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Smart Irrigation Technologies for Water Conservation in Pakistani Agriculture

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ABSTRACT:

The agriculture sector of Pakistan is greatly reliant on water, but it is greatly affected by water shortage because of climate change, irrigation methods that are inefficient and diminishing ground water resources. The application of smart irrigation technologies has a potential solution to the efficiency of water use and the productivity of agriculture. The paper will scrutinize the position, opportunities, and the obstacles of implementing smart irrigation systems in Pakistan such as drip irrigation, sprinkler systems, soil-moisture sensors, IoT-based irrigation controllers, and remote-sensing equipment. The paper cites the limitations, which include high initial expenses, lack of awareness to farmers, deficiency of technical capacity, and weak policy provisions, based on the recent studies. The results indicate that the integration of smart irrigation technologies can greatly decrease the waste of water, maximize crop production, and help agricultural development to be sustainable. Nevertheless, universal implementation necessitates favorable policies, subsidies, training of farmers and enhanced access to technological opportunities.

Keywords: Pakistan agriculture, smart irrigation, water conservation, drip irrigation, IoT-based irrigation, soil moisture sensors, climate change, water management, precision agriculture, sustainable farming.

INTRODUCTION:

Pakistan is largely an agricultural nation where water serves as the foundation of the economic sector as it supports almost 23 percent of the national GDP and provides over 37 percent of the working population in the nation (GoP, 2023). Although water plays such a central role in agriculture, Pakistan is believed to be among the water-stressed nations in the world. Water scarcity in the agricultural environment in the last several decades has been intensified by the rapid population growth, inefficient irrigation methods, climate change, and ineffective water management (Qureshi, 2021). IBIS is one of the largest irrigation systems in the world, but it has high losses of water in conveyance, distribution, and utilization at the farm level, where flood irrigation is still the prevailing form (Khan and Shah, 2022). As a result, the percentage of water wasted before reaching crops root zone is almost 60 percent (Ashraf and Ahmad, 2020). This scenario requires the shift of traditional irrigation to the more efficient and technology oriented methods which would be able to make the water resources sustainable in the long term.

The world has seen the introduction of smart irrigation technologies as a viable technology to achieve water savings without compromising agricultural output or increase agricultural output. These technologies are drip and sprinkler irrigation systems, soil moisture and climate sensors, remote-controlled irrigation devices, automated with IoT capabilities, crop monitoring via satellites, and decision-support software (Rahman et al., 2022). In contrast to the conventional irrigation that is usually done using estimates and regular timetables, smart irrigation uses water in accordance with real time information associated with soil moisture, crop demands and the environment. This kind of precision allows farmers to utilize water in a better way, prevent excessive water application, and enhance crop welfare. Under situations of severe water deficiency in a given country, the smart irrigation technology is capable of making groundbreaking contributions in terms of maximization of water usage.

The additional pressing demand of complex irrigation solutions is caused by chronic misuse of water resources in Pakistan and the problems of climate change (growing temperatures, unreliable rainfall, and long-lasting droughts) that make it impossible to satisfy the increasing population with the current resources (ADB, 2020). More than 90 percent of the freshwater available in the country is used in the agricultural sector, and it is clear that any small gains in the efficiency of irrigation could result in massive water-saving (Hassan and Ali, 2022). Nevertheless, there are several advantages, but the uptake of smart irrigation in Pakistan is rather slow. Although drip and sprinkler irrigation systems have been implemented in some progressive and commercial farms, they have not been fully realized because of social economic, infrastructural, and institutional constraints (Khalid et al., 2021).

Amongst the main limitations that confront farmers are high costs of installations, ignorance over the long-term advantages, limited sources of financing and inadequate technical skills. Also, the policies on water-efficient technologies have either been weak or not consistent and the lack of the extension services is also an impediment to the spread of the technologies. Being more exposed to modern technologies due to their rural nature, rural farmers use their traditional practices that have been transferred through the generations, making behavioral change a crucial but difficult part of the transition (Naseer et al., 2023). In addition, the current irrigation systems are old and not integrated to support sensor based and automated irrigation systems.

However, the possible advantages of intelligent irrigation in Pakistan are enormous. Empirical evidence indicates that drip irrigation would be sufficient to cut the use of water by up to 40-60 percent and also increase yields by 20-50 percent in crops like vegetables, fruits, and orchards (Baig and Afzal, 2022). The irrigation controllers based on IOT have also shown up to 30 percent water and electricity savings, since the irrigation patterns are controlled by the soil and weather data (Rehman & Zaman, 2021). Farmers have also indicated that there are increases in fertilizer efficiency, low labour costs and crop uniformity when precision irrigation is done. This is important in terms of the food security and viability of agriculture given the mounting water scarcity.

Moreover, the Vision 2025 and the agricultural transformation strategies of Pakistan stress the necessity of modernizing the irrigation and advancing the efficient water-use practice (GoP, 2023). The international development partners such as FAO, UNDP and World Bank have initiated programs to enhance climate smart agriculture in the country especially in enhancing the efficiency of irrigation. Another contributor to the emergence of low-cost IoT sensors, mobile applications, and farmer advisory platforms are digital agriculture startups and local research institutions that adapted their services to the needs of the smallholders (Yaseen & Tariq, 2023). Such developments suggest the positive direction although much work still has to be done.

Finally, smart irrigation technologies in Pakistan are on the agenda, and their implementation is not a matter of choice but a prerequisite to increasing water shortages. Although there are several limiting factors to adoption, increased awareness, technological progress, and policies can be used to speed up the process. With the increased challenges of climate change, smart, data-based irrigation practices are an essential channel of achieving sustainable agricultural practices, water resource conservation and livelihood protection throughout Pakistan.

LITERATURE REVIEW:

Smart irrigation technologies have become internationally regarded as the necessary tools to enhance the efficiency of the water-use, crop production, and the resilience of the agricultural systems in water-scarce environments. The recent years have been witnessing climate-smart agriculture, which has enhanced the contribution of technology in curbing the problem of water scarcity, especially in developing nations like Pakistan. This literature review looks into the available research on water scarcity in Pakistan, adoption efficacy of smart irrigation technologies, obstacles against adoption, socio-economic aspects, and policy frameworks that facilitate technology adoption.
Pakistan: The Water/Scarcity and Efficient Irrigation.

The water scarcity in Pakistan is acute and deteriorating, and it is caused by climatic variability, population increase, transboundary water, and old irrigation systems. Qureshi (2021) suggests that without immediate reforms, Pakistan would run out of water to a point where it is considered absolute water scarcity in the next 10 years. Agricultural fields are dominated by traditional flood irrigation, which constitutes high levels of water wastage, which is approximated to be almost 60 percent in the process of conveyance and application (Ashraf and Ahmad, 2020). As Khan and Shah (2022) note, canal seepage, unauthorized water resources extraction, unlined channels, and inadequate operation management are some of the inefficiencies in the Indus Basin Irrigation System. Due to the fact that agriculture uses over 90 percent of the freshwater in Pakistan, the efficiency of irrigating the land becomes crucial towards maintaining the sustainability on the long-term basis (Hassan and Ali, 2022). All these obstacles present a very solid basis on which smart irrigation technologies can be introduced.

Intro to Smart Irrigation Technologies:

Smart irrigation is a wide range of technologies aimed at optimizing the use of water depending on real-time information on the soil moisture, water needs of crops, and the weather conditions. One of the technologies that have experienced high adoption rates across the world is drip and sprinkler systems which provide high rates of water saving over surface irrigation. A study by Rahman et al. (2022) shows that compared to traditional irrigation systems, micro-irrigation systems may contribute to a 40-70 percent decrease in water consumption and improved the quality of yield. Another important device in smart irrigation is the soil moisture sensors that check the amount of water in real-time and only irrigate when it is required. The analysis of articles by Baig and Afzal (2022) demonstrates that irrigation with the use of soil sensors enhances the water-use efficiency and decreases the unwarranted use of water by 50 percent.

The new innovations in digital agriculture have further extended the meaning of smart irrigation. The irrigation control systems, remote control of the pump systems, the weather forecastings software, and the satellite-based crop monitoring are being increasingly applied all over the world. Rehman and Zaman (2021) concluded that the IoT-based irrigation systems save almost 30 percent of water and offer precise irrigation timing. Moreover, precision agriculture software involves combining data of a variety of sensors and remote sources of information to assist farmers in making water management decisions. These tools have the ability to cut down on water consumption besides increasing fertilizer efficiency and cutting down on labor input.

Effects of Smart Irrigation on Productivity of Crop

There is a vast amount of literature to justify the thesis that smart irrigation can greatly enhance the production of agriculture. Drip irrigation, according to studies carried out in semi-arid areas, such as Pakistan increases crop production by 20-50 percent as compared to rain-fed irrigation especially on crops that require a lot of water such as sugarcane, tomatoes, orchards, and vegetables (Naseer et al., 2023). Studies conducted by Yaseen and Tariq (2023) show that a combination of drip irrigation and fertigation systems increase the level of nutrient uptake and leads to improved crop uniformity and less wastage of fertilizers. Irrigation systems that are climate-controlled and change irrigation patterns according to weather predictions have also been discovered to reduce over-irrigation and prevent crops to drought stresses (ADB, 2020). These results show that intelligent irrigation is also a contributor of water savings as well as crop profitability.

Economic, Social, and Environmental/Technological/legal Obstacles to the Adoption of Smart irrigation technologies.

The use of smart irrigation in Pakistan is still not widespread despite the demonstrated advantages. One of the major obstacles is high initial costs of investment. Khalid et al. (2021) pose that the prohibitiveness of installing drip or sprinkler systems is a factor to smallholder farmers who represent the majority of the farming population in Pakistan. There is also inaccessibility to credit and monetary incentives which further inhibit technology adoption. Farmers too do not know the potential economic benefits of smart irrigation in the long term; many of them believe that modern technologies are complicated and hazardous, especially when first exposed to them or lack technical education (Hassan and Ali, 2022).

There are institutional barriers as well to adoption. It has been demonstrated that the extension services provided in Pakistan fall short of adequate preparation to guide the farmers towards the adoption of modern irrigation systems (Ashraf and Ahmad, 2020). Further barriers are caused by poor coordination of the agricultural departments, low investment in R&D, and unreliable government policies (Khan and Shah, 2022). Besides, a significant number of rural regions are not stable in terms of electricity, the internet, and digital infrastructure - important elements of the IoT-based irrigation systems. Through this, even those progressive farmers tend to experience a problem of operating automated systems efficiently.

Social-Economic and Cultural Problems.

The socio-economic determinants play an important role in determining the adoption of smart irrigation technology by farmers. Research indicates that small land size, poverty, and low literacy reduce access by farmers to new technologies (Baig and Afzal, 2022). It is also largely affected by cultural patterns towards traditional irrigation methods. Flood irrigation is popular among most farmers since it is well known, not requiring specific management and has been practised over the years. Naseer et al. (2023) additionally state that behavioral resistance is a stronger constraint than economic ones because the farmers are not trusting of new technologies.

Technology adoption is also determined by gender relationships. In rural locations, women do not have access to land, finance, and training which limits their capacities in taking part in decision-making on irrigation technologies. According to Yaseen and Tariq (2023), smart irrigation efforts should include gender-sensitive training and encourage the inclusion of all individuals in these efforts to have equal adoption.

Government Support and Policy Framework.

Policymaking frameworks are very important in the diffusion of technology. The Vision 2025 in Pakistan has focused on climate-sensitive agriculture and pointed out the necessity of enhancing the efficiency of water use. Nevertheless, researchers believe that the process of policy implementation is still weak because of bureaucracy, ineffective monitoring, and insufficient funding of farmers (Qureshi, 2021). There is limited progress in subsidizing drip and sprinkler systems, but the projects, the National Programme of Improvement of Watercourses (NPIW) and the High Efficiency Irrigation Systems (HEIS) initiative, have little influence on the situation (GoP, 2023). According to Khalid et al. (2021), subsidies can hardly penetrate the vulnerable farms, and smart irrigation systems are not maintained.

There are pilot projects of smart irrigation which have been promoted by international bodies such as FAO, World Bank and UNDP in various parts of Pakistan. Such projects show the viability and

advantages of contemporary irrigation but tend to be small and not maintained once donor funds have since been exhausted (ADB, 2020). This indicates the necessity of government-funded programs with the involvement of the private-sector in the long term.
New Trends and Future Projections.

According to recent studies, there are innovative trends that might influence the future of smart irrigation in Pakistan. There is increasing popularity of local-made inexpensive IoT sensors, irrigation advisory apps running on smartphones and solar-powered irrigation systems (Rehman and Zaman, 2021). These inventions are less expensive and are available to small farmers on a scale. Also, university-agricultural research center and tech-based startups partnerships are on the rise to assist in precision agriculture initiatives.

According to scholars, artificial intelligence and machine learning applied to irrigation scheduling could further maximize the efficiency of water and be more resilient to changes in climate (Baig & Afzal, 2022). Drones and satellites decrease remote-sensing data to enable farmers to know the health of the crops and identify water stress in the initial stages. Due to the affordability of these technologies, chances of their wide acceptance in Pakistan are bright.

METHODOLOGY:
In the present research, a mixed-method research design is employed as it is necessary to explore the position of the smart irrigation technologies, their advantages, and obstacles to water conservation in Pakistani agriculture. The research design, population, sampling, data collection processes, and methods of deriving findings are all contained in the methodology.

Research Design:
It was chosen to use the mixed-method research design (quantitative + qualitative).
This design is suitable since the smart irrigation adoption entails both measurable variables (e.g. water savings, cost, yield) and experiential variables (e.g. farmer perceptions, technical constraints and institutional barriers). By merging the two approaches the depth, accuracy and credibility of the study are heightened.

The quantitative section will address the responses of the farmers by using structured questionnaires whereas the qualitative section will address the understanding of the agricultural experts and practitioners.

Study Area:
The research was done in Multan District (Punjab, Pakistan).
Multan was purposively chosen because:

- It is agriculturally productive.
- There are a number of drip / sprinkler irrigation projects by the government and privately.
- Different farmers are exposed to smart irrigation technologies.

This renders Multan a perfect place to gauge adoption, performance and challenges.

Population and Sampling:

Population
The study population consists of:

- Multi-national farmers with (or knowledgeable of) smart irrigation systems.
- Extension agricultural officers.
- Irrigation engineers and individual technology sellers.

Sampling Technique:

- The sampling approach used was a purposive-random approach:

- Purposive choice of the study area (Multan).
- This guaranteed the availability of active smart irrigation projects.
- Farmers were sampled at random.
- One hundred farmers were randomly chosen among lists that were supplied by the Agriculture Department Multan.

Expert purposive sampling.
There were also 10 key informants who will be purposely chosen, and they will include:

- Extension workers
- Irrigation engineers
- Irrigation technology company representatives.

This combination will also guarantee generalizable data (farmers) and professional insights (professionals).

Data Collection Methods:
Data collection was done through three major ways.

Questionnaire (Quantitative Data)
A questionnaire was planned to be structured as a four-part questionnaire.

- Demographic (age, education, farm size, income)
- Smart irrigation technologies awareness and adoption.
- Perceived advantages (water savings, savings, increase in yield, etc)
- Factors of incapacitation (cost inability, absence of training, technicality, maintenance problems)

The item based on perception was to be given a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree).
The questionnaire was filled by personal visits to prevent erroneous response particularly to low-literate farmers.

Semi-Structured Interviews (Qualitative Data)
They were semi-structured interviews with 10 professionals.
These interviews explored:

- Installation and maintenance technical issues.
- Farmer training gaps
- Employment issues including policy and institutions.
- Smart irrigation system sustainability.
- Suggestions that should be adopted comprehensively.

The open-ended questions enabled the participants to elaborate on the same.

Document Review
The secondary data was gathered by analyzing documents on:

- Government reports (e.g., GoP, 2023)
- FAO, World Bank and ADB articles.
- Smart irrigation, water management, and IoT systems research articles.
- Drip irrigation and sprinkler irrigation projects in Punjab project appraisals.

The review of the documents made the results more credible because they confirmed the results in the literature.

Data Collection Procedure
The process of data collection was done in three stages:

- Pilot Testing
- Clarity and reliability of the questionnaire were tested by piloting it among 8 farmers. Minor changes were performed based on their comments.

- Field Data Collection

The questionnaires were administered by trained enumerators who paid a visit to farms. The process of data collection took 4 weeks.

Interviews:
Face to face and phone interviews were used. The interviews were transcribed and analysed after recording (with permission).

Data Analysis Techniques:

Quantitative Analysis
The analysis of qualitative data was done through the use of SPSS:

- Descriptive statistics: per centages, frequencies, standard deviations, and means.
- Correlation analysis: to test the relationships between adoption and perceived benefits.
- Regression analysis: to determine the important factors that affect adoption (e.g., cost, awareness, training, farm size).

The statistical results were tabulated to help make findings clear.

Qualitative Analysis:
The thematic analysis was used to analyze the qualitative data:

- Interpretation of interview transcripts.
- Coding of recurring ideas
- Development of major themes
- Cost barriers
- Lack of awareness
- Maintenance/ technical problems.
- Lack of institutional support.
- Farmer benefits witnessed.

Thematic interpretation with regards to quantitative outcomes.
The method offers more insights regarding issues and experiences.

Reliability and Validity:

- **Content validity:** guaranteed by reviewing items in the questionnaires by experts.
- **Construct validity:** attained through foundation of variables on past empirical investigations.
- **Reliability test:** Cronbach's Alpha was more than 0.75 which shows high internal consistency.

Ethical Considerations:
The research was conducted in accordance with all the ethical principles, including:

- All participants will provide informed consent.
- All personal information should be confidential.
- No force- it was all voluntary.
- Right to withdraw at any time
- Data used ethically with academic purposes.

DATA ANALYSIS AND FINDINGS:
This part gives a critical discussion of adoption, advantages and challenges of smart irrigation technologies among Multan farmers in Pakistan. The analysis was done using quantitative survey data of 100 farmers and qualitative information about 10 key informants.

Demographic Characteristics of the Respondents:
Demographic factors such as age, education, and farm size are important to understand the demographic characteristics of the farmers since they tend to adopt technology depending on their demographic characteristics.

Table 1: Demographic Profile of Farmers (n = 100)

Characteristic	Category	Frequency	Percentage (%)
Age	<30	18	18
30–45	42	42	
>45	40	40	
Education	Illiterate	25	25
Primary	28	28	
Secondary	32	32	
Tertiary	15	15	
Farm Size	<5 acres	34	34
5–10 acres	41	41	
>10 acres	25	25	

Analysis:
The vast majority of the interviewees were aged between 30-45, which suggests a possibly open-minded generation toward the use of new technologies.

Approximately 60% were educated to secondary or tertiary level, thus, understanding smart irrigation systems.

Most of the farms (75% were below 10 acres) and this indicates that smallholder farmers prevail in the study area. The relevance of this is that cost and scalability are factors that tend to determine the adoption by the smallholders.

Knowledge and Implementation of Intelligent Irrigation.
The results of the surveys show that there are different degrees of people being aware of the use of smart irrigation tools.

Table 2: Awareness and Adoption of Smart Irrigation

Technology	Aware (%)	Adopted (%)
Drip Irrigation	78	35
Sprinkler Irrigation	65	28
Soil Moisture Sensors	42	12
IoT-based Controllers	25	5
Remote Monitoring / Mobile Apps	18	3

Analysis:

- The knowledge of conventional technologies such as drip and sprinkler irrigation is fairly high.
- Older and more advanced technologies like IoT-based controllers or mobile applications have a steep drop in adoption.
- The attitude-behavior gap is mainly because of expensive installation, lack of technical skills, and unavailability of suppliers.
- Smart Irrigation as Perceived Benefits. The benefits were rated by asking the farmers to respond on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree).

Table 3: Perceived Benefits (Mean Scores)

Benefit	Mean Score	Std. Dev
Reduced Water Consumption	4.35	0.72
Increased Crop Yield	4.10	0.81
Reduced Fertilizer Use	3.78	0.88
Labor Savings	3.55	0.94

Improved Crop Quality	3.82	0.85

Analysis:
The biggest advantage as viewed by the farmers is the decrease in water use. An increase in yield is also one of the most appreciated values that prove that smart irrigation is associated with profitability. Smallholder farms are less affected on labor savings, possibly due to the fact that such farms are already depending on family labor.

Barriers to Adoption
The barriers were rated out of 5 points by farmers.

Table 4: Major Barriers to Adoption (Mean Scores)

Barrier	Mean Score	Std. Dev
High Initial Cost	4.50	0.65
Lack of Training	4.12	0.77
Limited Technical Support	3.95	0.82
Maintenance Difficulty	3.80	0.89
Lack of Awareness	3.70	0.88

Analysis:
The biggest barrier was that of high initial cost. There is also a limit on adoption due to lack of training and technical support, thus the need to enlist capacity-building programs. The issue of maintenance shows lack of familiarity with the farmers with complex systems.

Correlation Analysis
Correlations are used to demonstrate the relationship between the adoption of smart irrigation and the key variables.

Table 5: Correlation Between Adoption and Influencing Factors

Variable	Adoption	Correlation (r)	Significance (p)
Education	+0.45	$p < 0.01$	Significant
Farm Size	+0.38	$p < 0.05$	Significant
Awareness	+0.60	$p < 0.01$	Highly Significant
Income	+0.32	$p < 0.05$	Significant

Interpretation:
Adoption is most related to awareness meaning that training and information dissemination are essential.The education and farm size have a positive effect on adoption but at a lower level.

Thematic Analysis qualitative findings:
Interpretative analysis of the interview of 10 key informants showed that there were five major themes as follows:

- One of the topics is Financial Constraints.
- As pointed out by experts, small farmers cannot afford drip and sprinkler systems due to their high initial investment.
- The IoT based technologies are especially costly in terms of importation and localized production.

Theme 2: Training and technical Knowledge.

- It was mentioned several times that there was a lack of technical knowledge.
- Without the appropriate instruction, farmers have difficulties with installing their systems, calibration of the sensors, and timetable of irrigation.

Theme 3: Institutional Support.

- The adoption is hampered by weak extension services and meager government subsidies.
- Other farmers depend on the services of the private companies, which are very expensive in consultation fees.

The fourth theme is Infrastructure Limitations.

- Poor water distribution infrastructure and electricity unreliability decrease the performance of automated systems.
- Not all areas are connected to the internet, creating limitations to the application of the IoT-based solutions.

Theme 5: Benefits Realized

- Specialists attested to the creation of 30-50% of water savings through drip irrigation and sprinkler systems.
- Vegetables and orchards had enhanced crop yields.
- Farmers claimed that there was enhanced efficiency in the use of fertilizers and also the uniformity of crops was enhanced.

SUMMARY OF KEY FINDINGS:

Demographics: The farmers primarily are between the age of 30-45 years and have small to medium size farms. Technology understanding is backed by education level.

Adoption Levels: There are more adoption rates of drip and sprinkler irrigation; more sophisticated technologies such as IoT controllers are still scarce.

Perceived Benefits: Major motivation is water savings and yield improvement.

Obstacles: The main barriers are high start-up costs, untrained personnel and technical support.

Correlation Insights: There is a positive correlation of awareness and education to adoption; financial and infrastructure limitation is still an issue.

Qualitative Insights: The adoption must be scaled with institutional support, training programs, and improved infrastructure.

Conclusion from Data:
Smart irrigation technologies have shown distinct opportunities of conservation of water and improvement of yield. Adoption in Multan is however limited by cost, technical skills and infrastructures. There is a need to increase usage by providing policy support, subsidies, and capacity-building to promote usage among the smallholder farmers.

CONCLUSION:
The results of this research show that smart irrigation technologies can be of great potential in terms of increasing the level of water-use efficiency and in raising the agricultural productivity in Pakistan. In Multan, farmers cited concrete gains in the form of less water use, higher crop yields, more effective use of the farmers fertilizers and better homogeneity of crops. It is however adopted on a small scale which has been attributed to the high upfront costs, insufficient technical expertise, insufficient institutional backing, and poor infrastructure.

The quantitative analysis revealed that there was a strong relationship between adoption and awareness, education, and farm size indicating that informed and comparatively resource-rich farmers will have higher chances of applying smart irrigation. Qualitative interviews supported these results, with financial constraints, maintenance challenges, and lack of training being the most significant limitations.

In general, although smart irrigation represents one of the avenues to sustainable water management and climate-intensive agriculture, its scaling will need a unified policy development, funding, capacity-building, and technological access. The agriculture sector in Pakistan is still to overcome the challenges of water scarcity and inefficiency without addressing these constraints and this will only allow Pakistan to limit its potential of guaranteeing food security and sustainable development.

RECOMMENDATIONS

Otherwise, they are provided with financial incentives and subsidies.

- Offer low interest loans, grants or subsidies to lower the initial cost of drip, sprinkler and IoT based irrigation systems.
- Farmer Training and Capacity building.
- Organize workshops and field demonstrations to educate farmers about installation, operation and maintenance of smart irrigation technologies.
- Enhance Institutional Capacity.
- Enhance extension service and cooperation between agriculture departments, research institutes, and the providers of the technology to the privates.
- Infrastructure Development
- Make sure there is quality electricity and internet connectivity to serve automated and IoT-based irrigation systems.
- Awareness Campaigns
- Market the advantages of smart irrigation by mass media, local farmer associations and cooperative societies.

Research and Development

- The universities and research institutions should be encouraged to come up with low cost locally adapted smart irrigation technologies that can apply to the small holder's farmers.

Reaganomics and the Arduoitux Administration Policy.

- Have transparent policies that would help the process of climate-smart farming, water conservation, and adoption of precision irrigation technologies.

Monitoring and Evaluation

- In place water savings and yield gains and farmer adoption systems to guide future policy and project interventions.

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