% within Did you take advantage of subsidy available for micro irrigation systems?	48.9%	21.2%	10.3%	7.1%	12.5%	100%
		% within The annual income of the study participants.	48.9%	54.9%	65.5%	92.9%	44.2%	52.6%
		% of Total	25.7%	11.1%	5.4%	3.7%	6.6%	52.6%
	No	Count	94	32	10	1	29	166
		% within Did you take advantage of subsidy available for micro irrigation systems?	56.6%	19.3%	6.0%	0.6%	17.5%	100%
		% within The annual income of the study Participants.	51.1%	45.1%	34.5%	7.1%	55.8%	47.4%
		% of Total	26.9%	9.1%	2.9%	0.3%	8.3%	47.4%

Total	Count	184	71	29	14	52	350
	% within Did you take advantage of subsidy available for micro irrigation Systems?	52.6%	20.3%	8.3%	4.0%	14.9%	100%
	% within The annual income of the study Participants.	100.0%	100%	100%	100%	100%	100%
	% of Total	52.6%	20.3%	8.3%	4.0%	14.9%	100%

The above table clearly indicates that the maximum respondents are from the income of less than 50 thousand and then the respondents from one lakh followed by the respondents from less than ten lakh, the lowest count was for respondents who are having income more than three lakhs but less than five lakhs who avail the subsidy to install the precision irrigation systems to do the farming.

Research Question-6

Is there any correlation between soil health, water management and pest management due to the installation of precision irrigation systems?

Statistical Test: Pearson Correlation

Hypothesis:

Null (H0): There is no correlation between soil health, water management and pest management due to the installation of precision irrigation systems.

Alternate (HA): There is a correlation between soil health, water management and pest management due to the installation of precision irrigation systems.

Test Statistics:

Pearson's Correlations					
			Pearson's r		**p value**
Soil Health	-	**Water Management**	0.344	***	< .001
Soil Health	-	**Pest Management**	0.464	***	< .001
Water Management	-	**Pest Management**	0.514	***	< .001
*** p < .05, ** p < .01, *** p < .001**					

From the above correlation table we can say that there is a strong correlation between managing water through precision irrigation and pest management as well as soil health and pest management.

Research Question-7

Is there any correlation between cost involved into using precision irrigation systems and water situation due to precision irrigation system?

Statistical Test: Pearson Correlation

Hypothesis:

Null (H0): There is no correlation between cost involved into using precision irrigation systems and water situation due to precision irrigation system.

Alternate (HA): There is a correlation between cost involved into using precision irrigation systems and water situation due to precision irrigation system.

Test Statistics:

Pearson's Correlations					
			Pearson's r		**p value**
Cost Involved into using Precision Systems	-	**Water Situation Betterment**	0.416	***	< .001
*** p < .05, ** p < .01, *** p < .001**					

From the above correlation table we can say that there is a strong correlation between cost involved into using precision irrigation systems and water situation due to precision irrigation system. Hence as the cost goes down in managing and using precision irrigation system the more the better situation will be there of water availability for cultivation to the farmers.

Chapter-5: Conclusions and Recommendations and Scope for Future Research

5. 1 Conclusions of Research Study

1. After analyzing data, the researcher concludes that the farmers are educated now and have at least a graduation degree. Also, we can conclude that families with fewer members have lesser landholding than families with more members. From the income point of view, we can conclude that farmers having up to 2 hectares of land have less than 50 thousand income whereas 2.5 and above people are earning good, this suggests that farmers with more than 2.5 hectares are experimenting strongly with their farm's ideas as compared to the lesser landholding farmers.

2. Based on the water source, we conclude that farmers using tube well water have good soil health. It also creates a better situation of water availability in villages.

3. The other conclusion that we can draw is that farmers understand the risk associated with the farming approaches, and hence to do the risk mitigation, they are ready to use the multi-crop approach as they understand it is worth taking risks to experiment such things as it pays financially well to them.

4. The motivation that farmers are having in using the precision irrigations systems is that they understand that these systems will help them in watering more crops, and since water requirement is less, they can cover more areas and experiment with new crops, which will help them to increase their revenues or profits after the harvesting.

5. Numerous factors play a critical role in the adoption of precision irrigation systems; after the analysis, we conclude that different researchers getting published through mass media and being in the limelight of the public because of the installation of these systems are the critical factors adopting the precision irrigations systems. However, other factors are also there, but subsidy and family influence are not influencing that much pressure for adoption.

6. As we have seen the different factors of adoption of precision irrigation systems, we try to understand the different factors that create hurdles in adopting such systems leading to the non-adapter farmers. We conclude that villages still lack adequate infrastructure, especially in terms of the supply of power. Because of this hurdle, farmers believe that inconsistent power supplies and fluctuation in them lead to the failure or non-usability of such systems when required. People who have already experienced these irrigation technologies and have given up using them are leading to non-adopters.

7. After concluding, the various factors played a role in the adoption or non-adoption of precision irrigation systems. Now we will investigate how challenging it for the farmers is to operate and maintain these systems.
   Different challenges put farmers into a fix of how to operate and maintain these precision systems. The main significant challenges that farmers face are because rodents or wild animals are the major factors. After all, it creates damage to these irrigation systems on a larger scale.

8. Also, the researcher concludes that since graduate farmers are more, they understand the benefits they can have because of the precision irrigation systems, their education helps them understand different technicalities involved in installing, operating and maintaining such systems. Hence, the benefits received are less usage of power more coverage of land area cultivation leading to more income. This collectively creates a package of benefits that farmers believe in and adapt to precision irrigation systems.

9. When it comes to the question of subsidy, we conclude that farmers having income less than 50 thousand are availing the subsidy but the amount involved in the subsidy is considerably good, which disrupts the attitude of the officers involved in the subsidy process does not make it a smooth affair which demotivates lots of farmers from adopting the precision irrigation systems. The time involved in availing the subsidy is very high, disrupting the farmers' farming cycle and putting them at a loss.

10. As we have seen from the analysis that precision irrigation systems help in covering a large area of land with minimal cost in terms of water supply, we can conclude that farmers can expect high yields because of less usage of pesticides and the high impact of pesticides on pest control leads to cost saving in pesticides and the reduced manpower requirements.

11. The significant issues that farmers face in using these precision irrigation systems are the assistance from dealers and knowledgeable labourers for operating or maintaining such systems. This leads to the conclusion that the farmers have to bear the consequence of systems failures or to make these irrigations error-free in delivering a consistent water supply from time to time.

12. As we have seen from analysis, soil health is improving much more due to the usage of precision irrigation systems, and the soil is helping farmers conserve more water and use it strategically for other purposes apart from agriculture.

13. Also, we can conclude that since the water situation has been improved because of the better management of water and reducing the wastages, farmers can now use this water for other purposes than irrigation and fulfil the farmers' demands at grass root level adequately.

14. Since the coverage of land area can be done more with irrigation systems, this leads to the conclusion that now the farmers can make the use of different terrains to do their farming work using these precision irrigation systems at large as these systems will help to deliver that required water to all sort of lands at length and breadth.

5.2 Recommendations

The researcher has understood the outcomes of the research study, and based on that, the following recommendations have been made in two parts: farmers and policymakers.

Recommendations for Farmers

1. The farmers should make sure that the weed concentration in their respective lands should be minimal since it will help layout the irrigation systems quickly, and also it will help in managing and maintaining those systems can happen effectively.

2. The clogging of systems may damage the precision irrigation systems; hence the filters should be checked timely and replaced so that the systems do not clog, and the water delivery should occur consistently.

3. The tube well is the primary source of what farmers are using for irrigation hence the tube well should be well maintained, and farmers should build it in concrete or say pukka construction so that contamination of water will not happen due to the unwanted elements that fall into those tube wells.

4. The farmers with abundant water available to them should also adopt the precision irrigation systems as it will help in water conservation at large, and the extra water can be routed to water scare areas or villages having low water availability.

5. The farmers should use a mechanism such as poison bait or pitfall or pot trap to get rid of the rodents as we have seen these rodents damage the precision irrigation systems pipeline or other devices on the field.

6. Finding labour or manpower who can assist in the management of irrigation is tough hence the farmers should train themselves in precision irrigation systems maintenance and installations to become self-sufficient and train the labour or manpower they will use for managing these systems.

7. The farmers should fence the farms to stay away from wild animals who can destroy the systems. Also, they can use sound systems because wild animals will fear and not try to step into farms. This way, they can protect the systems from damage.

8. Since farmers are ready to experiment with new ideas that can protect them from crop failures by using multi crops, the farmers should build their knowledge around different crops that can complement each other and strategically the water can be utilized to water the crops.

Recommendations for Policy Makers

1. There are water conservation benefits of using precision irrigation technology, but these benefits are only apparent if the system is used widely and preferably at the group level of water scarcity villages.
   To maximize the conservation benefits of precision irrigation systems, policymakers should focus on the different research related to water usage in farming effectively and the agro economics with different geographical territories. This also necessitates support from policymakers so that farmers can use these irrigation systems over the long term to receive such systems' benefits.

2. Creating more significant market connections is critical for policymakers to get better market prices for precision irrigation systems. The technology has many benefits, but they come at a high price, and there is little protection against price concerns.
   As a result, policymakers are required to put a specific cap on these prices; hence it can be available to the farmers at a reasonable price.

3. Precision irrigation systems have several issues right now, including after-sales service. To address these drawbacks, policymakers should build a program for entrepreneurs to become service providers to farmers to resolve these issues and provide cost-effective precision irrigation solutions.

4. Many farmers find the subsidy process to be confusing, time-consuming, and inconvenient. This necessitates that policymakers revise laws to streamline the subsidy process and make it more convenient, transparent, and efficient for famers expecting to get subsidies for installing precision irrigation systems.

5. As many farmers still have not adopted the precision irrigation systems, the policymakers should devise training programs to educate non-adopters. Also, they should attempt to clear all the doubts and misunder-standings they are holding with them about the precision irrigation systems through other farmers who have stopped using such systems or rumours or from other sources and also create a process to tap which are the farmers who have undergone training has adopted the precision irrigation systems.

5.3 Scope of Future Research Study

The study has helped to explore different features of precision irrigation systems, and hence researcher has specific points which future researchers can ponder upon.

1. The researchers can study the drought region versus the regions having more rainfall and understand the usage of precision irrigation systems and their benefits.
2. Also, there is a scope to study the subsidy programs availed by different farmers among different geographic regions, and hence they can draw upon comparisons about the subsidy from the disbursement point of view and the problems faced by farmers.
3. The researchers can also study the technological advancements in managing and precision irrigation systems.
4. The study can be conducted on pest management using precision irrigation systems as in how controlled it is and its cost.
5. The study can also be done from the agricultural economic point of view on farming with precision irrigation vs conventional irrigation and the outcome as in productivity, quality and the income generated from the crops.

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Appendix-Questionnaire

Structured Questionnaire

* Required

1. Age group you belong to. *

Mark only one oval.

- <30 years
- 30-40 years
- 40-50 years
- 50-60 years
- 60+ years old

2. Qualification of study particpiants. *

Mark only one oval.

- illiterate
- Primary
- High School
- Undergraduate
- Graduate and above

3. Size of the family (number of members in family). *

Mark only one oval.

- <5 Members
- 5-10 Members
- More than 10 Members

4. The land holding size in hactares. *

Mark only one oval.

- <1.0 ha
- 1-2 ha
- 2.5 ha
- 5-10 ha
- 10+ ha

5. The annual income of the study partcipants. *

Mark only one oval.

- <50 Thousand
- <1 Lakh
- <3 Lakh
- <5 Lakh
- <10 Lakh

6. What is the source of water for Precision Irrigation Systems *

Mark only one oval.

- From Tanks
- From Rivers
- From Canal
- From Open Well
- From Tube Well

7. The willingness of the farmer to invest in adoption of precision irrigation technologies from his available potential resources. (To earn a profit, a farmer must prioritise higher yields.) *

Mark only one oval.

- Strongly Disagree
- Disagree
- Not sure
- Agree
- Strongly Agree

8. The willingness of the farmer to invest in adoption of precision irrigation technologies from his available potential resources. (A farmer must make his living, yet economic definition cannot determine the most important thing in life.) *

Mark only one oval.

- Strongly Disagree
- Disagree
- Not sure
- Agree
- Strongly Agree

9. The willingness of the farmer to invest in adoption of precision irrigation technologies from his available potential resources. (A farmers should cultivate cash crops in order to increase monetary profit compared to the production of domestic food crops. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Not sure
- Agree
- Strongly Agree

10. The willingness of the farmer to invest in adoption of precision irrigation technologies from his available potential resources. (The farmer should try any new farming idea which may earn him more money.) *

Mark only one oval.

- Strongly Disagree
- Disagree
- Not sure
- Agree
- Strongly Agree

11. The level of risk and uncertainty a study participant is willing to accept while embracing new ideas in farming.(A farmer can minimise risk by planting many crops in order to avoid having a single crop fail.) *

Mark only one oval.

- Strongly Disagree
- Disagree
- Not sure
- Agree
- Strongly Agree

12. Generally, a farmer who takes extra risks will end up better off financially. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Not sure
- Agree
- Strongly Agree

13. New farming ideas should only be attempted if they've proven successful in practise. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Not sure
- Agree
- Strongly Agree

14. A farmer attempting a whole new farming approach is taking a risk, but the results are worth it. *

Mark only one oval.

- Strongly Disagree
- Disagree
- Not sure
- Agree
- Strongly Agree

15. Perception of farmers about the factors affecting adoption of precision irrigation systems. (Mass media's influence.) *

Mark only one oval.

- Not Important at All
- Not Sure
- Less Important
- Important
- Very Important

16. Perception of farmers about the factors affecting adoption of precision irrigation systems. (Researchers' influence.) *

Mark only one oval.

- Not Important at All
- Not Sure
- Less Important
- Important
- Very Important

17. Perception of farmers about the factors affecting adoption of precision irrigation systems. (The irrigation equipment dealer's influence.) *

Mark only one oval.

- Not Important at All
- Not Sure
- Less Important
- Important
- Very Important

18. Perception of farmers about the factors affecting adoption of precision irrigation systems. (Influence of friends and family.) *

Mark only one oval.

- Not Important at All
- Not Sure
- Less Important
- Important
- Very Important

19. Perception of farmers about the factors affecting adoption of precision irrigation systems. (Self-interest.) *

Mark only one oval.

- Not Important at All
- Not Sure
- Less Important
- Important
- Very Important

20. Perception of farmers about the factors affecting adoption of precision irrigation systems. (Getting public attention due to the installation of precision irrigation systems.) *

Mark only one oval.

- Not Important at All
- Not Sure
- Less Important
- Important
- Very Important

21. Perception of farmers about the factors affecting adoption of precision irrigation systems. (Need for achievement.) *

Mark only one oval.

- Not Important at All
- Not Sure
- Less Important
- Important
- Very Important

22. Perception of farmers about the factors affecting adoption of precision irrigation systems. (When summer arrives, water is low in supply.) *

Mark only one oval.

- Not Important at All
- Not Sure
- Less Important
- Important
- Very Important

23. Perception of farmers about the factors affecting adoption of precision irrigation systems. (Subsidy availability.) *

Mark only one oval.

- Not Important at All
- Not Sure
- Less Important
- Important
- Very Important

24. Perception of farmers about the factors affecting adoption of precision irrigation systems. (Difficulty in finding workers having knowledge of irrigation systems) *

Mark only one oval.

- Not Important at All
- Not Sure
- Less Important
- Important
- Very Important

25. Perception of farmers about the reasons which creates hurdles for adoption of precision irrigation systems. (Lack of water for irrigation leads to water availability sufficient just for household use.) *

Mark only one oval.

- Not Important at All
- Not Sure
- Less Important
- Important
- Very Important

26. Perception of farmers about the reasons which creates hurdles for adoption of precision irrigation systems. (The initial expenditure is high.) *

Mark only one oval.

- Not Important at All
- Not Sure
- Less Important
- Important
- Very Important

27. Perception of farmers about the reasons which creates hurdles for adoption of precision irrigation systems. (In regions where there is enough of water, farmers are happy with conventional irrigation methods.) *

Mark only one oval.

- Not Important at All
- Not Sure
- Less Important
- Important
- Very Important

28. Perception of farmers about the reasons which creates hurdles for adoption of precision irrigation systems. (Water that is of poor quality may block a drip system.) *

Mark only one oval.

- Not Important at All
- Not Sure
- Less Important
- Important
- Very Important

29. Perception of farmers about the reasons which creates hurdles for adoption of precision irrigation systems. (Lack of information and awareness of drip irrigation.) *

Mark only one oval.

- Not Important at All
- Not Sure
- Less Important
- Important
- Very Important

30. Perception of farmers about the reasons which creates hurdles for adoption of precision irrigation systems. (The water delivered by the drip method is insufficient for proper crop growth, so it is believed.) *

Mark only one oval.

- Not Important at All
- Not Sure
- Less Important
- Important
- Very Important

31. Perception of farmers about the reasons which creates hurdles for adoption of precision irrigation systems. (A lot of people have quit using the technology.) *

Mark only one oval.

- Not Important at All
- Not Sure
- Less Important
- Important
- Very Important

32. Perception of farmers about the reasons which creates hurdles for adoption of precision irrigation systems. (Power shortages.) *

Mark only one oval.

- Not Important at All
- Not Sure
- Less Important
- Important
- Very Important

33. Perception of farmers about the reasons which creates hurdles for adoption of precision irrigation systems. (Voltage malfunction.) *

Mark only one oval.

- Not Important at All
- Not Sure
- Less Important
- Important
- Very Important

34. Perception of farmers about the challenges in operating and maintaining precision irrigation system. (A system clog from contaminants in irrigation water.) *

Mark only one oval.

- Not Important at All
- Not Sure
- Less Important
- Important
- Very Important

35. Perception of farmers about the challenges in operating and maintaining precision irrigation system. (Poor power supply.) *

Mark only one oval.

- Not Important at All
- Not Sure
- Less Important
- Important
- Very Important

36. Perception of farmers about the challenges in operating and maintaining precision irrigation system. (Voltage malfunction.) *

Mark only one oval.

- Not Important at All
- Not Sure
- Less Important
- Important
- Very Important

37. Perception of farmers about the challenges in operating and maintaining precision irrigation system. (Pipeline and dripper damage from rats.) *

Mark only one oval.

- Not Important at All
- Not Sure
- Less Important
- Important
- Very Important

38. Perception of farmers about the challenges in operating and maintaining precision irrigation system. (Pipelines and drippers are prone to damage by wild animals.) *

Mark only one oval.

- Not Important at All
- Not Sure
- Less Important
- Important
- Very Important

39. Perception of farmers about the challenges in operating and maintaining precision irrigation system. (A lack of understanding about utility, operations, and maintenance.) *

Mark only one oval.

- Not Important at All
- Not Sure
- Less Important
- Important
- Very Important

40. Perception of farmers about the challenges in operating and maintaining precision irrigation system. (Substandard post-sales service.) *

Mark only one oval.

- Not Important at All
- Not Sure
- Less Important
- Important
- Very Important

41. Perception of farmers about the challenges in operating and maintaining precision irrigation system. (Technical guidance received too late from the dealer's technicians.) *

Mark only one oval.

- Not Important at All
- Not Sure
- Less Important
- Important
- Very Important

42. Perception of farmers about the challenges in operating and maintaining precision irrigation system. (Ground-level weed concentration.) *

Mark only one oval.

- Not Important at All
- Not Sure
- Less Important
- Important
- Very Important

43. Irrigation systems has effectively served a variety of irrigation demands. *

Mark only one oval.

- Highly Unsatisfied
- Unsatisfied
- Not sure
- Satisfied
- Highly Satisfied

44. Reduction in the amount of electricity consumed to irrigate the fields *

Mark only one oval.

- Highly Unsatisfied
- Unsatisfied
- Not sure
- Satisfied
- Highly Satisfied

45. Your income has increased as a result of the use of irrigation systems. *

Mark only one oval.

- Highly Unsatisfied
- Unsatisfied
- Not sure
- Satisfied
- Highly Satisfied

46. Did you take advantage of subsidy available for micro irrigation systems? *

Mark only one oval.

- Yes
- No

47. The amount of the subsidy is sufficient. *

Mark only one oval.

- Very Bad
- Bad
- Okay
- Good
- Very Good

48. The ease with which the subsidy procedure can be completed. *

Mark only one oval.

- Very Bad
- Bad
- Okay
- Good
- Very Good

49. The actions and attitudes of the officials and agencies involved. *

Mark only one oval.

- Very Bad
- Bad
- Okay
- Good
- Very Good

50. Time required to avail subsidy was appropriate. *

Mark only one oval.

- Very Bad
- Bad
- Okay
- Good
- Very Good

51. Transparency in the application process to avail for a subsidy. *

Mark only one oval.

- Very Bad
- Bad
- Okay
- Good
- Very Good

52. Because of the widespread use of micro irrigation systems, the soil quality or the farm has improved over time. *

Mark only one oval.

- Sharp Fall
- Deterioration
- No Change
- Improved
- Highly Improved

53. A variety of terrains can be accommodated by micro irrigation systems. *

Mark only one oval.

- Very Low
- Low
- Medium
- High
- Very High

54. Water distribution can be done equally with micro irrigation systems. *

Mark only one oval.

- Highly Negative
- Negative
- No Impact
- Positive
- Highly Positive

55. The water wastage or misuse has drastically reduced due to the usage of micro irrigation systems. *

Mark only one oval.

- Highly Negative
- Negative
- No Impact
- Positive
- Highly Positive

56. The water quality has been improved over the years due to the usage of micro irrigation systems. *

Mark only one oval.

- Sharp Fall
- Deterioration
- No Change
- Improved
- Highly Improved

57. Precision Irrigation has reduced pest occurances on crops *

Mark only one oval.

- Very Low
- Low
- Medium
- High
- Very High

58. Precision Irrigation has helped in reducing the cost of pesticides *

Mark only one oval.

- Highly Negative
- Negative
- No Impact
- Positive
- Highly Positive

59. Precision Irrigation has helped in reducing the usage of pesticides *

Mark only one oval.

- Highly Negative
- Negative
- No Impact
- Positive
- Highly Positive

60. Precision Irrigation has help in curbing disease outbreak *

Mark only one oval.

- Very Low
- Low
- Medium
- High
- Very High

61. Precision Irrigation has helped in the reduction of weeds *

Mark only one oval.

- Very Low
- Low
- Medium
- High
- Very High

62. Precision Irrigation has helped in reducing the cost of harvesting *

Mark only one oval.

- Highly Negative
- Negative
- No Impact
- Positive
- Highly Positive

63. Precision Irrigation has helped in reducing the labour requirement drastically *

Mark only one oval.

- Very Low
- Low
- Medium
- High
- Very High

64. How is the overall water situation in your village due to the Precision Irrigation Systems *

Mark only one oval.

- Highly Negative
- Negative
- No Impact
- Positive
- Highly Positive

65. What happens to the saved water due to the Precision Irrigation Systems *

Mark only one oval.

- Used for other non agricultural purposes
- Used for other agriculture and related purposes
- Used for more irrigation to the same crops
- Used for expanding area under agriculture
- Used for irrigating more crops