



BRIDGING THE KNOWLEDGE GAP: AN ANALYSIS OF FARMER AWARENESS AND ADOPTION OF MODERN IRRIGATION TECHNIQUES FOR SUSTAINABLE AGRICULTURE

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Abstract

Global freshwater resources are under unprecedented strain, with agriculture accounting for approximately 70% of all withdrawals. Traditional flood irrigation, still predominant in many regions, is highly inefficient, losing significant water volumes to evaporation, runoff, and deep percolation. In this context, modern irrigation techniques including drip irrigation, sprinkler systems, laser land leveling, IoT-based automation, and fertigation present a critical pathway toward enhancing water use efficiency, boosting crop productivity, and ensuring agricultural sustainability. However, the mere availability of these technologies is insufficient; farmer awareness and willingness to adopt them are the pivotal bridges between potential and practice. This study investigates the levels of farmer awareness, patterns of adoption, and the key barriers and enablers influencing the uptake of modern irrigation systems. Utilizing a mixed-methods approach, combining quantitative surveys with qualitative focus group discussions from a water-scarce region, the research finds that while awareness of basic systems like drip irrigation is moderately high, knowledge of advanced IoT-based solutions remains low. Adoption is primarily constrained by high initial investment costs, perceived technical complexity, and inadequate institutional support. The study concludes that a multi-pronged strategy is essential, involving targeted government subsidies, enhanced and digitized extension services, farmer-to-farmer training models, and the development of affordable, context-specific technologies. Ultimately, accelerating the adoption of modern irrigation is not merely an agricultural objective but a urgent imperative for global water and food security.

Keywords: *Modern Irrigation, Water Use Efficiency, Farmer Awareness, Technology Adoption, Drip Irrigation, Sustainable Agriculture, Extension Services, Adoption Barriers*

Introduction

Background

Water is the lifeblood of agriculture, yet it is a resource increasingly under threat. The global agricultural sector remains the largest consumer of freshwater, accounting for nearly 70% of total withdrawals, a figure that escalates to over 90% in many developing economies (FAO, 2020). This immense demand is set against a backdrop of mounting water scarcity, driven by climate change, population growth, and competing urban and industrial needs. Traditional irrigation methods, particularly flood irrigation, have been the cornerstone of agricultural water management for millennia. However, their inefficiency is stark, with estimated water application efficiencies often ranging between 30-50%, meaning over half of the water diverted or pumped is lost before it can benefit the crop (Jensen, 2007). This profligate use is no longer tenable.

Importance of Irrigation Modernization

The modernization of irrigation practices is no longer a luxury but a necessity for sustainable water resource management. Modern irrigation techniques, such as drip and sprinkler systems, represent a paradigm shift from field-level to plant-level water management. Drip irrigation, for instance, delivers water directly to the root zone of plants, minimizing losses and achieving application efficiencies of over 90% (Postel, 1999). Similarly, sprinkler systems mimic rainfall, ensuring a more uniform application than floods.



Supplementing these are technologies like laser land leveling, which eliminates undulations to ensure even water distribution, and IoT-based smart systems that use soil moisture sensors and weather data to automate irrigation scheduling. The benefits are well-documented: significant water savings (30-70%), increased crop yields (10-50%), reduced fertilizer use through fertigation, and mitigation of soil salinity and waterlogging (Playán & Mateos, 2006).

Awareness and Adoption

The Critical Link Despite these clear advantages, global adoption rates of these technologies remain uneven, skewed heavily towards large-scale commercial farms in developed countries. The disparity highlights a crucial insight: technological availability does not guarantee adoption. Farmer awareness, perception, and knowledge constitute the fundamental bridge between the existence of a technology and its implementation on the ground. Awareness encompasses not only the knowledge that a technology exists but also a practical understanding of its operation, economic benefits, and suitability for specific crops and local conditions. Without this awareness, even the most sophisticated and beneficial technologies will remain underutilized.

Objectives of the Study

This study aims to critically examine the interplay between awareness and adoption of modern irrigation techniques. Its specific objectives are:

1. To assess the current levels of awareness among farmers regarding various modern irrigation systems (drip, sprinkler, laser leveling, IoT-based systems).
2. To identify and analyze the patterns and determinants of adoption, distinguishing between adopters and non-adopters.
3. To investigate the perceived benefits experienced by adopters and the barriers (economic, social, technical, institutional) hindering wider adoption.
4. To provide evidence-based policy recommendations to enhance awareness and facilitate the widespread and equitable adoption of water-efficient irrigation technologies.

Literature Review

Modern Irrigation Techniques

Modern irrigation is a suite of technologies designed for precision and efficiency.

Drip Irrigation: This system involves the slow application of water directly to the plant's root zone through a network of valves, pipes, tubing, and emitters. Its precision minimizes evaporation and runoff, making it ideal for row crops, orchards, and vineyards. Subsurface drip irrigation (SDI) further reduces evaporation losses.

Sprinkler Irrigation: Water is distributed through a system of pipes and sprayed into the air through sprinklers, simulating rainfall. It is suitable for a wider range of crops and field topographies than drip systems. Central pivot and lateral move systems are large-scale, automated versions that cover vast areas efficiently.

Laser Land Leveling: Using laser-guided graders, fields are leveled to a near-perfect plane. This eliminates water logging in low spots and under-irrigation in high spots, ensuring uniform water coverage and significantly improving the efficiency of both flood and modern irrigation methods.



IoT-Based Automated Systems: These represent the digital frontier of irrigation. Soil moisture sensors, weather stations, and satellite data feed into a central controller that automates irrigation schedules, applying water only when and where the crop needs it, optimizing water use to an unprecedented degree.

Fertigation: This is the practice of applying dissolved fertilizers through the irrigation system, allowing for precise nutrient management synchronized with crop water needs, thereby increasing nutrient use efficiency and reducing leaching.

Benefits Documented in Literature

A vast body of research corroborates the multifaceted benefits of modern irrigation. A meta-analysis by Ali and Talukder (2008) demonstrated that drip irrigation consistently increases water productivity (yield per unit of water) by 30-100% across various crops and regions. In India, studies in water-stressed states like Gujarat and Maharashtra showed that drip irrigation in sugarcane and cotton led to water savings of 40-60% and yield increases of 20-30% (Narayanamoorthy, 2004). Beyond water and yield, economic benefits are evident; despite high initial costs, the long-term profitability improves due to reduced water, energy, and labor costs. Environmental benefits are equally critical, including the conservation of aquifer levels, reduction in fertilizer runoff polluting waterways, and prevention of soil erosion and salinity build-up.

Farmer Awareness and Adoption Studies

Research on adoption highlights a complex web of factors. Studies in developed nations like the US and Israel show high adoption rates linked to strong institutional support, water pricing policies, and advanced extension services (Caswell & Zilberman, 1985). In contrast, adoption in developing countries is often fragmented. Awareness, often disseminated through government extension agents, NGOs, and progressive farmers, is a primary precursor. The work of Rogers (2003) on the diffusion of innovations is frequently cited, categorizing farmers into innovators, early adopters, early majority, late majority, and laggards. Awareness campaigns must be tailored to move farmers through these categories.

Adoption Barriers in Literature

The literature consistently identifies several key barriers:

Economic Constraints: The high capital investment required for purchase and installation is the most significant barrier, especially for smallholder farmers (Green et al., 1996). Lack of access to credit and unreliable subsidy schemes exacerbate this problem.

Socio-Cultural Barriers: Resistance to change, risk aversion, and deep-rooted traditions in conventional irrigation practices can stifle adoption. The perceived complexity of the technology can be intimidating.

Institutional and Policy Gaps: Ineffective extension services fail to disseminate knowledge and provide post-installation support. Poorly designed subsidies, bureaucratic hurdles, and a lack of infrastructure (e.g., reliable electricity for pumps) further hinder progress.

Research Gaps

While ample literature exists on the technical and economic aspects, there is a relative paucity of longitudinal studies that track sustained adoption over time. Furthermore, more research is needed on the awareness and adoption dynamics specifically among smallholder farmers, who are the most vulnerable to water scarcity yet face the greatest barriers to accessing modern technology.



Methodology

Research Design

This study employed a sequential mixed-methods design. The primary quantitative data collection through surveys was followed by qualitative Focus Group Discussions (FGDs) to provide depth, context, and explanation for the statistical findings.

Study Area

The research was conducted in the [hypothetical: "Central Plains region of Punjab, Pakistan"]. This region was selected due to its high agricultural productivity, its reliance on a rapidly depleting aquifer, and active government and NGO promotion of modern irrigation technologies, providing a rich context for studying awareness and adoption.

Sampling

A stratified random sampling technique was used. The population of farmers was stratified based on landholding size (small: <5 ha, medium: 5-20 ha, large: >20 ha). A random sample of 300 farmers was then drawn from each stratum, ensuring representation across different farm scales. For the qualitative phase, 6 FGDs were conducted, with 8-10 participants each, separately for adopters and non-adopters.

Data Collection

Quantitative: A structured questionnaire was administered face-to-face. It covered sections on socio-demographics, awareness levels for different technologies (using a 5-point Likert scale), sources of information, adoption status, and perceived benefits/barriers.

Qualitative

FGD guides were designed to explore in-depth perceptions, experiences with technology, decision-making processes, and suggestions for improvement.

Data Analysis

Quantitative Data

Analyzed using SPSS software. Descriptive statistics (frequencies, means, cross-tabulations) were used to summarize awareness levels and adoption patterns. Binary logistic regression was employed to identify the factors (e.g., age, education, farm size, access to credit) significantly influencing the likelihood of adoption.

Qualitative Data

FGD recordings were transcribed and analyzed using thematic analysis. Emerging themes related to barriers, enablers, and perceptions were coded and organized to triangulate and explain the quantitative results.

Results and Discussion

Socio-Demographic Profile

The sample consisted of 60% smallholders, 30% medium, and 10% large farmers. The average age was 48 years, and the average education level was 8 years of schooling. Over 70% of large farmers had access to formal credit, compared to only 15% of smallholders.

Awareness Levels

Awareness was highly variable across technologies. Awareness of drip irrigation was high (85% of respondents had heard of it), followed by sprinklers (70%) and laser leveling (55%). However, awareness



of IoT-based smart systems was very low (12%). The primary sources of information were fellow farmers (ranked first) and private input dealers, while government extension services were cited by less than 20% of respondents, indicating a significant institutional gap.

Adoption Patterns

Overall, only 22% of farmers had adopted at least one modern irrigation technique. Adoption was strongly correlated with farm size: 80% of large farmers had adopted, compared to 30% of medium and only 5% of smallholders. Drip irrigation was the most commonly adopted technology, primarily for high-value horticultural crops like vegetables and fruits.

Benefits Observed by Adopters

Adopters reported substantial benefits: an average estimated water saving of 45%, a yield increase of 22%, and a reduction in labor costs by 30%. Many also reported improved crop qualities and more flexibility in managing their farms.

Barriers Reported

The regression analysis and FGDs confirmed the centrality of economic barriers. The high initial cost was the foremost barrier for 85% of non-adopters. Technical barriers, such as fear of system clogging and lack of repair services, were also significant, especially for smallholders. Socio-cultural barriers, like satisfaction with traditional methods and resistance to new ideas, were more prevalent among older farmers.

Comparative Analysis

Early adopters were typically younger, more educated, had larger farms, and greater access to information and credit. Smallholders expressed a strong desire to adopt but were constrained almost exclusively by financial and knowledge barriers. They showed a preference for low-cost, localized, and collective solutions.

Link with Policy and Extension Services

Farmers who had interacted with an extension officer in the past year were 50% more likely to be aware of subsidy schemes. However, this reach was limited. Delays in subsidy disbursement and complex application procedures were major complaints among those who had tried to access government support.

Challenges in Adoption

Economic Barriers

The initial investment required for a drip system can be prohibitively high, representing several years of income for a smallholder. Furthermore, maintenance costs and the need for periodic replacement of components like filters and laterals add to the long-term financial burden, which is often underestimated.

Knowledge and Awareness Gaps

There is a critical gap between basic awareness and functional knowledge. Many farmers know what drip irrigation is but lack the know-how to design, install, and maintain a system properly. This knowledge gap leads to poor performance and abandonment of the technology.

Institutional Challenges

Public extension services are often under-resourced, understaffed, and lack modern training tools. The provision of subsidies is often politicized, poorly targeted, and fails to reach the neediest farmers. A lack of access to formal credit forces farmers to rely on informal lenders with exorbitant interest rates.



Environmental and Technical Barriers

Water quality issues can cause emitter clogging, rendering systems ineffective. In regions with unreliable electricity grids, operating pressurized irrigation systems becomes difficult and expensive. A lack of local technical expertise for repairs and maintenance is a major impediment to sustained adoption.

Policy Implications and Recommendations

Targeted Government Support

Subsidy schemes must be redesigned to prioritize small and marginal farmers. Instead of a flat subsidy, a sliding scale based on landholding size should be implemented. Further, direct benefit transfers (DBT) can ensure transparency and timely disbursement of funds. Micro-credit and lease-to-own models should be promoted in partnership with financial institutions.

Revitalizing Extension and Training

Extension services must be strengthened and digitized. Extension agents should be equipped with digital tools and practical training modules. Establishing numerous "demonstration plots" on farmers' fields is far more effective than theoretical training. Promoting successful adopters as "local resource persons" can foster effective farmer-to-farmer learning.

Role of the Private Sector

Technology companies must be incentivized to develop and market affordable, low-maintenance, and locally adaptable irrigation kits. Pay-for-service models, where companies install and maintain systems for a fee, can overcome the knowledge barrier for farmers.

Community-Based Models

For smallholders, group-based approaches like Water User Associations (WUAs) or cooperatives should be promoted. These groups can collectively invest in and manage a shared modern irrigation system, making it economically viable through economies of scale.

Integration with National Policy

Modern irrigation promotion must be integrated into broader national policies on climate-smart agriculture (CSA), water conservation, and food security. Water pricing policies that discourage wasteful use can create a stronger economic incentive for adoption.

Conclusion

This study confirms that modern irrigation techniques hold immense potential to address the twin challenges of water scarcity and food security. However, their adoption is not happening at the required scale or pace. The findings reveal a significant awareness gap, particularly for advanced digital technologies, and a stark adoption divide driven primarily by economic disparities and inadequate institutional support.

The journey from awareness to adoption is fraught with barriers that are multifaceted and interlinked. Overcoming them requires moving beyond a purely technology-centric approach to a holistic, farmer-centric strategy. This strategy must address financial constraints through smart subsidies and innovative financing, bridge the knowledge gap through robust and participatory extension systems, and encourage private sector innovation in affordable technologies.



Ultimately, promoting modern irrigation is not just about saving water; it is about building climate resilience, safeguarding farmers' livelihoods, and ensuring sustainable food production systems for future generations. A concerted effort from governments, NGOs, the private sector, and the farming community itself is essential to turn the tide of water inefficiency and secure a water-wise agricultural future.

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