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Investigating Contemporary Irrigation Solutions Promoting Agricultural Self-Reliance in Afghanistan

Abdul Qayoum Karim[1], Mohammad Shafi Sharifi[2]

[1] Faculty of Engineering, Kabul University, Kabul, Afghanistan
[2] Faculty of Engineering, Kabul University, Kabul, Afghanistan
✉E-mail: aqkarim@ku.edu.af (corresponding author)

ABSTRACT

The presence of moisture and water around the roots is responsible for the plant development and fertility. Without sufficient water availability, water needs to be supplied to plants effectively to make sure plants receive water according to the crop water requirement. This requires that different irrigation methods be used in consideration of soil types and other effective factors to reach the abundance of crops. The farm, concerning the soil, the topography of the area, and water resources, requires different irrigation methods that have been proposed and introduced worldwide and are not yet well common in Afghanistan. Knowing these irrigation methods enables farmers to apply them to increase crop fertility by considering the resources and characteristics of their farms. In this case study, modern irrigation methods are introduced and discussed along with their advantages and disadvantages to understand how effective these methods are in increasing crop fertility without wastage of water to help in agriculture and food self-sufficiency in the country. In this mixed-method study, the data is collected using a Google Form questionnaire focusing on finding the level of familiarity of the farmers and other stakeholders in the country with these methods, their evaluation of using these irrigation methods, the challenges they are facing using them, and their expectations from the government and their recommendations for the future. The findings are encouraging and useful.

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Introduction

With its mountainous characteristics, Afghanistan is an agricultural country that uses more than 93% of its water for farming and crop production. The majority of farmers still use traditional irrigation systems in cultivation. It is presumed that the farmers and other professionals have little knowledge of modern irrigation systems, which are vital for the efficient use of water in irrigation to meet crop water requirements, especially under the current circumstances where the world countries are facing global warming, climate change, and water scarcity (Ghimire and Johnston 2019). Afghanistan is not an exception. The government agricultural authorities are trying to improve irrigation systems to combat water

scarcity, prevent water wastage, ensure efficient water use, expand agricultural irrigation land, and increase agricultural products to meet society's food requirements (Abdelhaleem et al. 2021).

The MEW forecast of Flood, Drought, and Climate Change Effects on Water Resources Division on 2nd Feb. 2024 indicates that during the 3 months (October to January) of the water year (2023-2024) at an altitude of below 2500 meters compared with the long-term average of the year (2012-2023), 71% decrease occurred in rainfall, 75% in snowfall, and 47% in snow water equivalent. It shows that there will be insufficient water for different sectors in the summer season in some areas of the 5 river basins in the country.

Climate change is severely affecting both rural and urban areas, and urgent attention is required to ensure the well-being of communities over other issues (Jiang et al., 2023). Figure 1 shows an Afghanistan map of drought analysis prepared for the summer seasons of 2024, which indicates that different provinces are hit by different degrees of drought.

These forecasts underline the desire to investigate improving irrigation systems significantly (Collins et al. 2024). Their initiatives and activities need to be improved to be sufficient to move towards agricultural self-sufficiency (Ciceri and Allanore 2019). There is a need to determine what kind of relevant knowledge, information, and technologies the farmers and other stakeholders lack.

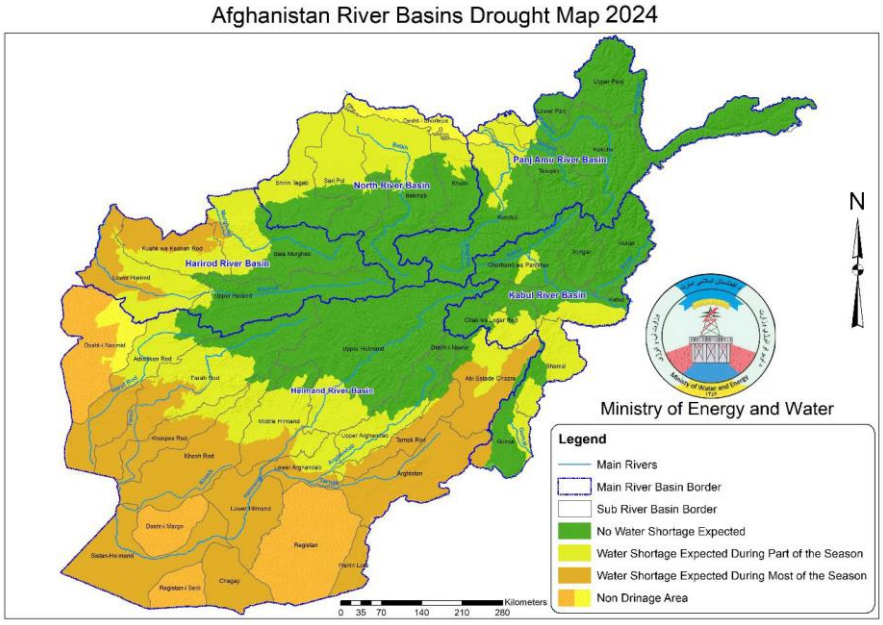

Figure 1: Areas under the threat of drought in Afghanistan

This quantitative and descriptive paper focuses on finding out about the level of familiarity of the farmers and other stakeholders with modern irrigation methods, how to increase the fertility of plants to lead the society towards food self-sufficiency, and evaluate the perception of society towards modern irrigation methods acceptances and practices to

reach an effective conclusion and make effective recommendations to identify ways leading to agricultural self-sufficiency (Agula et al. 2019).

Understanding the different crops' water requirements, soil types, and topography of the area as well as water resources and different irrigation methods, the advantages and disadvantages of irrigation methods enable farmers to increase the efficiency of their irrigation systems and to choose an irrigation method, which suits their local conditions best for better livelihoods and economic development (Boltana et al. 2024).

Literature Review

Irrigation Systems

Irrigation is the artificial application of water to the land or soil (Bennett et al. 2016). It may be defined as supplying water artificially to agricultural fields for crop production (Lenda et al., 2023). If water available to the plants from rainfall is insufficient, it is supplemented by irrigation water (Cheng et al., 2023). The primary irrigation water sources are rivers, springs, karezes, and wells. Farmers have used traditional irrigation methods for centuries (Hussain et al., 2008).

There are almost seven types of irrigation, i.e., Surface Irrigation, Localized Irrigation, Sprinkler Irrigation, Drip Irrigation, Centre Pivot Irrigation, Sub Irrigation, and Manual Irrigation. All these irrigation types are -based on their application method- divided into Traditional and Modern Methods (Rendon and Walton 2019). Apart from Sprinkler and Drip Systems, known as modern irrigation methods, others are all known as traditional systems (Taguta et al., 2022). Two methods to carry on irrigation, i.e., Traditional and Modern Methods, are briefly explained below.

Traditional Methods of Irrigation

In this method, irrigation is done manually. Here, a farmer pulls out water from wells or canals by himself or using cattle and carries it to farming fields. This method can vary in different regions.

The main advantage of this method is that it is cheap. However, its efficiency is poor because of the uneven distribution of water. Also, the chances of water loss are very high. Examples of the traditional system are the pulley, lever, and chain pump. Among these, the pump system is the most common and used widely.

This section discusses important factors to consider when determining which surface irrigation method is most suitable: basin, furrow, or border irrigation (Li et al., 2022). Again, it is impossible to give specific guidelines leading to a single best solution; each option has advantages and disadvantages.

Recent research shows that traditional methods have their advantages and disadvantages. The traditional method has a few problems that affect agricultural production (Yu et al. 2018). They include the following:

a) Excessive Labor Requirement: Traditional irrigation systems have extensive labor requirements. Lack of workforce is an obstacle that delays the agricultural and cultivation process, leading to decreased agricultural production.

b) Non-uniformity in water application is a cause of inappropriate use of water and water losses.

c) Water and electricity are not fully utilized. In this case, water is unnecessary water, which could be used to increase crop production.

d) Water losses are associated with unprofessional and ineffective use of water.

e) Evaporation loss is high in open channel flow.

Factors to be taken into account include:

a. natural circumstances (slope, soil type)

b. type of crop

c. required depth of irrigation application

d. level of technology

e. previous experience with irrigation

f. required labor inputs.

Basin irrigation is the simplest of the surface irrigation methods. Primarily, their operation and maintenance are simple if the small basins can be constructed by hand or animal traction. Furrow irrigation - except for short, level furrows -requires accurate field grading (Dibal et al. 2014). Machines often do this. The maintenance - plowing and furrowing - is also often done by machines. This requires skill, organization, and frequently using foreign currency for fuel, equipment, and spare parts. Short, level furrows - also called furrow basins - can, like basins, be constructed and maintained by hand.

Borders require the highest level of sophistication. They are constructed and maintained by machines. The grading needs to be accurate. Machine operation requires high skill, organization, and usually foreign currency. ([CSL STYLE ERROR: reference with no printed form.]) A survey was also conducted using a questionnaire through Google Forms to find out about different dimensions of understanding and implementing different modern irrigation systems with a focus on sprinkler, drip, and furrow irrigation methods, which are presented as a part of the findings.

Modern Methods of Irrigation

The modern method compensates for the disadvantages of traditional methods and thus helps in proper water usage. The modern method involves two systems, i.e., the Sprinkler and Drip systems (Bronson et al., 2018; An and Park, 2023).

Sprinkler System. As its name suggests, a sprinkler system sprinkles water over the crop and helps in an even distribution of water. This method is advisable in water-scarp areas (Suênio Anderson et al. 2021). Here, a pump is connected to pipes that generate pressure, and water is sprinkled through the pipes' nozzles. Water is distributed from a central location by overhead high-pressure sprinklers or from sprinklers from the moving platform.

Figure 2. An Example of a Sprinkler Irrigation System (https://www.istockphoto.com/search/2/image-film?phrase=sprinkler+irrigation)

Drip System. In the drip system, water supply is done drop by drop strictly at roots using a hose or pipe (Yoo et al. 2015). This method can also be used in regions where water availability is less. In this type, drops of water are delivered near the roots of the plants. This type of irrigation is rarely used as it requires more maintenance.

Figure 3. Modern Irrigation Methods of Sprinkler and Drip Irrigation Systems (https://www.istockphoto.com/search/2/image-film?phrase=sprinkler+irrigation)

Choice of Irrigation Method

The natural conditions such as soil types, slope, climate, water quality, and availability considerably impact the choice of an irrigation method (Lyu and Chen 2016; Rocha et al. 2020; Usman et al. 2023), as explained below.

Soil Types. Sandy soil has a low water storage capacity and a high infiltration rate. Therefore, they need frequent but small irrigation applications, particularly when the sandy soil is also shallow. Under these circumstances, sprinkler or drip irrigation is more suitable than surface irrigation. All three irrigation methods can be used on loam or clay soils, but surface irrigation is more commonly found. Clay soils with low infiltration rates are ideally suited to surface irrigation. When various soil types are found within one irrigation scheme, sprinkler or drip irrigation is recommended as they will ensure a more even water distribution.

Slope. Sprinkler or drip irrigation is preferred above surface irrigation on steeper or unevenly sloping lands as they require little or no land leveling. An exception is rice grown on terraces on sloping lands.

Climate. Strong wind can disturb the spraying of water from sprinklers. Under very windy conditions, drip or surface irrigation methods are preferred. In areas of supplementary irrigation, sprinkler or drip irrigation may be more suitable than surface irrigation because of their flexibility and adaptability to varying irrigation demands on the farm.

Water Availability. Water application efficiency is generally higher with sprinkler and drip irrigation than surface irrigation, so these methods are preferred when water is in short supply. However, it must be remembered that efficiency is just as much a function of the irrigator as the method used.

Water Quality. Surface irrigation is preferred if the irrigation water contains much sediment. The sediments may clog the drip or sprinkler irrigation systems. Drip irrigation is particularly suitable if the irrigation water contains dissolved salts, as less water is applied to the soil than surface methods. Sprinkler systems are more efficient than surface irrigation methods in leaching out salts (Fernández et al., 2020).

Types of Crops. Surface irrigation can be used for all types of crops. Sprinkler and drip irrigation, because of their high capital investment per hectare, are mostly used for high-value cash crops, such as vegetables and fruit trees. They are seldom used for the lower-value staple crops. Drip irrigation is suited to irrigating individual plants, trees, or row crops such as vegetables and sugarcane. It is unsuitable for close-growing crops (e.g., rice) (Peña et al., 2023).

Types of Technology. The type of technology affects the choice of irrigation method. In general, drip and sprinkler irrigation are technically more complicated methods. The purchase of equipment requires high capital investment per hectare. A high level of 'know-how' must be available to maintain the equipment. Also, a regular supply of fuel and spare parts must be maintained, which - together with the purchase of equipment - may require foreign currency.

Surface irrigation systems - mainly small-scale schemes - usually require less sophisticated equipment for construction and maintenance (unless pumps are used) (Peña et al., 2023). The equipment needed is often easier to maintain and less dependent on the availability of foreign currency.

Previous Experience with Irrigation. The choice of an irrigation method also depends on the irrigation tradition within the region or country (Kusano and Kemmelmeier 2020). Introducing a previously unknown method may lead to unexpected complications. It is not certain that the farmers will accept the new method. The servicing of the equipment may be problematic, and the costs may be high compared to the benefits. Therefore, it will often be easier to improve the traditional irrigation method than to introduce a new one.

They required Labor Inputs. Surface irrigation often requires a much higher labor input - for construction, operation, and maintenance - than sprinkler or drip irrigation, as shown in Figure 2. Surface irrigation requires accurate land leveling, regular maintenance, and a high level of farmers' organization to operate the system (Usman et al., 2023). Sprinkler and drip irrigation requires little land leveling; system operation and maintenance are less labor-intensive (Taguta et al. 2022).

Cost and Benefits. Before choosing an irrigation method, an estimate must be made of the costs and benefits of the available options (Grießbach et al. 2021). On the cost side, the construction, installation, operation, and maintenance (per hectare) should be considered. These costs should then be compared with the expected benefits (yields). Farmers will only be interested in implementing a certain method if they consider this economically attractive. Cost-benefit analysis is, however, beyond the scope of this paper.

Methods and Materials

This study is a quantitative research article that was conducted starting with desk research and a literature review. Desk research is considered to gather helpful information on irrigation methods and their advantages and disadvantages to provide readers with a thorough knowledge of them. Following that, a survey was designed and conducted using a questionnaire through Google Forms to determine which percentage of the population is familiar with and knows these irrigation methods (Verma et al., 2023). The information achieved through the desk research and the data collected is the basis of the research findings, which are discussed, the appropriate conclusion has been drawn, and useful recommendations have been made to be implemented by the stakeholders to increase the agricultural products and achieve the final goal of this paper. As the survey was conducted via Google Forms, the primary aim of sampling was to focus on an educated community that could respond to the survey questions online.

Analysis of the Responses of the Survey

The sample of the population for the survey was composed of 100% educated participants, 52% of whom had an undergraduate level of education, 44% of them had an MS/MA degree, and 4% had a PhD level of education. They included 40% teaching staff, 32% government employees, 16% NGO employees, and 3% others; 80% belong to the Urban areas, and 20% to the Rural areas. The findings show that 76% of the participants were familiar with modern irrigation techniques, 16% were somewhat familiar, and 8% knew nothing about them.

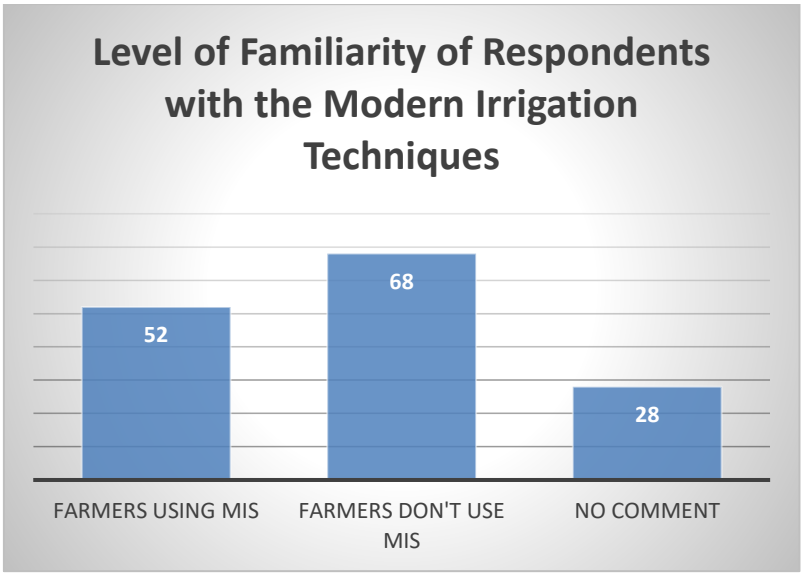

Figure 4. Level of Familiarity of respondents with modern irrigation techniques

60% of the respondents confirmed that the farmers are using different modern irrigation methods, such as sprinkler and drip irrigation; 36% thought that the farmers do not use any, and 4% were unsure whether the farmers were using any of these methods.

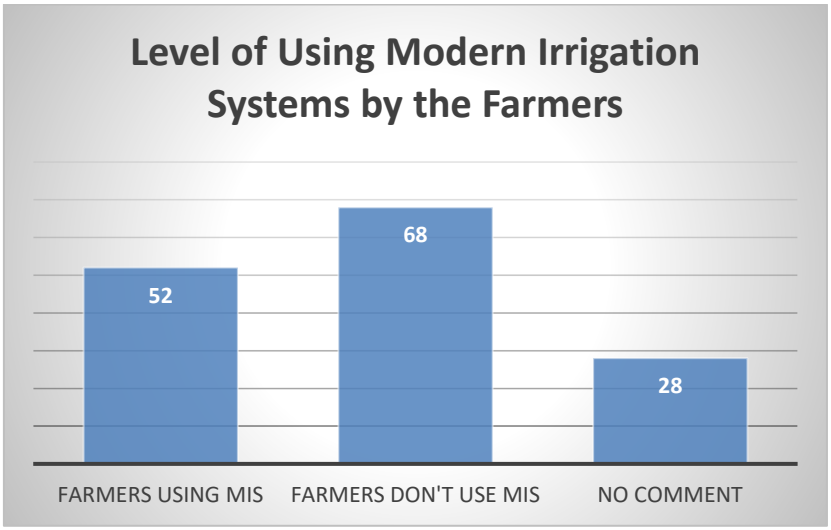

Figure 5. Level of using modern irrigation systems by the farmers

Analysis of the responses shows that 48% of the respondents strongly believe that the current irrigation methods are effective, 32% of them believe that they are effective, and 40% of them thought that the current methods are ineffective and need improvement.

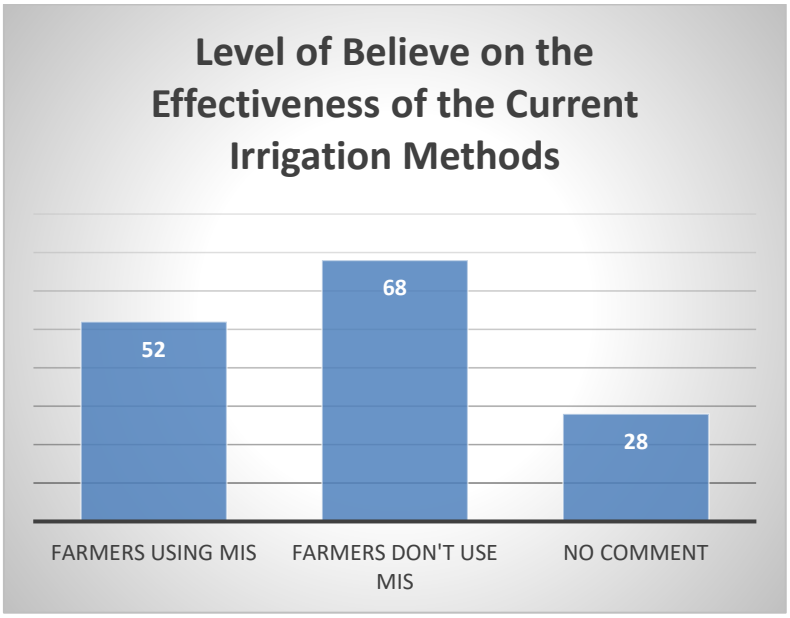

Figure 6. Level of Belief in the effectiveness of the current irrigation methods

The general assumption is that farmers face a few challenges and limitations in improving their irrigation systems. 72% of the survey respondents strongly believed, and 20% of them believed that the farmers were facing challenges and limitations in improving their irrigation systems. In comparison, 8% of them thought that the farmers were not facing any challenges and limitations.

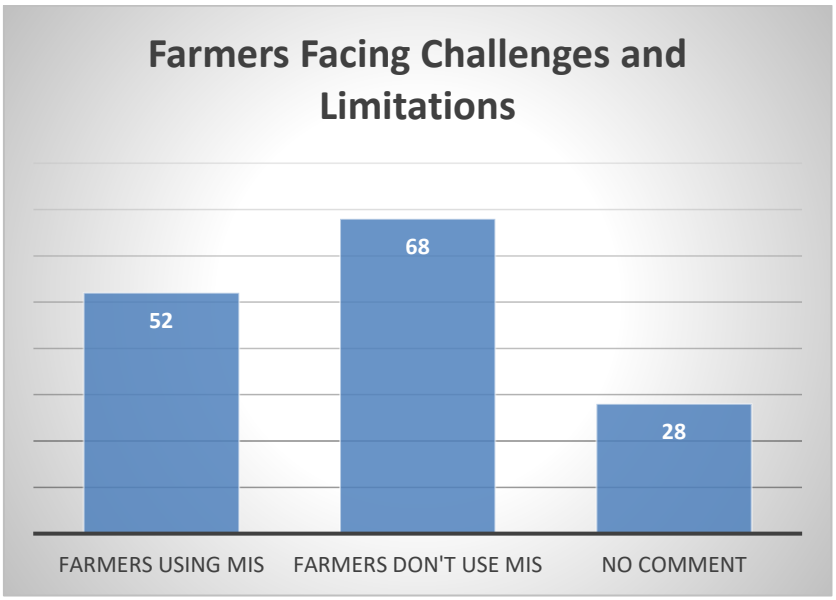

Figure 7. Farmers facing challenges and limitations

The responses describe that the farmers face some difficulties in maintaining new irrigation systems. A total of 64% of the respondents believe farmers are facing economic challenges, 20% of them lack familiarity with the irrigation methods, and 16% of them face a lack of understanding and need capacity building use them.

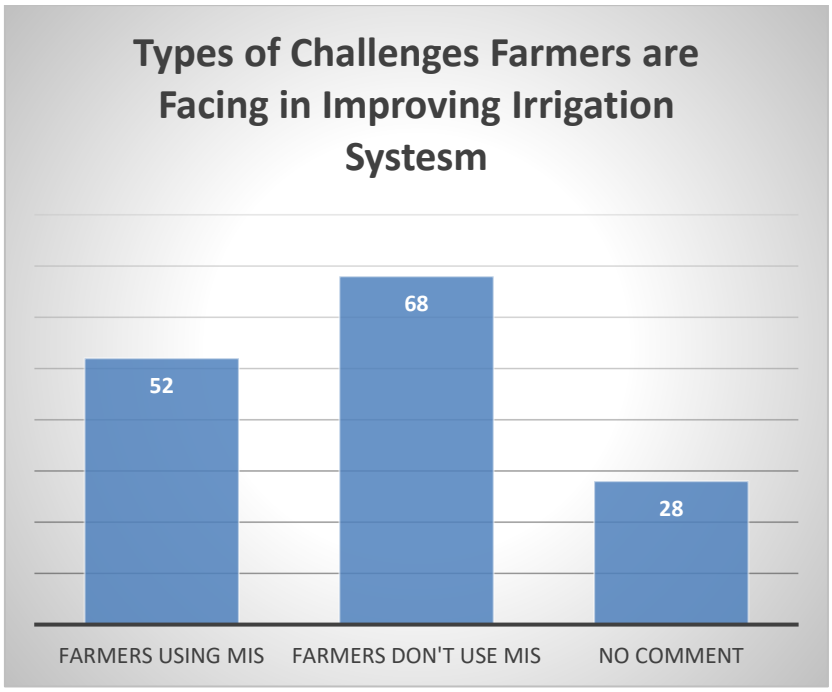

Figure 8. Types of challenges farmers are facing in improving irrigation systems

Finally, 48% of the respondents replied that they were aware of government initiatives to improve irrigation methods in the country, 36% had some information, and 16% did not know about it.

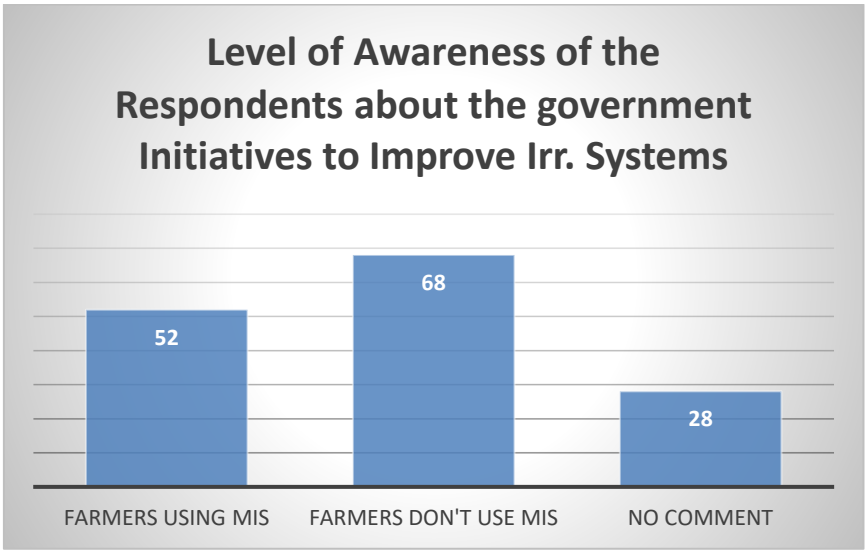

Figure 9. Level of Awareness of the Respondents about the government initiatives to improve irrigation systems

Results and Discussion

Familiarity with the Irrigation Techniques

The survey analysis reveals that the majority of the respondents from the educated community are familiar with modern irrigation systems and techniques. However, there is a strong need to determine how many percent of farmers in the country are familiar with these

methods to improve their irrigation systems. It shows the need to compare modern irrigation systems with traditional ones to determine their effectiveness in increasing agricultural productivity.

Familiarity with Different Types of Modern Irrigation Methods

The respondents confirmed that most farmers are interested in using different modern irrigation methods, such as sprinkler and drip irrigation. However, many of them still do not know about these systems. It highlights the need to raise farmers' awareness about these techniques and technologies, which will motivate the farmers in Afghanistan to go for modern irrigation systems.

Effectiveness of the Currently Used Irrigation Methods

From the responses, it is obvious that almost more than half of the educated community and academia respondents think that the traditional irrigation methods are effective. This is because no research has been conducted to compare modern and traditional irrigation methods to increase understanding of their benefits in Afghan society. It shows a serious need to conduct research and studies on the effectiveness and benefits of modern irrigation methods and information sharing in this regard through capacity building and awareness.

Irrigation Systems Improvement Challenges

The common understanding is that most farmers in the country face considerable challenges and limitations in improving their irrigation systems. The challenges are more than three-fifths economic, and almost one-fifth of each lacks familiarity with the irrigation methods and understanding the need for capacity building to operate, repair, and maintain these modern irrigation systems.

Government Initiatives to Improve Irrigation Methods

Government initiative is key to improving irrigation systems in the country as farmers are not fully empowered to use modern irrigation systems. Most of the educated community of Afghanistan is aware of government initiatives to improve irrigation methods in the country. However, further research is required to be conducted amongst the farmers' community to find out how many percent of them are aware of these initiatives, the types of initiatives to benefit from in improving their irrigation systems, and ultimately, participating in the process of contributing to the country to become self-sufficient shortly agriculturally.

Conclusion

In Afghanistan, where the society is facing water scarcity due to climate change, it is vital to adopt modern irrigation methods, i.e., Sprinkler and Drip Irrigations, to save water, use water effectively, and make water available for increasing agricultural productivity to reach self-sufficiency.

To achieve agricultural self-sufficiency, there is a solid need to familiarize the farmers and other stakeholders with modern irrigation techniques and types. It is the government's

responsibility to take the lead in familiarization and capacity building and provide financial and technical support to the farmers and other stakeholders in the improvement of the irrigation process. This research shows that the farmers in Afghanistan need economic, awareness, and technical capacity-building support to revolutionize the improvement of their irrigation systems and actively participate in the Afghanistan green revolution.

Recommendations

In light of this study's and the survey's findings, the following recommendations are practical in facilitating the green revolution in Afghanistan and leading the country to agricultural self-sufficiency. The government to prepare a national roadmap for improving irrigation methods and techniques in the country with the support of national and international stakeholders and donors to include actionable initiatives with a focus on the following:

A. Conduct public awareness and economic support for farmers on modern irrigation methods, techniques, operation, and maintenance.

B. Revision of the curriculum to enhance modern irrigation methods and techniques to increase agricultural productivity and safe water.

C. Construction of irrigation infrastructures, including irrigation canals, irrigation water reservoirs, water harvesting initiatives for irrigation purposes, etc., in consultation with farmers and other stakeholders.

D. Enhance surface water usage for irrigation purposes.

E. Support academia and research centers in conducting similar and other relevant research amongst the farmers and other stakeholders to identify and meet the challenges of improving irrigation systems, find assessment-based solutions, and share their findings with the government and other stakeholders for follow-up and improvement.

F. Monitoring the Agricultural Self-Sufficiency Roadmap Action Plan regularly, sharing lessons learned, and following up and adjusting the plan for further improvement.

Conflict of Interest: The author(s) declared no conflict of interest.

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