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EXPERIENCE OF BIO-SALINE APPROACH FOR REHABILITATION OF SALT-AFFECTED LANDS IN PAKISTAN

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ABSTRACT

Three salinity management approaches have so far been tried in Pakistan - engineering, reclamation and bio-saline. Based on the costs involved and complexity of approaches, the bio-saline approach got popularity in the country in the last about two decades. The first bio-saline project was Joint Satiana Pilot Project (JSPP) near Faisalabad between 1994 and 1997 based on interventions tested during earlier research projects targeting the poor farmers. Saline agriculture was successfully demonstrated to restore the productivity of about 400 hectare of salt-affected lands by planting E. camaldulensis tree and saltbushes (Atriplex amnicola and Atriplex lentiformis). The JSPP was jointly funded by United Nations Development Programme (UNDP) and Australian Agency for International Development (AusAID) and implemented by six national agencies and one non-governmental organization i.e. Action-AID Pakistan. The second bio-saline project "Pakistan Community Development Project for Rehabilitation of Saline and Waterlogged Land" was carried out from 1998 to 2002. The Project was executed by International Waterlogging and Salinity Research Institute (IWASRI), Lahore and co-funded by UNDP and AusAID. The overall objective of this project was to develop and promote sustainable biological farming systems for reclamation and rehabilitation of salt-affected and waterlogged lands. The Project activities were completed in 48 villages of three sites i.e. Pindi Bhattian (District Hafizabad), Sahiwal (District Sargodha) and Shorkot (District Jhang) of the Punjab Province. Salt Land User Groups (SLUGs) and Women's Interest Groups (WIGs) were established for their participation in the process of rehabilitation of marginal lands. The Project successfully demonstrated technical and social interventions for the rehabilitation of salt-affected and waterlogged lands. The Project developed a few packages of bio-saline agriculture involving salinity/waterlogging tolerant trees, crops, grasses and fodders plus fish farming and provision of tubewells particularly in water shortage areas. The local communities adopted these packages with open hearts because these packages had increased incomes, empowered women, reduced poverty and improved livelihoods & environments. The Project of approximately 4 million US$ produced asset appreciation of approximately 30 million US$ and an

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income stream of more than 5 million US$. The success of this project can be gauged from the fact that in only 3 years field operations, it successfully demonstrated bio-saline technology and rehabilitated about 17000 acres degraded lands through capacity building and participation of the local communities.

After looking the success of the Bio-saline Project (Phase-I), UNDP and Government of the Punjab through Asian Development Bank agreed to sponsor US$13.32 million Biosaline-II Project to up scale the achievements of Phase-I by increasing depth of coverage in the same three districts for rehabilitation of 80000 hectares over a period of four years (October 2006 to September 2010). This new project has good mixture of bio-saline and chemical approaches including the provision of gypsum to farmers. This integrated approach is becoming more popular among the farmers and all interventions are on cost sharing basis. For the last about three years of its operation, Biosaline-II Project has formed 636 community organizations i.e. 471 Salt Land User Groups (SLUGs) and 165 Womens' Interest Groups (WIGs). A total of 1393 community members have been trained in community management skills for participatory planning and implementation of development schemes. For land rehabilitation, the Project has demonstrated the reclamation technology on 369 demo plots. Successful accomplishment of various demonstration initiatives greatly encouraged the farmers' community to actively join the project activities for the rehabilitation of degraded lands. Resultantly, on cost sharing between the project and communities, 45143 hectares have been put in the rehabilitation process mainly through gypsum application and tree plantation. To facilitate communities' access to modern technology, 246 implement pools have been established. Moreover, 55 fish farms and 3700 kitchen gardens have been set up, 298 tubewells and 129 nurseries established.

1. INTRODUCTION

Pakistan is predominantly a dryland country with 80 percent of its land consisting of arid and semi-arid regions. The majority of its people depend on dryland area to support their livelihoods. No doubt, Pakistan's Indus Basin System is one of the largest contiguous irrigation systems in the world. This system provides irrigation to about 18.78 million hectares of the agricultural lands of the country but Pakistan is still among those countries, which are severely affected by desertification and land degradation. There is a serious problem of desertification in many parts of the country. The main causes of desertification in Pakistan include shortage of irrigation water, poor irrigation and drainage practices, over-grazing, flash floods, climatic conditions, population pressure, deforestation and poverty that may cause the famines, migration, social and political unrest and drain of economic resources. The key issues related to desertification in Pakistan are water/wind erosion, depletion of soil fertility, deforestation, livestock grazing pressure, loss of bio-diversity, drought and flooding, socio-economic constraints and above all the problem of waterlogging and salinity in the country.

The major factor contributing to waterlogging in cultivated areas of the country is excessive percolation from the canal system, which builds up the groundwater level. The human activities such as cultivation of high delta crops on

highly or moderately permeable soils, obstruction of natural drainage channels through construction of buildings and roads, improper alignment and poor maintenance of artificial open drainage system, inefficient disposal of excess rain water etc also add to waterlogging problem. The average (1993-02) severely waterlogged area with watertable depth of 0-1.5 meter in April-June is about 2 million hectares (WRPO & IWASRI, 2005). Salinity and sodicity are associated with irrigation but these also occur as a consequence of soil formation process over the centuries. The salt-affected soils in irrigated and non-irrigated areas of Pakistan are about 6 million hectares (Ghafoor et al. 2004). The latest surveys (2001-2003) by SCARPs Monitoring Organization (SMO), WAPDA indicate that 27 percent soils have surface salinity while 39 percent profile salinity problem in Pakistan (WRPO & IWASRI, 2005). Waterlogging, salinity and sodicity have reduced the drainage capacity of the soils resulting in lower soil fertility, decline in crop yields and loss of biodiversity.

2. LAND AND WATER RESOURCES

Table 1 shows the land use statistics of Pakistan. Out of the total geographical area of 79.61 million hectares, a considerable portion of 57.05 million hectares is composed of forest area (4.22 mha), land not available for cultivation (23.43 mha), culturable waste (8.25 mha) and cultivated area (21.17 mha). The real agricultural wealth of Pakistan lies in the lands of the Punjab and the Sindh provinces with major cultivated area lying in the Indus Basin. In this way, only 37 percent of the total reported area is being cultivated at present (Government of Pakistan, 2007-08).

Table 1: Land Use Statistics of Pakistan

(Million Hectare)

Province/Country	Geographical area	Total reported area	Forest area	Not available for cultivation	Culturable waste	Cultivated area
Punjab	20.63	17.47	0.50	2.97	1.60	12.41
Sindh	14.09	14.09	1.03	6.74	1.44	4.88
NWFP	10.17	8.34	1.33	3.89	1.21	1.91
Balochistan	34.72	17.15	1.36	9.83	4.00	1.96
Pakistan	79.61	57.05	4.22	23.43	8.25	21.17

Source: Agricultural Statistics of Pakistan, 2007-08

As far the water resources, the Indus Basin System of Pakistan is one of the largest contiguous irrigation systems in the world. It provides irrigation to 18.78 million hectares of the agricultural lands of the country. This irrigation system consists of 5 rivers, 3 reservoirs, 23 barrages/headworks, 12 link canals and 45 main canals throughout the country. The water resources include 142 MAF surface supplies (105 MAF diversions and 60 MAF at farm gate), 48 MAF groundwater and 18 MAF rainfall. Out of this 18 MAF rainfall, recharge to aquifer is 6 MAF,

evaporation & run-off is 5 MAF and crop use is 7 MAF. No doubt that irrigation is vital for the success of dryland agriculture but could be a necessary evil if used unscientifically. Despite a magnificent canal irrigation system, per acre yields in Pakistan are much below the potential crop yields. The main factors responsible for the low economic efficiency of the present irrigation system of Pakistan include inadequate drainage, excessive water losses, outdated land and water management practices, fragmented land holdings, and the twin menace of waterlogging and salinity

3. WATERLOGGING PROBLEM AND DRAINAGE MEASURES TAKEN

Waterlogging includes all forms of excess water in the root zone of the soil or even on the soil surface. In the first case plant growth will be affected through restriction in root growth; in the second the top part of the plant may also be affected directly. In brief, waterlogging is a relative term to indicate rise in water table creating the problem of oxygen deficiency in the root zone, salt build-up in the soil profile, and poor workability with soil. For practical purposes, lands with less than 1.5 meters water table depth are called as waterlogged. The deep percolation of water from the unlined canals in the irrigation system and irrigated lands formed a new increment of recharge greater than the discharge from the aquifer. As a result, watertable rose in the canal irrigated areas and reached near to the land surface. Within 100 years of the irrigation system, the watertable rose to within 3 meter on about 42 percent of the area of the Indus Basin. The situation was worst in Sindh province where watertable was within the range of 3 meter on about 57 percent of the irrigated area of the province (Ahmad, 1990). The problem of waterlogging developed mainly due to flat topography, seepage from the canal system, poor water management practices, in-adequate provision of drainage and poor operation & maintenance of the irrigation and drainage systems.

The groundwater table in the canal commands exhibits an annual cycle of rise and fall. In most of the Indus Plain, the watertable is at its lowest level prior to the monsoon (April/June) and as a result of the Kharif (summer) canal supplies and the effects of the rains, it rises and comes close to the land surface in October, after which it begins to decline again. The high watertable conditions after the monsoon, although transitory, interfere with the cultivation of Rabi (winter) crops. However, the watertable position in April/June is particularly critical as it persists throughout the year and is used as an index of waterlogged area. Previous data showed that 1/10th of the total irrigated area of Pakistan remained continuously under waterlogging conditions (Pakistan National Committee of ICID, 1992). However due to various measures adopted by the government to eradicate this menace, the condition is not further deteriorating and dry spell for the last few years has contributed in decreasing waterlogging in Pakistan. There are still some areas where timely cropping is not possible and crop yields are adversely affected by high watertable.

In Pakistan, the main types of drainage technologies applied individually or in combination are surface drainage, tubewell drainage (vertical drainage), pipe drainage (horizontal drainage) and bio-drainage (saline agriculture). Surface

drainage facilities not only remove excess or unwanted water from agricultural fields but also serve as conveyance channels for urban and industrial wastewater, sub-surface drainage and for surface runoff from outside agricultural areas. The technologies used for sub surface drainage include tubewells and pipe drains. The surface-drains, deep tubewells and pipe drains have been installed in different areas of the country. For combating the waterlogging and salinity problem in Pakistan, the Water and Power Development Authority (WAPDA) developed a programme of Salinity Control and Reclamation Projects (SCARPs) in Pakistan in the early sixties. Over 4 decades, WAPDA has completed 63 SCARPs up to June 2004. In all the SCARPs these activities involved installation of 16950 tubewells, construction of 14361 kilometers of surface drains and laying 12612 kilometers of horizontal pipe drains. As reported by Planning & Design Division (Water), WAPDA in 2004, the implementation status of drainage facilities in Pakistan is shown in Table 2. Additionally, the drainage problems are being covered through National Drainage Programme (NDP), Drainage Master Plan (DMP) and Bio-saline Projects of WAPDA.

Table 2: Implementation Status of Drainage Facilities in Pakistan

(GCA in Ma)

Province/ Country	Completed SCARPs						Ongoing SCARPs							
	Sub-surface Drainage				Surface Drainage		Sub-surface Drainage				Surface Drainage		Completed	On-going
	Tubewell		Tile				Tubewell		Tile					
	FGW	SGW	FGW	SGW	FGW	SGW	FGW	SGW	FGW	SGW	FGW	SGW		
NWFP	0.213	0.013	0.574	0.084	-	-	-	-	-	-	-	-	0.884	-
Punjab	6.869	2.176	0.030	0.205	0.622	0.948	-	-	-	-	0.357	0.432	10.850	0.789
Sindh	2.193	0.216	-	0.045	-	4.278	-	-	-	-	-	-	6.732	-
Balochistan	-	-	-	-	-	0.177	-	-	-	-	-	-	0.177	-
Pakistan	9.275	2.405	0.604	0.334	0.622	5.403	-	-	-	-	0.357	0.432	18.643	0.789
Total Completed and Ongoing													19.432 (7.864 mha)	

4. SALINITY/SODICITY PROBLEM AND SALINITY MANAGEMENT

The accumulation of excessive amounts of soluble salts in the root zone of plants is called the salinization process and the soils so developed called as salt-affected soils. The soils with excessive soluble salts have salinity problem and the soils with more exchangeable sodium have sodicity problem. The main sources of these salts in the Indus Basin are mineral weathering, groundwater and irrigation applications, which redistribute the accumulated salts. The high evaporation rate and the shallow depth to groundwater allow the salts to move up with moisture, through capillary action, near to the soil surface and accumulate in the topsoil. Salt concentration in soil varies widely both vertically and horizontally, depending on such conditions as variation in texture, plant growth, and hydraulic conductivity. This variation shows up strikingly as patchy growth or no growth of vegetation in salt-affected soils.

The magnitude of salinity problem can be gauged from the fact that more than 40000 hectares of good agricultural lands go out of cultivation because of this

menace each year in early sixties (Ali et al. 1997). For assessing the extent of the salinity problem, soil surveys have been carried out over the past about four decades by several agencies. The first countrywide soil salinity survey was conducted in 1953-54 under Colombo Plan. The second survey was conducted by Master Planning & Review Division, WAPDA during 1977-1979 covering 16.711 million hectares. The latest salinity survey has been carried out by SMO, WAPDA during 2001-2003. It covers an area of 16.797 million hectares. Table 3 shows surface salinity status of the Indus Basin during various surveys. The surface salinity survey data reveal that salt free lands increased from 56 percent in early sixties to 72 percent in 1977-1979 and 73 percent in 2001-2003 at Pakistan level. But, Sindh and Balochistan provinces showed a different pattern i.e. surface salinity was more in 2001-2003 as compared to 1977-1979.

Table 3: Surface Salinity Status of Indus Basin

(Percent of Area Surveyed)

Province / Country	Survey Period	Salt Free (S1)	Slightly Saline (S2)	Moderately Saline (S3)	Strongly Saline (S4)	Misc
NWFP	2001-03	86	2	2	<1	10
	1977-79	78	8	2	2	10
	1971-75	75	10	4	2	10
Punjab	2001-03	88	3	2	1	6
	1977-79	84	7	4	3	2
	1953-65	72	15	5	6	2
Sindh	2001-03	46	24	8	17	5
	1977-79	50	19	10	18	3
	1953-54	26	28	17	27	2
Balochistan	2001-03	67	15	9	7	2
	1977-79	74	17	5	4	<1
	1953-54	69	15	7	9	<1
Pakistan	2001-03	73	10	4	7	6
	1977-79	72	11	6	8	3
	1953-75	56	20	9	13	2

Table 4 shows soil profile salinity/sodicity status upto 1.5 m depth in Indus Basin during various surveys. It can be depicted from the data that profile salinity also decreased in Pakistan as the salt free profiles increased from 55 percent in 1962-65 to 61 percent in 1977-79 and remained unchanged in 2001-2003. However, profile salinity increased in 2001-03 as compared to 1977-79 in Sindh and

Balochistan Provinces. The reduction in surface and profile salinity is primarily due to increased irrigation water supply from surface and groundwater sources, better water management, increased cropping intensity and measures taken by Government of Pakistan to reclaim the waterlogged and salt-affected lands.

Constant use of agricultural lands in irrigated areas often results in the accumulation of soil and water borne salts during the repeated cycle of water reuse. Accumulation of salts in agricultural lands eventually leads to a point where alternate methodologies become essential for agricultural production. The major alternatives which seem more promising are: (i) reclamation of saline soils; (ii) development of cultural practices beneficial for growth under saline conditions; and (iii) selection of salt tolerant plants.

Table 4: Soil Profile Salinity / Sodicity Status Upto 1.5 m Depth in Indus Basin

(Percent of Profiles)

Province / Country	Survey Period	Total Profiles	Non Saline-Non Sodic	Saline	Saline Sodic	Non-saline sodic	Misc. Land Types
NWFP	2001-03	1253	83	9	6	2	-
	1977-79	1958	79	11	7	2	1
	1971-75	314	27	50	23	-	-
Punjab	2001-03	17294	68	6	16	10	-
	1977-79	39963	73	7	14	5	1
	1962-65	23662	55	6	27	11	1
Sindh	2001-03	5978	36	17	44	3	-
	1977-79	20543	38	17	42	2	1
Balochistan	2001-03	205	39	20	36	5	-
	1977-79	1402	35	26	38	1	-
Total	2001-03	24760	61	9	22	8	-
	1977-79	63866	61	11	24	3	1
	1962-65	23976	55	6	27	11	1

Source: Pakistan National Commission of ICID, 1991 and SCARPs Monitoring Organization (Unpublished).

Qureshi and Lennard (1998) have suggested the following three approaches for managing saline, sodic and waterlogged soils:

4.1 Engineering Approach

The engineering approach assumes that salinity in irrigated areas can be reversed using drainage schemes that lower watertables. Over 7.8 million hectares have so for been treated through Salinity Control and Reclamation Project (SCARPs) in Pakistan. Measures taken for combating waterlogging and salinity in Pakistan were very helpful for controlling waterlogging and its allied secondary salinization but still many salt-affected soils are not treatable and the sustainability of the approach for tackling the problem of salinity/sodicity is questionable. The International Commission on Irrigation and Drainage (1991) has reported that the waterlogging has generally been controlled in the SCARPs but at the same time the effect has been found diminishing due to reduction in the pumping capacity of tubewells with time or non-operation of tubewells due to some reasons or use of excess surface supplies etc. Despite of all drainage efforts, waterlogging and salinity is not being controlled as envisaged during the planning of the projects. This is mainly due to availability of inadequate funds for the running and maintenance of these projects.

4.2 Reclamation Approach

The basis of the reclamation approach are the use of small-scale interventions to improve soil condition. This is particularly appropriate where soils are saline because of their high sodicity (lack of soluble calcium) and low rates of water infiltration. Interventions include leaching of salt with higher levels of irrigation, use of chemical amendments (such as gypsum and acids), use of organic wastes, and use of plants to improve soil condition.

4.3 Bio-saline Approach

Under the bio-saline approach, useful production can be achieved from salt-affected wasteland (without reclamation). In these instances, the main focus is on the economic utilization of the land while still in the saline or sodic condition. There may be improvements in soil condition but this is a spin-off benefit. The use of this approach is not too old in Pakistan. The latest promising bio-saline approach involves re-vegetation of salt-affected lands using salt-tolerant crops, trees, grasses and saltbush. Growing salt-tolerant crops increases food and fibre for the ever-increasing population of the country. Sowing of salt-tolerant grasses can help improve the grazing for animals. Similarly, growing trees and saltbush has the added bonus that helps fill local needs for forage and fuel wood in which Pakistan has a national shortage. National fodder supplies are estimated to be only 60 percent of the total requirements. The most common fuel is dried animal dung but provision of alternative fuels would enable this to be returned to the fields to improve the fertility of the cropping land.

5. EXPERIENCE OF BIO-SALINE APPROACH

The huge investments and the sustainability factor forced scientists and engineers to think about the latest promising less expensive bio-saline approach that seemed to be more sustainable and cost effective solution to waterlogging and

salinity because both these interventions involve an effective farmer participation and can also be tried at on-farm level. As far the experience of bio-saline approach, the first bio-saline project was Joint Satiana Pilot Project (JSPP) near Faisalabad between 1994 and 1997 based on interventions tested during earlier research projects targeting the poor farmers. Bio-saline agriculture was successfully demonstrated to restore the productivity of about 400 hectare of salt-affected lands by planting E. camaldulensis tree and saltbushes (Atriplex amnicola and Atriplex lentiformis). The JSPP was jointly funded by United Nations Development Programme (UNDP) and Australian Agency for International Development (AusAID) and implemented by six national agencies and one non-governmental organization i.e. Action-AID Pakistan.

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