INTEGRATED WATER RESOURCE MANAGEMENT (IWRM) & ITS IMPACT ON AGRICULTURE IN PAKISTAN

RESEARCH STUDY

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SUMMARY

Pakistan has been gifted with large water resources by the Almighty Allah, which flow down from Himalayas and Karakoram heights in the northern side of the country. Being an agrarian country, agriculture sector contributes 19.5 percent in GDP and provides livelihood to 42.3 percent of the country's total labor force. Pakistan mainly contains three types of water resources i.e. surface water resources, ground water resources and rainfall. Surface water resources mainly consist of Indus River Basin System which brings 138 million acre feet (MAF) of water annually. Ground water resources are extended from Himalayan foothills to Arabian Sea, with the length of 1600 km and cover an area of 21 Mha. Pakistan receives rainfall in two seasons annually one in Rabi (October to April) and other in Kharif season (February to December). In Fiscal Year 2016-17 the river flow during the Kharif (summer) season was at 84% and during Rabi (winter) season remained 16%. While the seasonal water need is 66% in summer & 34% in winter resulting in surplus of 18% in summer and shortage of 18% in winter.

Pakistan has abundance of water resources however productivity of agriculture is decreasing due to high demand of quality water for non-agricultural practices as well as industrial use. The percapita availability is also below International standard of 1500 m^3 in the country. According to experts Pakistan will soon turn into a water scarce country, therefore there is need to utilize the available water more efficiently and wisely along with introducing innovative, integrated and high efficiency irrigation systems and follow Integrated Water Resource Management (IWRM) approach. IWRM is an ongoing process & practice of making decisions and taking actions while considering multiple viewpoints on water use efficiency, equal distribution among users and environment sustainability.

The IWRM framework developed by the (Global Water Partnership) GWP, consists of three E's - economic efficiency, social equity and ecosystem sustainability. IWRM is based on Dublin's four principles about management and protection of water resources. Fresh water is a natural resource that needs to be maintained by ensuring effective management of water resources. Water is a resource in which all individuals are stakeholder and should be involved in decision making process for effective use, supply and sustainable development of water resources. IWRM demands women's role in decision making process as women play an important role in domestic use of water. Water is a valuable source and all human beings have a right to access clean water at affordable price. It is important to recognize the economic value of water. Stakeholders should pay charges of water for efficient utilization of water.

In view of growing scarcity of water, an approach defined as IWRM suggests strategies for management of existing water-resources with the main aim to formulate a framework for dealing with drought. The approach involves identification of unexplored water resources and their utilization, management of already utilized resources, improving the institutional set-up and better governance of water-resource institutions & infrastructure. Based on this approach many strategies have been formulated like creating awareness among farming community about water utilization, construction of water storage bodies, growing water resistant crops and varieties, skimming the salted water, developing drought forecasting mechanism, identification of fresh water resources and rejuvenating already depleted sources.

To enhance the availability of water to fields, some Canal based practices like Watercourse Improvement, Laser Land Leveling, Furrow Irrigation, Gated Pipe Irrigation Technique, Pressurized Irrigation Technique and non Canal based practices like On Farm Storages, Mulching and Contour Cultivation can be practiced**.** Rainwater harvesting is the collection and storage of rainwater for reuse on-site, rather than allowing it to run off. The stored water of rain is used for various purposes such as gardening, irrigation. Broadly Surface Runoff Harvesting and Roof Top Rainwater Harvesting techniques are commonly used.

To implement the proposed strategies some course of action has been suggested. The execution of already planned megaprojects like Kalabagh Dam needs to be done without influence of politics. The provincial governments and its various research and development departments need to play a major role in the execution of the activities related to high-efficiency irrigation system and lining of minors and watercourses. Pakistan's water-resources are diminishing at an alarming rate and the quality of water is also deteriorating with time. Therefore it is need of the hour to follow IWRM planning and principles.

1. INTRODUCTION

Water is one of the basic necessities of life. Pakistan has been gifted with abundant water resources, with rivers flowing down the Himalayas and Karakoram heights from the world's largest glaciers which is a unique bounty for this land. Pakistan is basically an agrarian economy. Out of its total geographical area of 79.61 million hectares, cultivable area is 30.33 million hectares and 22.08 million hectare is cultivated. The total area under irrigation is 19.28 million hectares. Irrigated land supplies more than 90 percent of agricultural production and most of the country's food. Agriculture sector is regarded as the backbone of Pakistan's economy. This sector contributed 19.5 percent in GDP and remains by far the largest employer absorbing 42.3 percent of the country's total labour force (Pakistan Economic Survey, 2016-17).

Agriculture sector is also the major user of water and its consumption will continue to dominate water requirement. Similarly, for industrial development one of the main source of energy is hydropower which is generated by stored water in big dams and reservoir. The flow of water during the Kharif (summer) season is 84% and during Rabi (winter) season is 16%. The alluvial plains of Pakistan are blessed with extensive unconfined aquifer, with a potential of over 50 million acre feet (MAF), which is being exploited to an extent of about 38 MAF by over 562,000 private and 10,000 public tube well. During the year 2016-17, the availability of water for Kharif, 2016 was 71.4 million acre feet (MAF) showing an increase of 9.0 percent over Kharif, 2015. While during Rabi season 2016-17, the water availability remained at 29.7 MAF, which was 9.7 percent less than Rabi 2015-16.

Unfortunately Pakistan is not utilizing its resources efficiently and huge amount of water is lost each year ultimately the country is going to become water-deficient country. The low water availability is one of the main constraints in increasing per acre yield and bringing more area under cultivation especially during winters. The per capita availability of water has reduced from 5,650 m^3 in 1951 to 1032 m^3 in 2016 against the current international standard of 1500 m^3. It will decrease to 800 m^3 in 2025. Moreover, competition for water is also increasing with the rise in population, urbanization and industrialization. In facts domestic and industrial water uses will increase to 15% by 2025.

This low percapita availability of water is due to low water use efficiency, result of conventional irrigation methods and poor agronomic practices. Under this situation there is need to utilize the available water more efficiently and wisely along with introducing innovative, integrated and high efficiency irrigation systems and follow Integrated Water Resource Management (IWRM). Implementing IWRM thereby helps to protect the world’s environment, foster economic growth & sustainable agricultural development, promote democratic participation in governance, and improve human health.

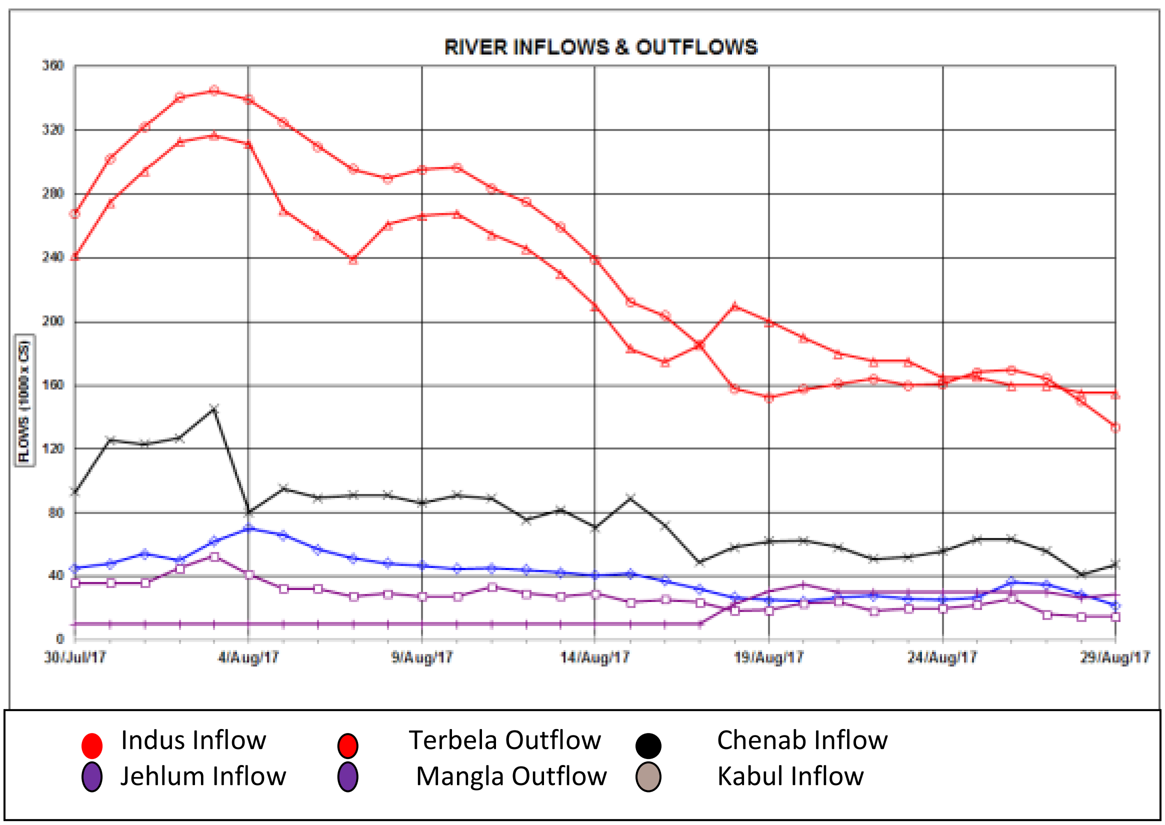
2. WATER-RESOURCES OF PAKISTAN

Water-resources of Pakistan include surface water, rainfall, and groundwater. The extent of availability of these resources is location-specific. A brief description of water resources of Pakistan is given in the following sections.

2.1 Surface Water-Resources

Surface water-resources of Pakistan are mainly based on the flows of the Indus River and its tributaries which bring in about 138 million acre feet (MAF) of water annually. The Indus River has a total length of 2,900 kilometers (Km) and the drainage-area is about 966,000 sq. km. Five major tributaries joining its eastern side are Jhelum, Chenab, Ravi, Beas and Sutlej; besides, three minor tributaries are the Soan, Harow, and Siran, which drain through mountainous areas. The Indus River alone provides 65% of the total river flows, while the share of Jhelum and Chenab is 17% and 19% respectively. The months of peak-flow are June to August during the monsoon season.

A number of small tributaries also join the Indus towards its western side. The biggest of such tributaries is River Kabul. Rivers in Pakistan have individual flow characteristics, but all of them generally start to rise in the spring and early summer, with the monsoon rains and snow melting on the mountains and have a combined peak discharge in July and August. The speed of flow is minimum during winters e.g., during the period November to February, when mean monthly flows are only about one tenth of those in summer. Besides the major rivers, there are numerous small rivers and streams, which are only seasonal in flow depending on rain fall and carry practically no water during the winter months.



2.2 Groundwater Resources

Most of the groundwater resources of Pakistan exist in the Indus Plain, extending from Himalayan foothills to Arabian Sea, and are stored in alluvial deposits. The Plain is about 1,600 Km long and covers an area of 21 Mha and is blessed with extensive unconfined aquifer, which is fast becoming the supplemental source of water for irrigation. In Baluchistan, groundwater is extracted through dug wells, tube wells, springs and karezes, which are the main dependable source of water for irrigation of orchards and other cash crops.

2.3 Rainfall

There are two major sources of rainfall in Pakistan i.e. the Monsoons and the Western Disturbances. There is about 70 percent of the annual Monsoon rainfall from July to September. The entire Indus plain receives an average seasonal rainfall of 212 mm and 53 mm in the Kharif and Rabi seasons respectively. The rainfall varies from the north and northeast to the south of the country. The intensity of rainfall and the volume of downpour are much more than can be utilized readily in summer.

3. WHAT IS INTEGRATED WATER RESOURCE MANAGEMENT (IWRM)?

As discussed above, water is the critical and ignored element in sustainable development. For effective, long lasting solutions of water problems, a new water management paradigm is required. Such a new paradigm is encapsulated in the Integrated Water Resources Management (IWRM) concept, which has been defined by GWP (Global Water Partnership) as **"A process which promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems."**.

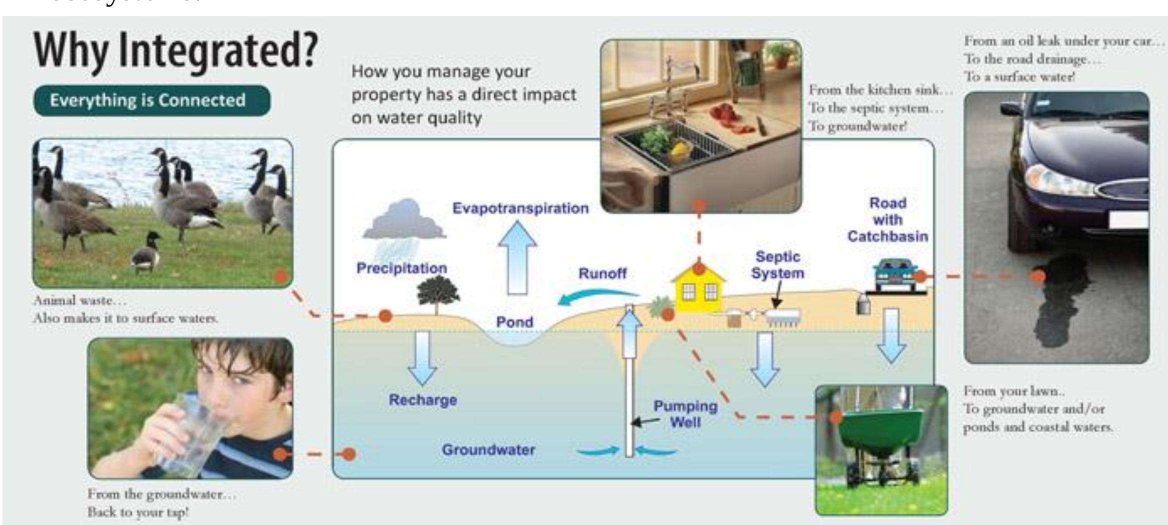
It is a cross-sectoral policy approach, designed to replace the traditional, fragmented sectoral approach to water resources and management that has led to poor services and unsustainable resource use. IWRM is based on the understanding that water resources are an integral component of the ecosystem, a natural resource, and a social and economic good.

Integrated Water Resources Management (IWRM) is the practice of making decisions and taking actions while considering multiple viewpoints e.g. how water should be managed and used? These decisions and actions relate to situations such as river basin planning, organization of task forces, planning of new capital facilities, controlling reservoir releases, regulating floodplains, and developing new laws and regulations. In Pakistan future water needs are substantially greater than the total potential supply. There is a need to reduce the water losses from the water supply systems, improvement of overall irrigation system, construction of water reservoirs on potential sites along with adoption of artificial ground water recharge techniques to integrate the rain and excess flood water to supplement the depleting water aquifers.

It is a sub-set of water cycle management. This integrated approach explicitly challenges conventional, fragmented water development and management systems. IWRM has no fixed beginning and probably never ends. The emphasis is on coordinated decision making across sectors and scales. Water is an essential natural resource that shapes regional landscapes and is vital for ecosystem functioning and human well-being. At the same time, water is a resource under considerable pressure of human being activities. Alterations in the hydrological regime due to global climatic, demographic and economic changes have serious consequences for people and the environment.

As the global economy and society is dynamic and the natural environment is also subject to change, IWRM systems will, therefore, need to be responsive to change and be capable of adapting to new economic, social and environmental conditions and to changing human values. IWRM is not an end in itself but a means of achieving three key strategic objectives.

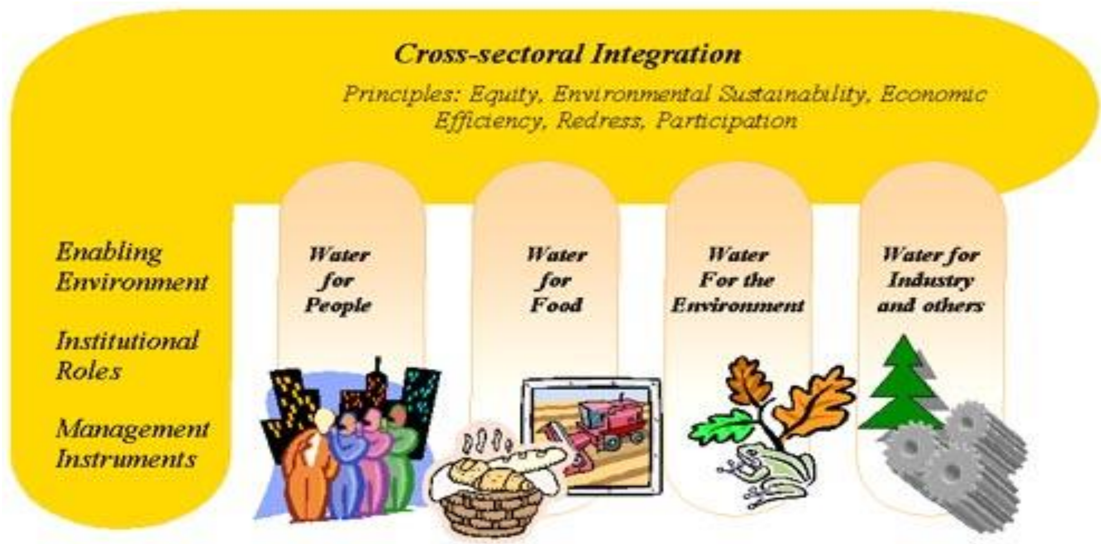
- Efficiency to make water resources go as far as possible
- Equity, in the allocation of water across different social and economic groups.
- Environmental sustainability, to protect the water resources base and associated ecosystems.



3.1 IWRM Framework

Integrated Water Resources Management is based on the perception of water as an integral part of the ecosystem, a natural resource and a social and economic good, whose quantity and quality determine the nature of its utilization. The IWRM framework, was developed by the Global Water Partnership (GWP), consists of three E's - economic efficiency, social equity and ecosystem sustainability.

- **Economic efficiency in water use**: Because of the increasing scarcity of water and financial resources, the finite and vulnerable nature of water as a resource, and the increasing demands upon it, water must be used with maximum possible efficiency.
- **Equity**: The basic right for all people to have access to water of adequate quantity and quality for the sustenance of human well-being must be universally recognized.
- **Environmental and ecological sustainability**: The present use of the resources should be managed in a way that does not undermine the life-support system thereby compromising use by future generations of the same resource.



3.2 IWRM Four Principles - The Dublin Principles

A meeting of experts on water related problems took place on 31st of January 1992 at the International Conference on Water and the Environment (ICWE), Dublin, Ireland.

The Dublins Statements on Water and Sustainable Development are also known as the Dublin Principles. The Dublin Statement on Water and Sustainable Development recognizes the increasing scarcity of water as a result of the different conflicting uses and overuses of water.

Principle 1: Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment

Water sustains life in all its forms and is required for many different purposes, functions and services. Holistic management, therefore has to involve consideration of the demands placed on the resources and the threats to it. Holistic management not only involves the management of natural systems, it also necessitates coordination between the range of human activities which create the demands for water, determine land uses and generate water borne waste products. Creating water sensitive political economy requires coordinated policy making at all levels (from national ministries to local government or community – based institutions). There is also a need for mechanisms which ensure that economic sector decision makers take water costs and sustainability into account when making production and consumption choices. The development of such an institutional framework capable of integrating human systems – economic, social and political – represents a considerable challenge for policy makers.

Principle 2: Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels

Water is a subject in which everyone is a stakeholder. Real participation only takes place when stakeholders are part of the decision making process. This can occur directly when local communities come together to make water supply, management and use choices. Participation also occurs if democratically elected or otherwise accountable agencies or spokespersons can represent stakeholder groups. The type of participation will depend upon the spatial scale relevant to particular water management and investment decisions and upon the nature of the political economy in which such decisions take place.

Principle 3: Women play a central part in the provision, management and safeguarding of water

It is widely acknowledged that women play a key role in the collection and safeguarding of water for domestic and - in many cases - agricultural use, but they have a much less influential role than men in management, problem analysis and in the decision making process related to water resources.

Gender needs should be part of the overall policy framework which can ensure that policies, program and projects address the differences in experiences and situations between and among women and men. Equal participation in social and political issues involves women's equal right to articulate their needs and interests, as well as their vision of society, and to shape the decisions that affect their lives. Their ability to do this can be strengthened through community organizations and institutions, and building participatory capacity.

Principle 4: Water has an economic value in all its competing uses and should be recognized as an economic good

Within this principle, it is vital to recognize first the basic right of all human beings to have access to clean water and sanitation at an affordable price. Past failure to recognize the economic value of water has led to wasteful and environmentally damaging uses of the resource.

Managing water as an economic good is an important way of achieving efficient and equitable use, and of encouraging conservation and protection of water resources. Value and charges are two different things. The value of water in alternative uses is important for the rational allocation of water as a scarce resource, whether by regulatory or economic means. Charging (or not charging) for water is applying an economic instrument to support disadvantaged groups, affect behavior towards conservation and efficient water usage, provide incentives for demand management, ensure cost recovery and signal consumers' willingness to pay for additional investments in water services.

4. PROPOSED WATER MANAGEMENT-STRATEGIES

Three-pronged approach towards formulation of strategies to meet the growing scarcity of water needs is proposed. The general approach involves:

- **a.** Utilization of existing un-utilized resources and development of new and unexplored water-resources.
- **b.** Management of explored water-resources, to achieve the goal of maximum production per unit of water used.
- **c**. Improving the institutional set-up and better governance of water-resources institutions and infrastructure.

Based on the above approach, the following actions are suggested for management of existing water-resources with the main aim for dealing with drought, during the immediate two crop seasons. Some of the suggested actions for short-term may continue during the medium and long-term.

- **Awareness Campaigns**: Most of the problems associated with the water-sector have risen from illiteracy and lack of knowledge and understanding of water-conservation practices and high-efficiency irrigation-systems among users at large. An extensive social awareness campaign is required, using mass-media and a village-to-village campaign of extension services. Moreover, effective extension service mechanism must be developed to transfer new and efficient irrigation methods, technologies, and practices to farmers. To motivate the farmers for adoption of the high efficiency irrigation-systems, incentives/ subsidies and soft loans may be given.

- **Increasing On-Farm Application Efficiencies**: Precision land-levelling increases field application efficiencies in plain areas, where basin irrigation is practiced. Efforts to introduce laser-guided land-levelling with cost effective locally developed technology should be encouraged. Similarly, farmers in upland areas, with undulating topography, should be encouraged to use high-efficiency irrigation systems, like trickle, bubbler, and sprinkler, to conserve water. For this, demonstration plots on cost-sharing basis need to be established in the entire country.
- **Improving Conveyance Efficiencies**: Earthen improvement of distributaries, minors and watercourses, with installation of concrete control-structures, should be undertaken to enhance conveyance-efficiencies, which are presently around 55 per cent.
- **Improved Surface Irrigation Methods:** In plain areas, where row and grain crops like cotton, wheat and maize are grown; bed and furrow irrigation methods should be made mandatory for adoption by farmers, to increase the application-efficiency of water.
- **Changes in Cropping Patterns and Crop Varieties**: To conserve water, meet water shortage, and match water-requirements with supplies, appropriate changes in cropping patterns may be considered. This would require change over from high-delta to low delta crops, capable of giving higher returns to the farmers. Similarly, growing drought and salt-resistant crop varieties is another option that can be considered.
- **Reduction in Cultivation Areas:** To reduce the chances of crop-failures, due to anticipated water shortage, planned reduction in cultivation areas to match water-availability may be propagated in a very timely fashion.
- **Regulation of Groundwater**: To reduce and control the over-extraction of groundwater resulting in mining, groundwater use must be regulated and properly priced through appropriate legislation and its strict implementation. Uncontrolled abstraction of groundwater has played havoc in terms of quantity and quality in the arid areas of Baluchistan and parts of Punjab and Sindh. This needs to be checked through a stringent regulatory framework on groundwater-abstraction.
- **Undertaking Skimming Wells Projects**: In areas where fresh water is overlying saline water, it would help if skimming-well technology were used to pump out fresh water, without disturbing the underlying saline layer. For this, it would be necessary to undertake an investigation exercise to delineate such areas.
- **Finding and Developing New Resources**: Glaciers and winter snowfall in the northern areas form an important and extensive potential source of water in the Indus River System. Experiments to harness this resource in a sustainable and environment friendly fashion, should be undertaken.

To tap the surface water going to waste, identification of possible surface water storage sites for small and large dams should be done on top priority bases. WAPDA and provincial irrigation departments should be asked to complete this task as soon as possible.

- **Rejuvenation of Depleting Aquifers**: Due to ever increasing number of depleting fresh water aquifers, there is a need to rejuvenate them. Various artificial recharge measures should be tried/experimented upon, in areas where depletion of aquifers is becoming a serious problem like in Pishin and Nari basin in Balochistan and Lahore area in the Punjab. Appropriate methods of artificial recharge should be identified.
- **Establishment of a Central Organization**: A central organization may be established or strengthen to monitor the progress of the implementation of strategies and their effect on overall water availability for crop use, drinking and other purposes with its branch offices in all provinces.
- **Involvement of Water-User Organizations**: Water User Organizations (WUOs) in irrigated areas are very effective to motivate the farmers to solve the problems related to water use because of their presence at grass root level. Their involvement in the planning, execution and management of all water resources development projects should be ensured for sustained operation and maintenance of the projects.
- **Providing Farmers with Information on Water Requirements:** Dissemination of information to farmers regarding actual crop water requirements of various crops in major agro climatic zones should be undertaken on top priority basis to avoid over and under irrigation. This will help in controlling wastage of water and overcoming problems like water logging and salinity.
- **Lining of Conveyance System:** Lining of canals, distributaries and watercourses is an important option to reduce water-losses and increase water-availability at the farm gate. However, since the system conveyance-loss can be recouped in good-quality aquifers by pumping, preference should be given to lining of distributaries, minors and watercourses in saline groundwater areas.
- **Construction of Storage Reservoirs:** To harness and utilize water currently going waste, small dams/storage reservoirs need to be constructed. These storages could be at appropriate sites in the Northern Areas or downstream of Tarbela. WAPDA and provincial irrigation departments have already identified most of the sites and the construction of dams for development of water-reservoirs is included in their medium and long-term plans.
- **Identification of Fresh Groundwater Areas***:* To decide on where to implement the strategy regarding preferential lining of the conveyance-system, installation of new tube wells, and regulation of groundwater, it is necessary that fresh groundwater areas be identified and mapped with regard to water table depth, potential, and quality.
- **Developing Drought-Forecasting Mechanism:** The country is deficient in drought forecasting methods and techniques. Models should be developed to predict the

incidence of droughts for better preparedness and to plan ahead in the event of any drought calamity.

- **Developing Conjunctive Use Methodologies:** The saline groundwater extensively available in various parts of Pakistan should be made use of, through developing conjunctive use methodologies and change of crops, etc.
- **Corporate Farming and Consolidation of Land Holdings**: The land-holdings in the irrigated areas are increasingly becoming fragmented, due to inheritance laws. This hampers adoption of new and modern technologies. Popularizing the concept of corporate farming and consolidation of land holdings is an important area for consideration.
- **Undertaking Watershed-Management:** The heavy amount of sediment loads brought in by the feeding-streams in our reservoirs must be checked. For this, undertaking water shed management works in catchments of existing reservoirs and planning such activities in new project as well as projects in pipeline may be ensured.
- **Formulating A National Water-Policy**: Despite heavy dependence on water for its economy, the country still does not have a national water-policy. This policy will be formed to form the basis for future planning, development, and utilization of water-resources. The present document with little more work can provide the essential elements of such a policy.

5. WATER CONSERVATION METHODS - MANAGEMENT PRACTICES

Water conservation practices are defined as practices that are carried out to protect resources of water to ensure availability of water for plants, animals and human beings.

5.1 Canal Command Practices

5.1.1 Watercourse Improvement

The watercourse improvement / renovation consists of complete demolishing of community channel and its rebuilding/re-aligning according to the engineering design to increase conveyance and efficiency by reducing seepage, evaporation, and operational losses. Parts of reconstructed channel are lined and necessary water control structures are installed to improve conveyance of the canal and tube well water. The standard "Pucca" lining carried out under previous and ongoing On Farm Water Management (OFWM) programs, is a rectangular shaped channel using double-brick masonry walls (23 cm) and a brick masonry bed (7 cm) plastered inside and on top of the walls. This design has proved to be durable and easy to install. Other types of lining like pre-fabricated concrete (pre-cast parabolic lining), pipe, and plastic have also been considered keeping in view the farmers' choice, field conditions, and cost effectiveness.

5.1.2 Laser Land Leveling

Leveling, smoothing and shaping the field surface is an important practice for preparation of proper seed bed and directly involve in plant growth and development because all nutrients and water move according to soil gradient. Land leveling is a measure which is used in surface irrigation, such as basin and furrow irrigation. The advanced method to level or grade the field is to use laser-guided leveling equipment. Laser land leveling is leveling the field within certain degree of desired slope using a guided laser beam throughout the field. It helps in controlling water erosion through slope.

5.1.3 Furrow Irrigation

Furrow irrigation is conducted by creating small parallel channels along the field length in the direction of predominant slope. Water is applied to the top end of each furrow and flows down the field under the influence of gravity. Furrow irrigation is conducted by creating small parallel channels along the field length in the direction of predominant slope. Water is applied to the top end of each furrow and flows down the field under the influence of gravity. Furrow irrigation is suitable for many crops, especially row crops.

5.1.4 Gated Pipe Irrigation Technique

The efficient use of water through modern irrigation systems is becoming increasingly important in arid and semi-arid regions with limited water resources. Saving water and improving water use efficiency need to be developed. Water saved will be used for increasing the cultivated area and overall crop production. Developing surface irrigation using gated pipes is a new method used to distribute water to furrow as strategy based on water saving. The gated pipe has many advantages:

1) It requires small area of land to install the system
2) Reduces the seepage and evaporation losses and better water distribution
3) low cost and maintenance requirements
4 Can improve human public health by avoiding contact with infected water

5.1.5 Pressurized Irrigation

A pressurized system is a system that relies on water pressure to work. If the system is connected to the pressurized water main (mains pressure) no pump is needed, however, if the water source is not pressurized, then a pump will be needed to pressurize the system. Types of pressurized systems include:

- fixed irrigation systems
  - mains pressure or low pressure
  - below and above ground systems
  - emitters, trickle, t-tape, mini-sprinklers
- Portable irrigation systems
  - Travelling irrigators, center pivot, linear move, powered side roll hand shift permanent, bike shift/easy shifts.

5.2 Non Canal Command Based Practices

5.2.1 On Farm Storages

Various techniques are being used for storage of runoff water like pond, check dams, small dams and mini dams in arid and semi-arid regions of the country. A pond is water storage body which can be designed for aesthetic ornamentation, fish farming, and to store thermal energy. While check dam is also a small structure, which can either be temporary or permanent, built across a minor channel drainage ditch. They reduce erosion and gully formation in the channel and allow sediments to settle. They also lower the speed of water flow during storm events. Mini Dams are an emergent very successful irrigation method utilized in Barani areas of northern Punjab. The design is based on a proven method used to store year round rainfall and floodwater that otherwise would not be available during the dry season and pass downstream and escape unutilized. Mini dam uses diverted water of the perennial flows, and runoff.

5.2.2 Mulching

Mulch is natural or artificially applied layer of plant residues or other material on the surface of the soil with the objective of moisture conservation, temperature control, prevention of surface compaction or crust formation, reduction of runoff and erosion, improvement in soil structure and weed control. Artificial mulches of different kinds such as *Jowar* or *bajara* stubbles, stubbles, paddy straw or husk, sawdust increase absorption of water and minimize evaporation. They also control run off and soil losses.

5.2.3 Contour cultivation

Tillage operations viz., ploughing, harrowing, sowing and intercultural should be done across the slope of land. This will help in creating obstructions to the flow of water at every furrow, which acts like a small bund and results in uniform distribution of water. This helps more initiation of water less run off and erosion, and gives higher crop yield.

6. METHODS OF RAINWATER HARVESTING

Rainwater harvesting is the collection and storage of rainwater for reuse on-site, rather than allowing it to run off. The stored water is used for various purposes such as gardening and irrigation. Various methods of rainwater harvesting are described in this section. Broadly there are two ways of harvesting rainwater.

1. Surface runoff harvesting
2. Roof top rainwater harvesting

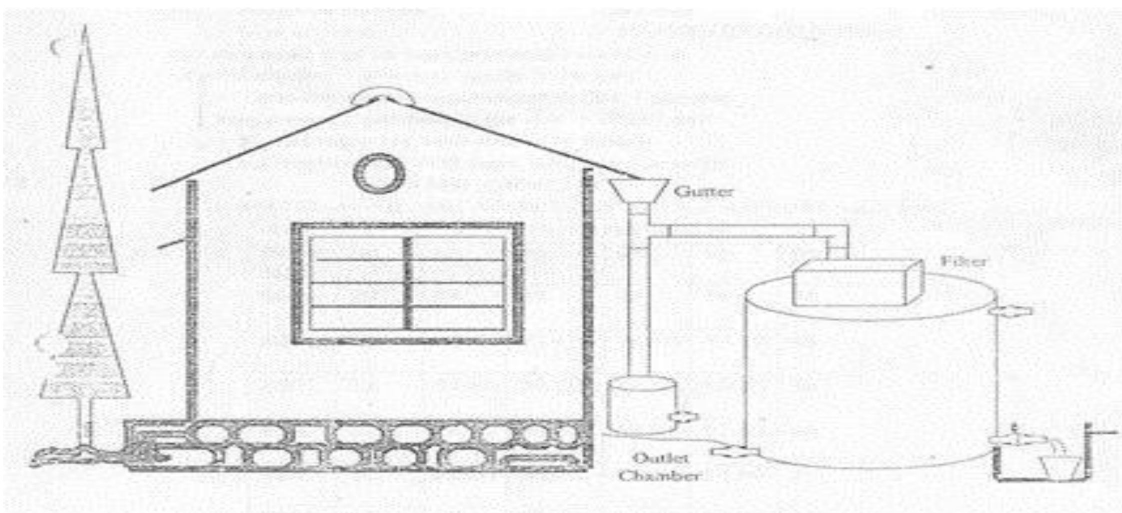
6.1 Surface runoff harvesting

In urban areas rainwater flows away as surface runoff. This runoff could be caught and used for recharging aquifers by adopting appropriate methods. Rainwater harvesting is the collection and storage of rainwater for reuse on-site, rather than allowing it to run off.

These stored waters are used for various purposes such as gardening and irrigation. Various methods of rainwater harvesting are described in this section.

6.2 Roof Top rainwater harvesting

It is a system of catching rainwater where it falls. In rooftop harvesting, the roof becomes the catchments, and the rainwater is collected from the roof of the house/building. It can either be stored in a tank or diverted to artificial recharge system. This method is less expensive and very effective and if implemented properly helps in augmenting the ground water level of the area. Harvesting system is given in the typical schematic diagram shown in figure.



7. RECOMMENDATIONS

Pakistan's water-resources are diminishing at an alarming rate and will become water scarce county in future, therefore it can be concluded that the quality of water is deteriorating with time and can be improved by following IWRM planning and principles. The suggested actions need to be implemented in an organized and coordinated way, through concerted efforts including better water management at the field level and good governance and institutional arrangements. The following recommendations are put-forth for implementation of the proposed strategies.

- The Provincial Governments and its various Research & Development Departments like the On-Farm Water Management Project, the extension directorates of the Agricultural Department, can play a major role in the execution of the activities related with high-efficiency irrigation systems and lining of minors and water courses, etc. The Irrigation Department can execute water-development projects at local and regional level like small dams and reservoirs, karez management, harnessing spring-water, groundwater regulation, and stream-flow diversions, etc.

- Comprehensive planning of water sector coupled with integrated development and management of irrigated agriculture is essential to achieve self-reliance in agricultural.
- Research on developing low-cost and effective liners for lining of canals and watercourses should be focused.
- Irrigation companies should be encouraged in the private sector to provide services to the farmers on turnkey basis. For this purpose, training should be imparted to the unemployed agricultural engineers to initiate Irrigation Companies.
- Research on productivity and sustainability should be initiated to address the issues of water scarcity and inequity.
- The country faces flood situation each year due to political interference & unwillingness in the construction or development of Dams therefore such projects should be free from politics. For example Kalabagh Dam which have ability to irrigate 800,000 acres of cultivable land in 100–150 feet above the level of River Indus. The Dam can provide 6.5 million acre feet of water to cultivate seven million acres of currently barren land in addition to the 3,600 megawatts (4,800,000 hp) of electricity, however it has still not seen the light of the day.
- Pakistan has no approved Water Policy therefore there is need to frame national water policy. National water policy should address the rights and entitlements of all users of water. Water rights in the Indus basin are linked to land ownership where preferential land allotments along the canal system ensures that only the rich and influential landlords have control access of water. Allocation and access of water to inhabitants of rural water-deprived areas should be a priority to achieve social and economic development. The water policy should call for an equitable distribution of water.
- On-Farm Water Management Programs in the provinces should be reoriented to address both the issues of surface and groundwater. They have to reorient their technical backstop support system to make it more responsive to the needs of Farmers' Organizations.
- In metropolitan city like Karachi, water scarcity remains a major problem for residents. A lot of politics has been done on the issue however the matter still remains unresolved.
- Government should also pay attention on water security as pays on food security.
- Regulating ground water pump age by issuance of licenses to check overdraft of aquifer.
- Better water management for increasing cropping intensity with riverine area.
- Technical land levelling, surge irrigation, high irrigation efficiency technology including drip and sprinkler should be used.

- Better and more efficient use of funds on implementation of projects.
- To harness the uncultivated lands for irrigation purpose, storage of flood water during Monsoon season by construction of a series of small dams/reservoirs on the barren lands and Barani areas of Northern Punjab, KP and Balochistan.
- Launching of incentive based public campaign emphasizing conservation of water at all levels.
- Surface water resources especially the small dams used for provision of domestic water supply have to be increased to meet future needs. The losses of pipeline supply systems have to be decreased to provide additional water.
- Mass awareness progammes needs to be initiated to motivate domestic agricultural and industrial water users' in conservation of water.
- Emphasis should be placed on the recycle and re-use of water including the management of waste water.

8. LEARNING FROM NEIGHBORING COUNTRY, INDIA

Agriculture is a dominant sector in Indian economy, which employs about half of the population. India has 26 million groundwater pumps, which mainly run on diesel or electricity, however these water pumps have produced various challenges to both farmers and the government. Electric pumps tend to be unreliable, diesel is a costly fuel for water pumping, and both types of pumps rely on approximately USD 6 billion per year in government subsidies.

8.1 Role of Government of India

The Ministry of New and Renewable Energy (MNRE) and several state governments have starting promoting solar water pumps for agriculture. The solar water pumps come under the off-grid Photo Voltic (PV) scheme of the Jawaharlal Nehru National Solar Mission (JNNSM), and are provided up to 30% capital subsidy and soft loans at 5% interest rates. Among the states, Rajasthan offered an additional subsidy of 56% over and above the MNRE subsidy, which means that the solar water pump owner gets 86% subsidy in total. In Tamil Nadu, a total of 80% subsidy is provided, whereas in Punjab, the total subsidy comes to about 70%.

State governments are also procuring the pumps from suppliers (OEMs/integrator) approved by MNRE and distributing it to the farmers. 31,472 solar pumps have been installed in FY 2015-16 and the expected figure for 2016-17 is around 38,000 pumps. Under the scheme, 92,305 solar pumps have been installed as of 31 October, 2016. Government demand is expected to cross a mark of 50,000 solar pumps in FY 2017-18.

8.2 Role of National Bank for Agriculture and Rural Development (NABARD)

NABARD is promoting the scheme of Ministry of New and Renewable Energy (MNRE), GoI, Solar Photovoltaic Water Pumping systems for Irrigation and other purposes in the country. The main objective of the scheme is to replace diesel pump sets with solar pump sets as also to reduce dependence on grid power. The solar pump sets are environment-friendly and offer tremendous benefits to farmers. They involve very low operating cost and provide uninterrupted power supply to farmers enabling increase in agriculture production and income. Subsidy under the scheme is available only for solar systems that are procured from empanelled manufacturers/entrepreneurs by MNRE, GoI for solar water pumping programme.

In budget of FY 2017-18 Rs. 1 billion has been allocated for this scheme by the Government of Punjab (GoP) and planned to set up solar photovoltaic projects to run over 2000 agriculture pump sets by extending 80 per cent subsidy in 2017-18.

8.3 Ground Water Depletion in Gujrat

In Gujrat, the State of Gujrat and Government of India provided a subsidy to the farmers on Agricultural inputs, reliable electricity for pumping ground water, marketing and price of their produce over three decades. Unfortunately farmers' pumping of ground water was excessive, eventually the level of ground water fell down and now the future of Northern Agriculture is in jeopardy. The effect of acute water shortages goes beyond immediate impacts on farmers.

8.4 Ground Water Depletion in Punjab

Farmers of Punjab mostly grow wheat and rice because both crops account nearly 20 and 12 percent for the nation respectively. This ubiquitous practice caused enormous consumption of resources, fertilizer and ground water. Due to excessive ground water drafting for above said crops ground water table has dropped at an alarming rate. Now the water table has fallen down 90 percent of the state. The potential effects of groundwater depletion include the drying up of wells, reduced stream flows, deteriorating water quality and sinking land as well as increased costs and lower profit margins for farmers..

9. ROLE OF PAKISTANI GOVERNMENT

Solar tube wells in Pakistan are the most economical solution for all water pumping needs of all sectors of the economy. Solar tube well use solar power panels to run solar pump. Pakistan is located in a region with ample sun energy that makes it suitable to utilize solar power technologies. The conversion of tube wells onto solar energy shall help reduce long term costs for the farmers; provide a predictable supply of electricity, and a hedge against market fuel price volatility. This shall further help mitigate harmful emissions. According to an estimate, per hour cost of running an average-sized tube well on electricity is Rs. 138, on diesel it is Rs. 173 and on solar energy it is Rs. 83. Farmers who have tube wells with less than 50 feet water table can save Rs. 131 per hour and hence Rs. 314,400 per year with solar tube wells compare to diesel-run tube wells.

In FY 2015-16 the Federal Government of Pakistan launched a scheme of solar tube well for small farmers owing up to 12.5 acres under the Prime Minister's Kissan Package. The mark up of seven years would be paid by the federal government with a cost of Rs 14.5 billion as subsidy. This ensures a saving of Rs 1,600 and Rs 500 per day for the farmers running tube wells on diesel for five hours daily and on petrol for same duration, respectively.

Government decided to install 10,000 solar tube wells annually with the budget of Rs. 10 billion. Amount of annual subsidy payable will of course depend on the amount of loan and recoveries, etc but should be well under Rs.100,000 per tube well or Rs 1 billion per annum, if 10,000 solar tube well are installed annually and interest/profit rate of 10% is assumed. Rs. 7 billion subsidy will be provided to small farmers of Punjab under Punjab Khadim-e-Ala Package 2017.

10. PRIVATE INITIATIVES IN PAKISTAN:

10.1 Goat for Water:

The role of private sector for the development of water sector is very crucial, however in Pakistan, Private Sector involvement in development and management of water resources is at nascent stage. A private organization Goat For Water (GFW) inspired by old age barter system, aims to provide community-led solutions to cash strained and water stressed rural communities' water and energy needs, to enhance livelihood and quality of life through access to energy & water. They identify off-grid and grid deficient rural communities in remote areas of the country to understand their energy requirements and capacity to pay to develop solutions that allow them to meet their energy and water needs in a creative, sustainable and scalable way.

The GFW provides solar-powered water pump or solar home-lighting solutions to rural community by exchanging their Goat Holdings. This model is currently being tried in off-grid villages in Sindh, which are facing energy crises but have ample access to sunlight to sustainability meet their energy needs. GFW offers its services to those farmers who are operating their tube wells through tractor engine or diesel. The received number of goats by GFW is equal to the communities' one year expenditure on diesel fuel consumed to pump water from the ground and the market price of the goat.

They have successfully installed solar pumps in three villages, Pathan Goth, Faiz Muhammad and Haji Nabi Buksh of sindh Province. The cost of tube well vary from village to village depends on well depth for 300 to 400 feet well, the cost is usually Rs. 1 million to 1.5 million. One solar pump provides water to about 200 households on daily basis. In a normal transaction a farmer gives up 30 goats for one solar-powered pump. GFW sells obtained animals at the time of Eid ul Azha when demand for these animals is high.

This system improved the health, hygiene and livelihood of the inhabitants. Quick and regular access of water increased the quality and value of their livestock. This system also helped the women or girls because they do not need to go distant areas to bring water. These girls can utilize their time by go to school or doing any productive work. The initiative also economically empowered women who rear goats therefore following Dublin Principles in full sprit.

11. ROLE OF ZARAI TARAQIATI BANK LIMITED (ZTBL)

11.1 Shamsi Tawani Scheme (Solar Energy)

In order to help the farmers to overcome energy crisis, the Bank had also launched a scheme to provide an alternate energy resource. Under this scheme the maximum loan limit is Rs.1.500 million per borrower/party. 10% of the loan amount is kept in the deposit account of the borrower which is accounted for in the last installment of loan. Tangible properties owned by the borrowers are kept as collateral as per policy of the Bank. The loan is recoverable within 10 years in half yearly installments. During the year 2016, the Bank disbursed an amount of Rs. 1.750 million for this purpose.

11.2 Farmers Awareness Program

For farmers awareness program ZTBL conducts field days each year at own farmers training centers across the country. In each event farmers participates and get trained in several aspects of agriculture including use of alternate energy resources, solar energy, biogas, drip and sprinkler irrigation and tunnel farming. Demonstration of solar energy tube wells, biogas units and use of hybrid seeds is arranged by the Bank. In view of water conservation focus of Government of Pakistan and to facilitate farming community in the country ZTBL is financing sprinkler, drip or center pivoted irrigation system under General Credit with minimum rate of markup.

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