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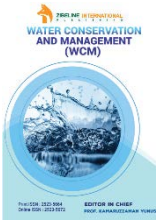

RESEARCH ARTICLE

INADEQUATE SUPPLY OF WATER IN AGRICULTURE SECTOR OF PAKISTAN DUE TO DEPLETING WATER RESERVOIRS AND REDUNDANT IRRIGATION SYSTEM

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ABSTRACT

Present study aim is to reveal current situation of water availability for agricultural productivity through factors responsible for water depletion and improper use of irrigation water. The paper discuses major problems identify future scenario and suggests making policies implementation to increase agricultural productivity in Pakistan. In Pakistan, agricultural productivity decreases due to the facts that the available natural water resources get depleted due to pollution, silting in reservoirs, leaching, salinity etc leads to water scarcity. It's a world known fact that Pakistan is an agricultural country; however, the irrigation traditional methods used here are a major reason to decrease the yield per drop. Moreover, certain considerations like barriers to technical adaptation, farming system practices for enhancing water productivity, integrated land and water management, water logging and reclaiming irrigated lands needs to be implemented to fulfill the sufficient water supply for agricultural lands. Protection of water sources, wastewater reuse, low-cost water supply and treatment systems, impacts of farming practices, climate change effects and efficiency of water transport and distribution systems are the key points needs to execute to overcome the water scarcity problem for agriculture sector. Water governance, technology transfer and knowledge sharing are mandatory for the sustainable agricultural development.

KEYWORDS

Water reservoirs, redundant irrigation system, agricultural productivity, climate change.

1. INTRODUCTION

Pakistan is situated into a subtropical region that is semi-arid and has northern east location in the world, just above tropic of cancer that is 23.5°N with magnitude of 240.30'N– 370 N and 610 E – 750 E, approximately. Climate and agriculture in Pakistan are greatly influenced by the coastline existing in 1046 km south. During monsoon season in summer, almost 90-97% rainfall is received while in winter only a few showers occur in Pakistan. However, flooding and drought period leads to specific characteristics for certain areas. In Pakistan most of the times seasonal showers used for irrigation purpose on agricultural lands, therefore agricultural productivity is mostly influenced by the global warming and climatic variability. In Pakistan entire soil region is 96.9%, while 3.1% comprises of water reservoirs. However, 90% agricultural land is irrigated and just 10% is rain fed for total 23.04 million hectors cropped area of Pakistan.

Indus Basin, Kharan Desert system and Makran coastal drainage, three hydrological units exists in Pakistan. However, Indus basin contributes major surface and groundwater resources. Geographical distribution in Pakistan allows a small number of inter basin transfers that are economical and technically feasible. Moreover, desalination of saline water can supplement the water resources for profitable applications. In Pakistan water withdrawal is high as a total sum of almost 184 billion cubic meters surface and groundwater withdrawal is occur that is 78% of overall standard resource annually. Though this total represents a considerable double counting error for the reason that most of the withdrawal from groundwater is the former withdrawal as surface water through diversions into irrigation canals that then leach down or added up in ground water through canal system.

In terms of groundwater withdrawal, almost 70% is prop up by leakage from canal water and irrigation drainage and rest comprises of rainfall and river recharge (Laghari et al., 2012). To adjust this dual counting error, consider about 136 billion cubic meters almost 59 % of the total renewable water resource as net withdrawal annually. It's a rough estimate that for agriculture, municipal use and industry withdrawal is 94 %, 5% and 1%, respectively (FAO, 2011). In Pakistan drinking water resource requires considerable attention of the respective management, because clean water availability to the increasing population of urban and rural areas in a sustainable manner is now become a challenge specifically in certain areas of Sindh and Baluchistan, where population suffers from acute drinking water scarcity. This water scarcity occurs because of depletion of natural freshwater bodies' like rivers, lakes and streams due to pollution, wastewater dumping, increased water withdrawal and less water recharge.

Another major concern is to conserve and maximally utilize the floodwater as most of it gets wasted as runoff and it also helps to prevent the undesirable effects of major floods, which then can overcome the human suffering and economic loss by such catastrophic activity. There is an emergent need to conserve water from different catastrophic activities

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like floodwater and rainwater to meet the demands of industrial, agricultural and domestic needs for continuous increasing population. Pakistan being an agricultural country, has major consumption of water in agriculture sector of about 94% of total available surface and groundwater resources that ultimately results in new and unending challenges both in terms of quality and quantity of water resources management. Agricultural, municipal and industrial effluents affect the quality of freshwater bodies, therefore recent scenario impose a pressure to increase the agricultural productivity by decreasing the environmental stress.

Contribution of agricultural sector to GDP of Pakistan is 19.5%, provides work for 42% labor force, comprises of 64% of export earnings and endow with employment to 62% of country population (Economic Survey, 2016-17), as agriculture sector is the largest user of water in Pakistan. In Pakistan the water availability is already below the scarcity level of 1000 m^3/person and climatic effects in the region also worse the situation. Minimum per capita domestic water requirement is 50 liters whereas almost 2600 to 5300 liters requires growing food per person for a day (Rijsberman, 2006). Consequently, food availability depends on the water security as water demand increases 50-70 times more than for domestic purpose. Irrigated agriculture contributes about 90% food production however rain fed dry land agriculture contributes just 10% due to inadequate less rainfall in Pakistan. In terms of quantifiable social and economic onsite benefits derived from irrigation agricultural productivity is 12 times direct (World Bank, 2006). In Pakistan government and population both are very much concerned to highlight the current and future impacts of water scarcity on human life and their survival. This problem is extremely insightful and broad in multiple aspects like requiring manifold and enduring measures to deal efficiently with water deficiency confronting various areas and different sections of the society. In perspective of escalating water scarcity, the problems need to be highlighted and controlled include: enhance water storage capacity, minimize water loss at various steps in different sectors, enhance water productivity, development of suitable regulatory agenda to manage the surface and ground water, formulate and put into practice the specific and suitable crop zones and cropping patterns and cut back on prices for water usage in different sectors. Approved National water policy 2018 is an important achievement in policy development and can be used as guiding principle to address the water scarcity issues.

Likewise, to increase the agricultural productivity and to fulfill the municipal, domestic and industrial water demands environmental issues also gets highlighted. The knowledge and recognition for least environmental flows in freshwater bodies and delta ecosystems also require supplementary water. All these expansions will ultimately decrease the available water quantity for agricultural sector. Water a basic necessity for sustaining good quality of life on earth. This limited service has direct bearing on approximately all sectors of country's economy. As agriculture is the major consumer of water, thus sustainable agricultural development is based on the well-timed and sufficient supply of water. However, due to increase in population, anthropogenic activities and industrial development need of water demand increase in these sectors that will ultimately reduce the water availability for irrigation purpose. Therefore, technology foresight should provide in-depth and sustainable solutions for prevention of water loss during loss during flooding and agricultural water management.

1.1 Problem Statement

"How can we address inadequate supply of water in agricultural sector?"

To sustain and increase the GDP production from agriculture sector and to fulfill the population food requirement there is an urgent need to identify the problems involved in the inadequate supply for agriculture. Also, it's vital to critically observe the factors responsible for depletion of natural water reservoirs of Pakistan also the methods make the use of available irrigation water inefficient. Moreover, there is an urge to offer the economical and efficient proposals to save the available natural water resources and improve available redundant irrigation system.

1.2 Research Questions

This research proposal has been developed by answering the following questions:

1. In Pakistan, how can we address inadequate supply of water due to depleting water reservoirs and the inefficient use of available water resources due to redundant irrigation system in agriculture sector?
2. How deliverance of water supply system affects the agriculture sector for its odious usage in irrigation?

1.3 Research Objectives

Major objectives of present study include:

1. To study the factors responsible for depletion of water reservoirs
2. To identify the inefficient ways to use the available water resources
3. To identify shortfalls in redundant irrigation system of Pakistan and suggestions to improve irrigation water productivity

1.4 Significance of Study/ Benefits/ Scope/ Importance

The purpose of this study in part is to reflect gaps in existing knowledge and in part to inform future programmers. Currently all over the world and specifically Pakistan has facing the water scarcity because of depleting natural water reservoirs, climate change and its unfavorable consequences. As a result, mostly developed countries and also the developing ones emphasize on the development of advanced agricultural techniques like drip irrigation to acquire maximum yield per acre by using limited water quantity that will ultimately increase the water productivity. However, Pakistan being a developing country faces manifold issues like no proper water storage setup, no proper water distribution setup and also no advance technological developments in case of irrigation system.

Consequently, water availability is badly affected by climate changing patterns and rapid depletion of available natural water in the country. There is an urgent need to recycle the wastewater for agricultural practices to balance the water scarcity, along with that also need to build dams having maximum capacity for efficient water storage. Moreover, needs to develop sustainable practices both for management of water supply and water demand for all sectors. Federal and provincial governments need to initiate pilot projects at national level for the development of complementary treaties regarding irrigation water demand and delivery. This research article highlights the shortfalls in our irrigation water management and distribution system and proposes feasible options to optimize the water availability for agriculture sector.

2. Literature Review

In Pakistan's economic development agriculture act as backbone a major supplier to food availability and security as it contributed agricultural GDP almost 20.9% to national GDP of Pakistan and accounted for almost 60% of overseas trade earnings (GoP, 2015; MNFSR, 2015; Chandio et al., 2016). Dharmasiri reported that agricultural productivity means "*output per unit of input*" (Dharmasiri, 2012). Soil salinity rigorously consumes the land productive ability and leads to significantly less crop production. At present in Pakistan, almost 4.5 MHA area got salinized due to the underground saline water available near to the earth's surface and also due to agricultural field irrigation with tube well water having poor quality (Qureshi et al., 2008). However, secondary salinity caused because of poor groundwater quality used for irrigation. Indus basin pump sodic or saline-sodic water in 70% tube wells due to which 2.3 MHA of agricultural field have become sodic-saline (Qureshi and Barrett-Lennard, 1998; Pakistan Council of Science and Technology, 2003).

Another major environmental issue that degrades the land productive capacity is water logging. Presently almost 5 MHA about 30% of irrigated land (17 MHA) is potentially water logged due to the water table within 3m depth from earth's surface and 2 MHA about 12% area encompasses 1.5 m depth of water table seriously gets water logged (Iqbal and Ahmad, 2005; Aslam et al., 2008). Pakistan is a semi-arid country located in south Asia, where average annual rainfall is almost 250 mm (Kahlown and Majeed, 2004). Almost 67% rainfall occurs in monsoon summer season within time period of July-September. In Pakistan total land area is 80 million hectares out of which 22 million hectares area is used as agricultural land (Ahmad, 2009). Out of total cultivated area of 22 MHA almost 17 and 5 MHA area are irrigated and rain fed, respectively (Qureshi et al., 2010; Kahlown and Majeed, 2004). Irrigated land yield almost 90% of agricultural productivity (Qureshi et al., 2010; Kahlown and Majeed, 2004). In Pakistan, the irrigation system of Indus basin supplies surface water to irrigate the agriculture fields.

However, ground water also plays a significant role to fulfill almost 50% irrigation requirement of croplands (Qureshi et al., 2010). Rain fed agriculture adds up to almost 10% of overall agricultural productivity in Pakistan (Kahlown and Majeed, 2004). During application, Pakistani farmers still largely utilize the highly inefficient system of flood irrigation to water their croplands. Although widely practiced, this method is detrimental to producing better crop yield. In fact, many studies have shown that you can produce 'more crop per drop' by using more water economical methods such as drip or sprinkler irrigation and by creating

bed and furrows, trench plantation, and leveling land appropriately for crops (Janjua, 2018; Jabri, 2018). Despite tempting government subsidies in the drip irrigation system, uptake has been low, mostly because the upfront costs are too high for those without solid financial backing. With the 80 percent subsidy to install solar plants in farms, many landowners found it easier to reduce their high diesel costs for running the pumps.

However, some find it challenging to implement drip irrigation in row farming with crops such as maize, wheat, and rice. Provincial government agencies need to impress upon the need for awareness at the grassroots amongst farmhands who struggle to come to terms with alien methods of irrigation that require almost 50 percent less water per acre (Japanese Ministry of Environment Report). Scheduling irrigation has also proved effective in many regions across the world. In India, sugarcane farmers were advised through text messages when to begin irrigating and for how long. This is a great method in a country where the vast majority of the rural population has access to phones but lacks the basic knowledge required in scientifically determining the most efficient way to irrigate their crops. As such, it could be implemented in Pakistan as well (Kamal et al., 2012). Another water saving method in which to irrigate crops that has seen success in Israel, is to use effluent water.

This water that would usually be left to drain into the sea is instead reclaimed and stored in an underground aquifer – a step that further reduces losses through evaporation. Presently, over 40 percent of Israel's agricultural water is supplied by effluent water (Khan, 2019). Kamal et al. believe that an important shift from 'water supply' to 'water demand' must be made and requests for more water must be critically analyzed. "Why be supposed to consider this demand whilst agriculture sector already consumes 97% of total available surface water and almost all ground water for sustaining one of the lowest agricultural productivity in the world per unit of land and water?" An important observation is regarding the drought of 1999-2000, where despite the drastically low water availability, a bumper crop of wheat was harvested (Khan, 2018). This proves that it is possible to produce a higher crop yield using less water.

3. METHODOLOGY

In the present study, factors responsible for inadequate supply of water to agricultural sector like water reservoir's depletion have been identified, also stated improper uses of available water reservoirs and methods to improve redundant irrigation system in Pakistan.

3.1 Data collection method

Qualitative data has been collected from the reported literature and reports for content and thematic analysis.

3.2 Data Analysis Technique

This is a fundamental part of study for the reason that it represents the regulatory framework to meet up objectives of study. It has further been divided into following sub parts:

3.2.1 Content Analysis

Review of different studies has been done to observe the facts that were and will be responsible for the inadequate supply of irrigation water to agricultural fields. In some reported literature it was stated that natural water resources depletion in Pakistan and then the traditional irrigation methods both are responsible for decrease in irrigation water availability. Unavailability of sufficient irrigation water ultimately leads to the loss of agricultural productivity. Different tabular data reported in literature also has been studied to observe the factors responsible for loss of agricultural productivity due to redundant irrigation system.

3.2.2 Thematic Analysis

For qualitative thematic data analysis, inadequate supply of irrigation water to agriculture sector is taken as global theme, with basic themes of water resource depletion and redundant irrigation system with respective codes for each basic theme to fulfill the specific study objectives.

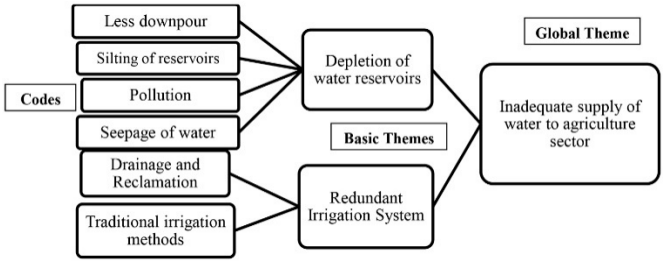

Figure 1: From codes to Basic and global themes

3.3 Data Analysis/ Results

Data extracted from the reported literature analyzed by content and thematic analysis and the results are reported as follows:

3.3.1 Irrigation System in Pakistan

In July-September, 2018 during monsoon season normal average rainfall was 140.9 mm, however the actual rainfall reported was 96.1 mm depict a cut down of 31.8%. In October-December, 2018, during post monsoon season normal average rainfall was 26.4 mm, however the actual recorded rainfall was 15.6 mm showing decrease of 40.9%. For the duration of winter season in January-March 2019, normal average rainfall was 74.3 mm, whereas the actual rainfall documented was 107.2 mm show increase of 44.3%. Rainfall recorded during the monsoon, post monsoon and winter is given in Table 1.

Table 1: Rainfall* Recorded During 2018-19 (in Millimetres)

	Monsoon Rainfall (Jul-Sep) 2018	Post Monsoon Rainfall (Oct-Dec) 2018	Winter Rainfall (Jan-Mar) 2019
Normal**	140.9	26.4	74.3
Actual	96.1	15.6	107.2
Shortage (-) /excess (+)	- 44.8	-10.8	+32.9
% Shortage (-) /excess (+)	-31.8	- 40.9	+44.3
*:Area Weighted, **:Long Period Average (1961-2010)			

Source: Pakistan Meteorological Department

For the duration of April-September, 2018, during kharif season water withdrawal from canal head was turn down to 59.62 Million Acre Feet (MAF) depicting a decline of 15% in comparison to 69.97 MAF during the same time period of last year. For the period of Rabi season October-March, 2018-19 there is 3% rise in water withdrawal from canal head was reported and 24.76 MAF in comparison to 24.15 MAF last year during the same period. The province wise details are shown in Table 2.

Table 2: Canal Head Withdrawals (Below Rim Station) Million Acre Feet (MAF)

Province	Kharif (Apr-Sep) 2017	Kharif (Apr-Sep) 2018	% Change in Kharif 2018 Over 2017	Rabi (Oct-Mar) 2017-18	Rabi (Oct-Mar) 2018-19	% Change in Rabi 2018-19 Over 2017-18
Punjab	35.51	29.19	-18	12.76	13.25	4
Sindh	31.37	27.75	-12	9.75	10.10	4
Baluchistan	2.07	1.69	-18	1.12	0.97	-13
Khyber Pakhtunkhwa	1.02	0.99	-3	0.53	0.45	-15
Total	**69.97**	**59.62**	**-15**	**24.15**	**24.76**	**3**

Source: Indus River System Authority

Pakistan in spite of being an agricultural country facing rigorous water scarcity because of an extremely inefficient irrigation system and practices, over exploitation of surface and ground water, insufficient storage capacity of reservoirs and pollution in surface and ground water, all have collectively affected the quantity and quality of available water resource. The major goal of 12th five-year plan 2018-23, is to buildup and line up economic investment for water sector for newly developed water storage reservoirs and to increase the system efficiency. For the development of water sector project including Mohmand and Diamer-Basha Dam during the year 2018-2019, an amount of Rs. 63.717 billion has been allocated, out of which Rs. 44.776 billion (70%) has been released so far and it is anticipated that total water sector's development budget for the fiscal year 2018-19 will be consumed by the end of June, 2019.

The major water sector projects are given in Table 3.

Table 3: Major Water Sector Projects

Project	Location	Irrigated Area (Acres)	Status
Basha Dam (Dam Part only)	Khyber Pakhtunkhwa & Gilgit Baltistan	-	ECNEC approved Dam part of the project on 14-11-2018 (out of 479 billion Rs. 232 billion will be federal grant, Rs. 144 billion commercial financing, Rs. 98 billion WAPDA equity)
Gomal Zam Dam	Khyber Pakhtunkhwa	191,139 Acres (17.4 MW Power Gen.)	Completed & Operational. Work on Command Area Development in progress.
Kachhi Canal (Phase-I)	Baluchistan	72,000 Acres	Physically completed. (Phase-I). Clearance of remaining liabilities is in progress.
Darawat Dam	Sindh	25,000 Acres (0.30 MW Power Gen.)	Physically completed. Work on Command Area Development in progress.
Nai Gaj Dam	Sindh	28,800 Acres (4.2 MW Power Gen.)	52 % Physical works completed
KurramTangi Dam (Phase-I,Kaitu Weir)	Khyber Pakhtunkhwa	84,380 New 278,000 existing (18.9 MW Power Gen.)	31% works completed
Naulong Dam	Balochistan	47,000 Acres (4.4 MW Power Gen.)	Feasibility & Detailed Engg. Design completed Works on dam not yet started.
Mohmand Dam Hydropower Project (800 MW)	Mohmand District of Khyber Pakhtunkhwa	16,737 Acres (800 MW Power Gen.)	ECNEC approved Phase-I on 30-06-2018 at a total cost of Rs. 309.558 billion (Dam part+Power cost). Work not started yet.
Right Bank Outfall Drain RBOD-I RBOD-II RBOD-III	 Sindh Sindh Baluchistan	ROBD-II will help to dispose 3,520 cusecs of drainage effluent into Sea received from RBOD-I & III	 85% completed 72% completed 86 % completed

Source: Ministry of Planning, Development and Reform

3.4 Limitations of Irrigation Water Management

3.4.1 Biased canal water distribution

Biased canal water distribution within a water channel along with uneven outlet discharge leads to lessen the irrigation water application efficiency that ultimately result in significantly less agricultural productivity. Sufficient and consistent water supply with unbiased water supply is essential for increased crop yield. Literature has reported that unreliable and scarce canal water distributions along with unequal water supply led to less crop production (Hussain et al., 2003).

3.4.2 Inappropriate collective consumption of canal and groundwater

It was reported that approx 8.4 MAF and 37 MAF water from public and private tube wells, respectively are being consumed for irrigation purpose by farmers in Pakistan (Aslam and Prathapar, 2006). Direct use of sodic-saline tube well water cannot give high crop yield irrespective to have proper soil, water and crop management system in that area (Rashid et al., 1997; Ghafoor et al., 1998). Mostly farmers don't pursue appropriate conjunctive use model and may also use poor quality ground water for irrigation purpose with no consideration of proper crop, soil and water management, that ultimately result in secondary salinity leads to less crop yield.

3.4.3 Less water use competence

In Pakistan, water use efficiency of wheat is 0.76 kg/m^3 which is 24% less than world average of 1.0 kg/m^3 and of rice is 0.45 kg/m^3 which is 55% lower than the Asian average of 1.0 kg/m^3. However, water use efficiency for cereal crops is 0.13 kg/m^3 which is very low in comparison to 0.39 kg/m^3 of India and 0.82 kg/m^3 of China (Watto and Mugera, 2016). It reveals that potential water productivity is not realized in Pakistan and mostly it occurs due to poor irrigation water management and bad quality of irrigation water (Hussain et al., 2003).

3.4.4 Traditional methods for cultivation

Generally poor farmers make use of traditional cultivation methods that leads to less crop productivity regardless of increased application of fertilizers and other inputs (Khan, 2012; Sattar, 2012; Ali, 2010). It's a major drawback to not aware of updated advanced farming practices and technological developments, along with that poverty and expensive modern technologies are also major factors responsible for using traditional cultivation methods (Jehangir et al., 2007).

3.5 Efficient Irrigation Methods

In Pakistan agriculture depends upon almost 93% available irrigation water. River water system in Pakistan is one of the largest water systems of the world that was developed after Britain arrival in the sub-continent, which was later extended over a large area after Indus basin treaty, gets signed. It was reported that probably 16 million hectares land is irrigated by river Indus irrigation system, in spite of that available water resources available in Pakistan are less in comparison to that of world. Moreover, 60% of available water is lost during transportation in canals and other water reservoirs during application in agricultural lands. Continuous increase in population ultimately leads to increase in food demand that pose a pressure on available water resources to fulfill the need of irrigation for available agricultural fields for maximum crop yield. Keep considering this situation it is important to enhance the water storage capacity by constructing small and large dams wherever possible and also make efficient use of available water resource on land. To execute the listed methods a considerable amount of water can be stored:

3.5.1 Lined water canals

It was estimated that almost 50% of water is lost from canals that are unlined, that not only decreases the available water quantity but also raise the ground water table, that ultimately results in salinity and water logging. To line the water reservoirs not only enhance the water delivery efficiency but also prevail over the issue of salinity and water logging. The stored water can be used for more land to be cultivated (horizontal crop expansion) or enhance crop intensity (vertical expansion).

3.5.2 Level Agricultural field

Water gets wasted on irregular patchy lands that also lead to loss of available soil nutrients results in soil erosion, therefore smooth land cover not only increase the agricultural productivity but also prevent soil erosion.

3.5.3 Cropping Prototype

Cropping prototype in any area affect water utilization rate as crops which consume more water like sugarcane or rice so these should be grown in the areas where enough irrigation water is available along with high rainfall.

3.5.4 Appropriate Irrigation Schedule

Growth stages of each crop demands particular water quantity, therefore it's vital to supply water as per crop need. Mostly farmers don't have any idea regarding specific crops' water requirement due to the mistaken belief that more water yield more crop. However, excessive water gets seeps into ground results in salinity and water logging, along with removal of required nutrients by plants from the soil that will ultimately affects the crop yield.

3.5.5 Bed and Furrow Irrigation method

Water logging, salinity and water loss can be inhibited by using bed and furrow irrigation in fields. In Pakistan crop lands are irrigated by flooded basins, due to which water needs more time to reach the end of the field,

along with that upstream gets more water in comparison to downstream, which ultimately leads to uneven crop growth results in low yield. On the other hand, if crops grow on beds can save up to 50% of water, as irrigation water applied in furrows. The wild plant seeds move along with irrigated water get trapped in furrows and can easily be removed. Crop lodging will be less, more water can be saved and crop yield will get increased.

3.5.6 Zero Tillage Technique

When rice crop is harvested, adequate soil moisture is available and mostly this moisture gets wasted because of usual ploughing. In this way wheat crop plantation also gets delayed and sowing cost gets increases. Mostly farmers burn the rice straw that results in loss of soil moisture, decay available soil organic matter and decay friendly soil microbial population also adds pollution in the environment. However, in zero tillage method direct plantation occurs where seeds are sowed directly in uncultivated land through mulch layer by using seed drill. Moreover, weeds growth can be prohibited, soil fertility, infiltration, moisture retention and organic matter gets increases by direct seed drilling in rice-wheat cropping pattern. In this way CO_2 and greenhouse gasses emission also gets reduced, and wheat cultivation can be done on time after rice harvestation. By this method first irrigation gets saved and for second and third irrigation less water is required in comparison to usual cultivation processes.

3.5.7 Drip and Sprinkler Irrigation

To conserve water resource drip and sprinkler irrigation methods contributed to a great extent as better crops can be cultivated by using limited water quantity. Drip irrigation is conventional for row crops and orchards, as water is applied as per plant requirement and four times more area can be irrigated with same amount of water for conventional irrigation method used. Along with that fertilizer added directly to plant roots as water is added directly to plant roots leads to less weed germination in the surrounding area, also no need of leveled land. In sprinkler irrigation water is applied through sprinklers to the crop, here also land leveling is not the requirement and water applied to the crop as per its requirement only. By considering water scarcity in Pakistan drip and sprinkler irrigation methods can be adopted to increase crop productivity in less irrigated areas.

3.5.8 Rain fed Agriculture

In dry areas agriculture depends mostly on rainfall, therefore it is essential to harvest rainwater and use for rain fed agriculture wherever required. For the storage of rainwater in soil bunds are made to protect the land and use planking to dissociate the soil aggregates. Field ploughing need to be done in opposite direction of land slope which improve rainwater storage and protect land from erosion. Rainwater can also be stored in ponds or dams and can be used up on requirement for supplementary irrigation.

3.5.9 Crops Grown with Saline Water

In Pakistan almost 70% tube wells pump poor quality water and as water scarcity increases its very important to use this water more carefully. For this an important step is to analyze ground water first and then select the crop to be planted accordingly. Along with that crops that can grow in salty areas planted over there and can be irrigated with salted water.

3.5.10 Irrigation Water Management Progress

Water scarcity is becoming a major limitation for agricultural productivity. GoP (2005) reported that per capita water availability of >1700 m^3/capita has decreased in current situation to < 1000 m^3/capita and Pakistan has moved from water sufficient country to water scarce country. Increasing shortfall in water supply in comparison to water demand will continuously increase in the future. As per estimates, water scarcity would increase from 28 MAF in 2015 to 41 MAF in 2025 (GoP, 2010). Major causes for water shortage are reported as decreasing storage capacity of existing reservoirs due to silting, negligence in the formation of new dams and an unproductive irrigation system. Present scenario requires an urgent consideration of the policy makers, developers and decision makers in terms of urgent construction of water storage reservoirs, conservation and efficient use of available water resources.

Expected overall average irrigation water efficiency ranges from 38.7 to 42.6% in Pakistan, which is quite less due to deprived operation, maintenance and development of the irrigation infrastructure (Punjab Irrigation Department, 2009). Due to complete lined canal systems, highly efficient and productive irrigation systems like sprinkler & drip and watercourse developments at agricultural fields could lead to increase in an overall irrigation efficiency of about 81.2% (Ahmad, 2009). Distribution of surface water between distributaries along the main canal and along the distributaries between the outlets is considerably unequal in Pakistan (Vander, 1990; Kuper and Kijne, 1992; Bandaragoda and Rehman, 1994; Arif et al., 2014). Unequal water distribution leads to deprived agricultural productivity.

Therefore, novel developments are required to enhance the operation of irrigation canals by this means improved water supply leads to an increasing agricultural productivity. It's a poor factor that water use efficiency is not apprehending in Pakistan (Watto and Mugera, 2016). Less water use efficiency is basically due to the poor irrigation water management, lack of timely and enough irrigation water availability, inefficient irrigation methods and technologies, deficiency of irrigation scheduling adoption, inappropriate conjunctive use of surface and groundwater for irrigation and low quality of irrigation water (Hussain et al., 2003). However, water use efficiency can be enhanced by innovative developments in agronomy and irrigation water management practices which would ultimately demand shift in agricultural practices, policies and effective institutes.

To overcome the inadequate water supply for agriculture sector following major developments play a significant role in the increase of agricultural productivity:

- Revision of the national and provisional irrigation and drainage authorities act to make clear the function and responsibilities in irrigation management between irrigation and drainage management authorities and government departments.
- *Warabandi* needs to be replaced with new water distribution rules depending upon the economic efficiency and farmer equity.
- Modification of irrigation taxes to reveal the practical operation and maintenance costs.
- Reinforce the capacity with water resource management department of provisional government to supervise the drainage and irrigation authorities and working performance of water user and farmer organizations.
- Reinforce the water user organizations for enhanced system operation and supervise *abiana* collection in a better way.
- Modify water user and farmer organizations governance to check influential capture.
- Made technological developments in the irrigation system including advanced hydraulic control structures and canal linings in saline and water logging areas.
- Hydraulic structures should be automated using real time data acquisition systems.
- Drainage infrastructures should be systematically developed.
- Manage ground water table so that it does not obstruct crop growth or lead to soil salinity and underground salted water infringement.
- Introduce bio fertilizers and bio pesticides to minimize groundwater pollution.

4. CONCLUSIONS

It has been concluded from the above listed facts that agricultural productivity is not constant as analyzed over the time period. It is very important to increase agricultural productivity that sufficient water should be available for irrigation of agricultural lands. To fulfill the adequate supply of irrigation water, natural water reservoirs must have plenty of freshwater in canals and water streams along with groundwater. For this there is an emergent need to control the factors of pollution, lack of reservoirs storage capacity, seepage of water, soil erosion etc. that are responsible for water scarcity in Pakistan. Moreover, there is an utmost requirement to improve the traditional irrigation methods through technological advancement to overcome the water scarcity. In Pakistan, there is enough agricultural land but due to lack of proper irrigation water management and no developed policies implementation, the agricultural productivity is much decreased as expected.

Following conclusions can be drawn from present study:

- Control release of polluted water or sludge in surface water bodies to inhibit contamination of ground water.
- Development of efficient irrigation system like drip & sprinkler irrigation, zero tillage irrigation to conserve available water resources
- Development of updated policies leads to increase agricultural productivity
- Improve methods for rain water collection to enhance rain fed irrigation

- No differentiation should be made in water allocation to rich farmers with large land area and poor farmers with small lands
- Encourage farmers by giving them incentives for the improvement of water availability, its quality and crop yield per drop
- Irrigation methods and plans specially considered to assist the poor farmer by setting up precise circumstances for savings, maintenance and treatment of developed irrigation water infrastructure.

RECOMMENDATIONS

Recommendations take account of enhancement of agricultural field research; accelerate diffusion and adoption of most recent agricultural developmental technologies and inputs, enhanced irrigation water management and improving water recovery and drainage.

Following conditions are recommended for positive outcomes to overcome the inadequate supply of irrigation water:

- To introduce the concept of agricultural-climatic zone
- Indus basin should be divided into sub regions and introduce overwhelmed long term effective water policy and instruction for each also.
- Modification of agricultural practices
- Establishment of more crop per drop technology
- Check the feasibility and introduce micro irrigation technologies
- Refurbish and maintain already existing infrastructure for irrigation
- Water quality should be improved and update water quality standards
- Inhibit water pollution from multiple point and non-point sources
- Forcefully promote and implement the water conservation strategies
- Develop strategies to adapt the changes in climatic factors
- Develop rainwater collection setup and its use for rain fed irrigation

LIMITATIONS

Development of project proposal to study the factors responsible for water scarcity and its inefficient use in irrigation system in Pakistan has certain limitations:

- To complete this research, a major constraint is the availability of updated published data.
- Pakistan has sufficient water reserves; however, to complete this research work a major constraint is the sample size. As for quantitative analyses there is requirement of quite large sample. To collect this huge sample certain resources are required like manpower and funding.
- Another limitation is the degree of generalizability if sample size gets reduced. As stereotyped results obtained from this sample size cannot be considered true for the large sample.
- For large samples rigorous data collection, interpretation and analysis is more difficult to sustain, evaluate and reveal.
- However, in case of large sample, data volume makes its analysis and interpretation time consuming.
- For qualitative analysis to fill up the questionnaire presence of researcher is sometimes affecting the subject's answers.

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