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REVIEW ARTICLE **OPEN ACCESS**

Review based on Advanced Technologies for Increasing Water Efficiency in Agriculture

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ABSTRACT
As per a recent report of the United Nations (UN) World Water Development Day Report, nearly 6 billion people will be suffering from freshwater scarcity by 2050. This is resultant of the increased water demand, increased pollution, and reduction in water resources driven by the factors like exponential population economic growth. While the UN report endorses the spontaneous adoption of new agricultural methods, there is also an urgent requirement to regulate the economy and demography, preservation of aquifers, and save water. In addition to these steps, the use of advanced technologies can be useful for maintaining the water efficiency of arable lands. The unique water-sensing abilities of these modern devices enable them to control and perform weather-based irrigation by acquiring data about when and how water is required. These Water Sense labeled irrigation controllers use weather data for irrigation which saves time, money, and natural resource as water. Other than these research outputs for intelligence-based irrigation, several International treaties and laws have been floated for tackling water management and crisis-related issues.
KEYWORDS: *Agriculture, Groundwater, Irrigation, Management, Productivity, Soil, Water.*

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INTRODUCTION

Water that is used to cultivate plants and feeds livestock is known as Agriculture water. The use of agricultural water allows the cultivation of fruits and vegetables as well as the raising of animals, all of which are important components of the present diet system. According to a report from the United States Geological Survey, approximately 65 percent of the world's freshwater extractions are being used for irrigation purposes excluding thermoelectric power[1]. Water requirement is critical for maintaining food security. Agriculture dependent on irrigation accounts for more than 40% of total food production worldwide and 20% of total cultivated lands[2]. Pieces of evidence also show that irrigated agricultural lands are two times more productive than rainfed lands which support crop diversification and intensifies production. Recent years have witnessed major climatic changes, urbanization at its peak level, extreme pollution, and population explosion, which has led to increasing water constrain in very near future, with particular impact over agriculture. As per the estimation, this continuous growth in rural and urban population will result up to 10 billion by 2050 and for the fulfillment of this basic requirement for food, fiber for this huge number the agriculture production will be needed to increase by 70% in 2050 which is a challenging issue with the shrinking agriculture land and other determining factors[3].

The potential to increase agricultural water management is often limited by insufficient policies, the underperformance of responsible institutions, and funding constraints. Institutions of public and private importance like Ministries of agriculture, irrigation departments, water consumers, and farmers' organizations, typically lack enabling environment as well as the necessary capacities for performing their functions effectively. Furthermore, most of the government authorities and water users fail to provide proper maintenance of irrigation and drainage. Although operational activities without proper management play a role in the poor performance of irrigation and drainage systems, the failure in maintenance results in deteriorating performance which result in the need for recovery[4]. The case of failure to supply sufficient funds for the repair of irrigation and drainage device has resulted in a "build-neglect-rehabilitate-neglect" loop in this sector.

Despite the above restrictions, the management of agricultural water is currently repositioning itself for providing sustainable and modern facilities. It recommends a unique water strategy for constructing resilient water systems and maintaining water supplies, mitigating the risks associated with wider social and economic levels. This involves the transformation in service and governance by providing support in watershed management with reformation and innovation schemes[5].

This could be achieved by the proper management of the Water Cycle in Agriculture. As described in Figure 1, the Water cycle/Hydrological cycle is the free and continuous movement of water from the surface of the earth to the atmosphere back and forth. Thus it's a constantly moving circular cycle with no end point and water goes through all three states of solid, liquid, and gases. Liquid water flows across land through runoff and percolates or infiltrates into the ground and changes as groundwater. Plants absorb the groundwater through their rootswhich evaporates from plants into the atmosphere through transpiration. The rainfall again fed the groundwater and this cycle goes on. Water at the surface can also be converted into Solid ice and snow which can directly turn into gas through sublimation. The factors which affect the water cycle are the Sun, airflow, and other natural or manmade reasons like pollution, and hindrances in the path of water[6].

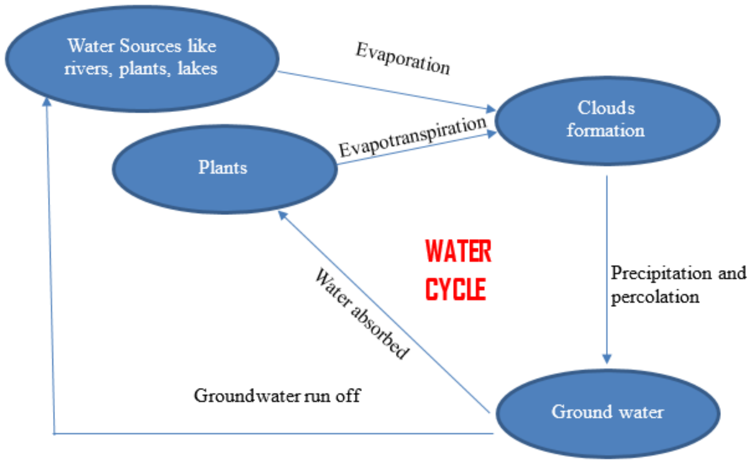

Figure 1: Flow of water in the Water Cycle. Plants absorb the groundwater through their roots and evapotranspire the water vapors for cloud formation which precipitates and refills land water reservoirs in form of groundwater

LITERATURE REVIEW

Almost 97% of earth's water is present in seas and oceans in form of salt water. Around 60% share of the residual 3% of water is as ice and snow on mountains and only the remaining is found as a global freshwater source. Almost 98% of this 1% fresh water occurs as a groundwater source and only the left 2% is present as a visible water source in form of rivers, lakes, and streams[7]. These figures show the less amount of water present for human use and thus require proper management in form of water storage through artificial recharge and artificial banking where the water is stored underground to prevent its evaporation and other factors which make impossible of water storage above the ground. A 98% of freshwater is stored as groundwater which hints about the space available for more storage[6]. Artificially recharge of water is attained by keeping it on land so that it can penetrate soil which transfers down-ward to the underground water. Permeable soil like gravels &sands is ideal for free flow in groundwater for such systems. During flooding, penetration rates usually vary from 0.5 to 3 meters per day[8]. On the other hand, continued flooding causes suspended particles in the water to be collected over the soil surface which forms a clogging layer that decreases the rate of penetration. The biological growth in the clogged waters worse the condition and prevents infiltration. So, the infiltration systems should be dried regularly and must be allowed for cracking, and the clogging layer is mechanically removed. Long-term infiltration rates for year-round operations of surface refill technologies could be in the region of 100–400 meters annually, depending upon dryness seasons [9].

Herman Bouwer in 1993 showed the recycling of water through the global hydrologic cycle. The increasing popularity of planned water reuse is because of two main reasons: First, sewage effluent discharge into the surface water has become more expensive and difficult as the treatment requirements have become very strict to defend receiving water value for supportive aquatic life, its regeneration, and downstream employers. The cost of stringent treatment might also be financially unattractive for the municipalities for treating the water for reuse rather than discharge[10]. Secondly, municipal wastewater can be a significant water source, especially in the water-scarce area, which may be used for various purposes. Most advantageous and logical reuse can be for non-potable purposes such as agricultural, urban irrigation, toilet flushing, dust control, firefighting, and other industrial uses like cooling and processing or environmental enhancement in form of new wetlands, urban lakes,etc. These objectives can be achieved by proper treatment of effluent so that the water should meet the quality requirements for intended use [11].

A recent report by International Atomic Energy Agency on Agriculture water management shows that approximately 70% of global water is being used for agricultural purposes yet in terms of water use efficiency, most countries lie below 50%[12].Nuclear & isotopic methods give information on water consumption and losses due to soils evaporating, allowing irrigation schedules to be optimized and water consumption to be improved.

WATER CONSERVATION STRATEGIES

Agriculture irrigation withdraws around 70% of all groundwater worldwide. A considerable portion of water precipitation flows down to rivers or groundwater, which can be reused by downstream water users with proper water management. Irrigation has more than doubled globally since 1960, but in many key areas, irrigators have hit the maximum of usable water. Middle East, South Asia, and North Africa are using half of the available water for human consumption, which is an unacceptable situation. To cope with this situation, we need higher crop-water productivity. Yield growth will be crucial in resource-constrained areas, but it will depend on technological advancement[13].

Earth Observation Technologies

Within the past 3 decades, the population explosion would result in 9 to 10 billion stomachs being filled with agricultural produce by 2050 which will certainly require lots of water. Thus there should be careful management of water sources. By the year 2050 world's freshwater reservoir will be depleted nearly or fully because of excessive use in agriculture or pumping of water for drinking purposes which may lead to an alarming situation if not tackled at proper timing[14]. Now it’s high time to carefully monitor the water productivity in agriculture. It is a certain amount of water that can be used for a certain amount of harvest.

But the question is how to monitor this water productivity and how it can be increased in the future to grow more crops in a single drop of water[15]. The answer is ‘Earth Observation Technologies’,which are the outcome of modern scientific development and facilitate the user to monitor key data like natural resource management through satellite remote sensing technology which is required for sustainable agriculture production[16]. These satellites quantify the water content in the air reaches through evaporation from water bodies, canopy interception, soil, and evapotranspiration from plants. These advanced devices also assess plant growth by using satellite remote sensing technology[17]. Water productivity can be enhanced with the increase of biomass production in a crop or a decrease the amount of water required for that production.

As shown in Figure 2, Many satellites of the EPA (Environmental Protection Agency)and NASA (National Aeronautics and Space Administration) provide free data on spatial resolutions that vary from tens to hundreds of meters, globally which are updated in the time frame of one to ten days[18]. FAO brings all data in its open access database WAPOR (Water Productivity through Open access of remotely sensed derived data), for remotely sensing the water productivity to help the farmers to achieve more reliable agricultural yields and allowing for the optimization of irrigation systems[19]. WAPOR provides open access database for water productivity by analyzing thousands of underlying map layers. WAPOR, when used at a high resolution, generates detailed maps to track the functioning of irrigation schemes to promote modernization plans, and also offer improved water services to the irrigators[20]. Agricultural extension programs use data to help farmers to prevent crop failure and thus improve smallholder farmers’ livelihoods and enable them as more resilient towards climate change. As a result, FAO has created a publicly available near real-time database based on satellite data that enables agricultural water production to be monitored[21]. In this way, the Food and Agriculture Organization (FAO) contributes to the capacity development of the agriculture sector along with sustainable use of water in agriculture and securing food demand of the growing population especially benefitted African and near east countries at a significant level.

WAPOR's main functional areas include:

- Assessing continental water productivity
- Monitor irrigation areas
- Evaluating water output

- Monitoring the impact of drought
- Calculating how much water crops use.
- Keeping track of variations in agricultural output.
- Supplying farmers with consultation services
- Conducting a nationwide assessment of water resources

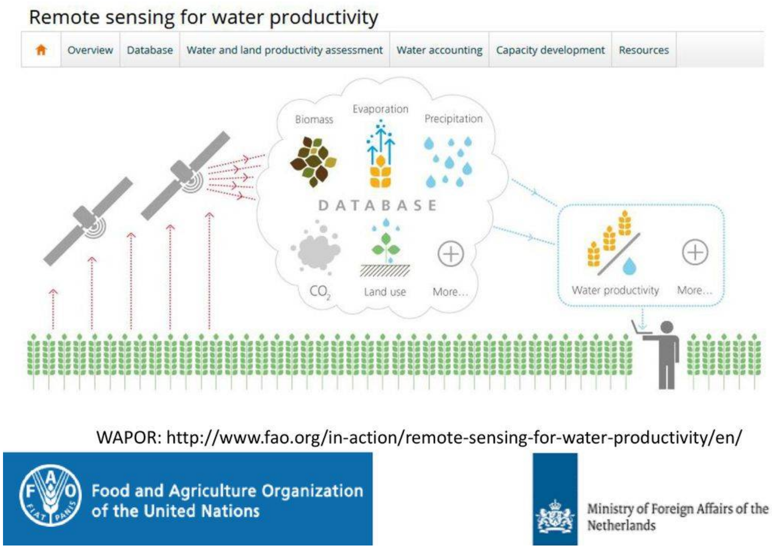

Figure 2: Schematic representation of Satellite Sensing for water vapor in the atmosphere and incorporation in the WaPOR database, facilitated by the Food and Agriculture Organization of United Nations [FAO]

Wireless underground sensor network (WSN)

This wireless sensor network includes autonomous sensor nodes to store and relay environmental data wirelessly. The nodes are tiny computers with limited memory and processing capacities. These sensors are under field trial and collect real-time information about the crop condition, and soil texture and transmits these data to the computing unit or the user platform to enable the farmer to make an immediate and informed decision at the time of need. This system is energy efficient and inexpensive too, it is powered by two AA batteries and works with a wireless sensing network with 100 % communication reliability[22].

The development in MEMS (Micro-electromechanical System) technology has eased up the formation of minor-sized little price sensors. These devices enable the sensor node to gather near by information. As mentioned in Figure 3, these nodes work based on provided commands and sensed data, thereafter these nodes network amongst themselves for performing the required implementation[23].Imagine an agricultural area with wireless sensor networks installed across the area for autonomous watering. These sensors will regulate the soil's moisture content and then estimate the duration and time required to irrigate that field. The choice would then be communicated to sensor nodes connected to water pumps through a similar connection[24].

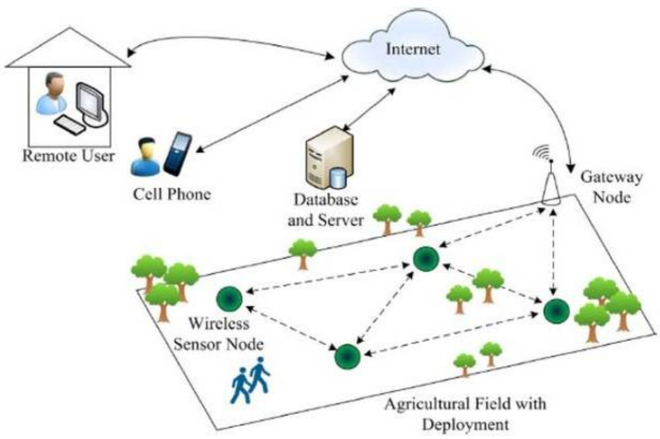

Figure 3: Illustrates an example of a wireless sensor network used for agriculture purposes which can be controlled by a user platform or device [24]

This system will enable the soil to tell the farmer what to do. This means when it requires water or whether there is a water-logged condition in the field. This will decrease the chances of crop failure by understanding the best possible need for the soil and the crop[25].

Since 1960, in the United States of America, double production could be achieved because of the improved irrigation facility. The requirement for irrigation was monitored with the help of Vapor pressure deficit (VPD), as lower VPD shows a higher level of moisture over the soil/plant surface therefore less irrigation is required. These intelligent irrigation techniques have increased crop water productivity which results in the improved harvest with efficient use of water. These recent advancements in water management and irrigation technology are very critical[26]. This Pressure based irrigation method decreases the conveyance loss and also improves the ability for managing irrigation systems in combination with other advances which include coupling irrigation scheduling systems with weather station networks, improvements in the crop and water requirements predictions, and region-wise water demand predictions by satellite.

Irrigation Scheduling Improvement Techniques

In the landlocked countries of the Mediterranean, mid-Europe, and Asia, the very least percentage of their territory is intensively cultivated irrigated land in river valleys as in Jordan and Uzbekistan where this value is around 10% only[27].In a country like Jordan, the irrigated area is small but it is socially and economically. Because of the country's geographical location, irrigation is a big challenge as evaporation leads to huge water loss. Hence, the evolved irrigation method in this country involves covering the irrigated area with plastic houses, thus increasing productivity to high levels. Other irrigation scheduling improvements include the organization of the weather station network, correspondence with the farmers through text messages, and the use of a weighing lysimeter for determining crop cover effect over water use[28].

For irrigation purposes, Uzbekistan adopted drip irrigation as the country has an insufficient means of surface irrigation. Drip irrigation was first developed and applied on an industrial scale as an independent method of irrigation in Israel in the early 1960s[29]. This method secured positive results in a very short period and resulted in its widespread acceptance in many other world countries. Drip irrigation works by the inflow of water into the root zone of plants in a limited amount. The water supply quantity is adjusted in such a way as to fulfill the need for water for the plants. In the drip irrigation method, there is a uniform distribution of water to all plants, as much as the plant requires, also without causing soil flood or water depletion. One brilliant example of drip irrigation is rice production. The majority of rice varieties are grown in flooded soil but under drip irrigation, the harvest can be produced in much water-efficient way[30]. Figure 4 shows the optimum water requirement in the rice field in place of flooded soil. This way of water use has a positive impact on the less consumption of water which can be utilized to fulfill other purposes.

Figure 4: Drip irrigation in high water requiring rice fields[7]. The picture shows the harvest growing in a water-efficient manner with less water consumption and a constant wet root system as required by the paddy field

Center pivot irrigation in Saudi Arabia

This is a typical irrigation project for isolated arable places scattered throughout arid and hyper-arid regions. Under this project, a dam network has been developed to catch and utilize important seasonal floods. Deep wells also tapped vast underground water reservoirs. Desalination plants convert saltwater to fresh water for its utilization in industries and other urban uses including irrigation. Other facilities are present there for dealing with municipal and industrial runoff for rural drainage. These practices have collectively led to the turning of vast swaths of desert into fertile farmland[31].

Despite these advancements, many obstacles remain to improve efficient agricultural water use. Technological and economic affordability, water pricing, land tenure challenges, and equitable markets are critically important and must be tackled effectively[29].

CONCLUSION

The water crisis has emerged as a critical issue that needs immediate attention to deal with water scarcity and management-related issues, now there is international consensus on water policy to consider the economic value of water. On at least a catchment size, the consensus favors an adaptive strategy for water management and multi-sectoral views about water use. Water management is considered along with aspects of environmental security, economic efficiency, sustainability, and interests of vulnerable and disadvantaged communities. Decisions should be made with the consent of consumers, especially females, and must be guided by the requirements of the group. Water reserves must be economically effective, financially sustainable, and socially reasonable.

A strong water sustainability plan requires that the whole stock of natural water should not be depleted. Thus, the activities must be in support of the conservation of the natural environment which also requires ensuring that any loss of natural resources must be replaced or compensated considerably. Any developmental projects with negative environmental impact should be overcome by employing the factors which ultimately generate net environmental benefit. For example, in the U.S.A. wetland mitigation policy provides a strong sustainability requirement that demands compensation in form of the establishment of any alternative wetland of equal quality in return for the damage to a wetland.

These new approaches toward water policy seek to follow a more sustainable approach led by stewardship, justice, and transparency concepts. This will result in constraining the mindset and market processes that regard water as a product with its numerous functions and attempting to establish an effective allocation of water between competing end users. Efficiency is critical but not an adequate prerequisite for sustainability, but how constraining sustainability requirements can be an open science and policy challenges. This paper is focused on exploring recent strategic development and approaches to build an efficient water management model which can better address complex and composite sustainability questions and challenges.

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CONFLICT OF INTEREST

The authors have no conflict of interest

AUTHOR CONTRIBUTIONS

Dr. Mohinder Singh conducted the research, analyzed the data, proposed the methodology, and wrote the initial draft; Dr. Rohit Kumar modified and supervised the initial draft; Dr. Ram Lakhan Maurya supervised the research and wrote the final version of the manuscript. All authors had approved the final version.

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