MANAGEMENT OF WATER-RESOURCES IN SOUTH ASIA

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SUMMARY

The South Asian Region consists of Pakistan, India, Nepal, Bhutan, Bangladesh, Sri Lanka and Maldives. The region has high altitude mountain terrain, sub–mountaineous tracts, large flood plains with a network of rivers and streams, deserts and large coastal areas. The South Asian Region has three distinct rainfall systems. Most of the rainfall is in summer (80%) and is brought by southwestern monsoon system. In winter, the rainfall is brought about by northeastern monsoon in Bangladesh / adjoining areas and by western weather system in Pakistan and other parts of the region. The winter rains are very important source of water supply for crops as the water scarcity peaks during this period.

Indus, Ganges and their tributaries mainly cover the sub continent. There are wide fluctuations in the river flows during the year. The supplies peak up generally in monsoon and during snowmelts (July- September) and the flows largely recede in dry season, particularly in winter. A huge irrigation network , the world's largest has been built on the rivers in the region. A water reservoir capacity of 248 MAF has been built in the region for a sustained production of crops. In addition, these reservoirs have provided an important opportunity in hydel power generation, fishing and a ground-water recharge of the adjoining areas.

Groundwater is an important source of water supply. Large parts of the South Asian Region have a sweet-water aquifer. In all countries of the region, subsurface water is pumped through shallow wells or deep tubewells/ turbines, mainly for agricultural purpose. The total water withdrawals from surface and subsurface are estimated at 772 MAF. About 90 % of the water supplies in the region are used for agriculture and remaining for households, industry and other purposes. Canals irrigation is mostly in public sector and wells/tubewells are generally in private sector.

The population of South Asia is 1.30 billion. The cropped area of the region is 204.8 million ha. Rice is the single predominant crop of the region occupying 22.6% of the cropped area, followed by wheat 14% area. Other important crops grown in the region are coarse grains grown on area of 12.1%, pulses 10.5%, cotton 4.5%, oilseeds 4.5%, beans 3.8% and sugarcane 2.0%. The plantations as tea, coconut and rubber, although having high commercial value, are grown on considerably smaller area.

About 40 % cropped area in this region is irrigated and 60 % is dependent upon rains. Water requirements for the 8 important crop (grown on 74 % area) have been worked at 1166 million-acre feet (MAF). Rice is the single largest irrigated crop (more than 90% irrigated) consuming 63 % of the water among these crops. In some countries it is almost the only irrigated crop. Wheat is the second largest crop grown, both under rainfed and irrigated conditions. Water requirements have been estimated at wheat 10%, coarse grains 7%, pulses 6 % and sugarcane 6 %. The water requirement for these five crops makes 92 % of the water requirements.

Prolonged dry weather many a times results in droughts in the region. The impact of drought is generally of universal nature, affecting vast areas in a country or the region. There were acute shortages of water in drought hit areas. The crops were damaged and the pastures dried up. Even drinkable water became a problem. Excessive mining of water in some areas lowered the water-table to dangerously low levels. There was massive human and livestock migration from these areas. The damage to the livestock sector was colossal. It is proposed that the regional countries should, put in place a system that forecasts droughts, assesses damages and provides relief assistance to minimize the hardships of life. Some countries of the region have already started putting piped water-supplies and building communication-networks in these areas. The regional countries should take short and long-term measures to mitigate the affects of drought.

The reservoirs although useful, there are growing concerns on building reservoirs in the countries of the region. These concerns are both national and international in character.

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There is a growing feeling that the reservoirs result in displacement of people/farming communities, create environmental problems and on many a times, lead to politicization of the issues. High initial capital investment is another issue. Most of the reservoirs have watershed management programs in the catchment areas. However sometimes the catchment is in adjoining countries, which makes it impracticable to launch watershed programs. Once the reservoirs are built, the rapid sedimentation is a big issue and calls for appropriate policy and action plans.

Governments of the region need to make policies for conservation of water resources that optimize use efficiency. The countries of the region in general have agencies that have already done useful work in water resources development through construction of a net work of water structures as reservoirs, dams, barrages, canals, link canals, lakes and ponds. The water distribution systems have been geared to match water requirements during the critical growth stages of crops. De-silting of canals and minors and renovation of water courses for improving water delivery efficiency have been carried out in various parts of the region.

At farm, programs have been undertaken to improve water-use efficiency through precision land leveling of uneven fields., sowing of crops on ridges and beds, use of pressurized irrigation system for orchards, vegetables, floriculture and other high valued crops. The cropping patterns are being adapted to minimize water indents. All these works need to be furthered. Some of countries of the region need to have a second look on their heavy dependence on mono-crop system of growing rice a water-thirsty crop.

The statistics on subsurface water and from glacier melts many a times are inadequate or faulty and the countries of the region need to improve it for planning purposes

Most of the rivers and creeks in their upper reaches have good quality water. As water flows down stream, the industrial and urban effluents load this water with heavy metals, injurious chemicals and biological pollutants. Cases of ill health through pollution of drinkable water have been reported in Pakistan and other countries. Iron and nitrate pollution has been noticed in Sri Lanka. The salinization of subsurface water through intrusion of seawater has been reported in India, Pakistan, Maldives and Sri Lanka in the coastal areas. This is an area that needs attention of the Governments in the region in the context of appropriate legislation and implementation of sound environmental policies.

Over last two decades, there is a growing participation of the farming communities in water resource development, distribution and on farm water management programs, in the countries of the region. Water users' associations have been organized and actively

Figure - 1: Map of South Asia

involved in the planning and development programs of water sector in agriculture. These farmers' organizations can be further involved in transforming agricultural/rural scenarios.
The studies carried out in countries of the region indicate that a large O & M cost are being incurred on irrigation networks by maintaining them in public sector. At least part of this expenditure can be minimized through participation of farmers in maintenance of these canals. The subsidies on irrigation lead to an inefficient water use. The Governments can have a second look on this issue.

INTRODUCTION

South Asian Region consists of Pakistan, India, Nepal, Bhutan, Bangladesh, Sri Lanka and Maldives. The map of the region is given in figure-1. The region has high- altitude mountain terrains, sub–mountainous tracts, large flood-plains, with a network of rivers and streams, deserts and large coastal areas. The famous Indus and Gigantic civilizations thrived and prospered in this region.

Agriculture has been the main pursuit in the region since the human civilization began. Land and water have been the primary resources for this activity since primeval times. Initially, the human settlements were built near the water-bodies, like rivers and lakes. Human beings learnt from experience that water is a basic input in raising crops. Agriculture continued to be mainly carried out under rain fed conditions. Irrigated agriculture started much later.

As primary structures, wells and karezes (sub-surface irrigation ditches) are known to have been built in various parts of the world, including South Asia. These Structures helped an assured production of crops and also helped to raise farm-productivity. With expansion in human population, the land and water resources came under pressure. The disasters, like drought, disease, insect hazards (locust and others) resulted in crop damages, many a times leading to famines. In addition, the process of degradation of land and water-resources, through salinization, water logging, industrial effluents and other environmental hazards, is an on-going process and is a major threat to agriculture. There is a need for a judicious management of these scarce resources.

A number of efforts were initiated in the South Asian region, particularly during last millennium, for the proper management/use of land and water-resources. This becomes more demanding at a time when large fertile tracts of agricultural land are falling victim to rapid industrialization, urbanization and other non-farm uses. Similarly, management of water-resources is of prime importance for fostering activities of agriculture sector on commercial lines.

Table - 1.1: Population (million)

Category	Total	Agricultural	% in Agriculture
World	5,978.40	2,575.50	43.08
Asia	3,634.30	1,956.50	53.83
South Asia	1,309.40	735.70	56.18
Bangladesh	126.90	72.00	56.74
Bhutan	2.10	1.90	90.48
India	998.10	553.20	55.43
Maldives	0.3	0.08	26.67
Nepal	23.4	21.8	93.16
Pakistan	140.0	78.0	55.71
Sri Lanka	18.6	8.7	46.77

Source: FAO Production Year Book, 1999

SOUTH ASIAN SCENARIO

Population

The population of the world in 1998 was 5.98 billion, Asia 3.63 billion and South Asia 1.30 billion. The population of South Asia was 21.7 % of the world population and 36.0 % of Asian population. The data is as in Table-1.1.

The world has a population of 43% in agricultural discipline. However, Asian involvement in agriculture is 53% and South

Table - 1.2: Area Profile of South Asian Countries.

Category	Land Area	Cultivated Area	Irrigated Area	Per-head Cropped area
Unit	**000 Ha**	**000 Ha**	**000 Ha**	**Ha**
World	13,048,407	1,511,964	271,432	0.25
Asia	3,085,414	557,633	191,171	0.15
South Asia	412,917	204,810	82,631	0.16
Bangladesh	13,017	8,774	3,844	0.07
Bhutan	4,700	160	1	0.08
India	297,319	169,500	59,000	0.17
Maldives	30	3	-	0.01
Nepal	14,300	2,968	1,135	0.13
Pakistan	77,088	22,050	18,000	0.16
SriLanka	6,463	1,888	651	0.1

Source: FAO Production Year Book, 1999.

Asia 56%; Bhutan and Nepal have more than 90% of their population in agriculture sector. The Maldives, on the other side has less than the South Asian %age population engaged in agriculture sector.

Land

The cropped area of the world is about 1512 million ha. The cropped area in Asia is 557.6 million ha and South Asian cropped area is 204.8 million ha. This makes 12.6 % of the world-cropped area and 36.7 of the Asian cropped area. The cropped area in South Asia is 40% irrigated (82.6 million ha) and 60 % rainfed (122.2 million ha). The per-head cropped area in the world is 0.25 ha and in Asia only 0.15 ha. The cropped area per head is 0.16 ha in South Asia. The detailed data is as in Table-1.2.

Important Crops in South Asia

The cultivated area in South Asia is 204.8 million ha. Extrapolating through a cropping intensity of 130 % from Indian cropping pattern (largest crop-machine in the region) for the South Asian region, the cropped area works out to be 266 million ha.

Eight important crops grown in the region are rice, occupying 22.6% of the cropped area, wheat 14%, coarse grains 12.1%, pulses 10.5%, cotton 4.5%, oilseeds 4.5%, beans 3.8% sugarcane 2.0%, and other crops 26 % of the cropped area. The data is shown in Table-1.3.

Water Requirements Of Important Crops

In South Asia, the crops are grown both under irrigated and rainfed conditions. It is little difficult to work out the exact requirement to be supplemented to the crops through the irrigation-network, in addition to rains. However, in the background of requirement of crops in Pakistan, the water requirements have been worked out for the 8 important crops at 1166 million-acre feet (MAF). About 63.6 % are required for rice alone; wheat 9.8 %, coarse grains 6.8%, pulses 5.7 %%, sugarcane 5.9 %. The water-requirement for these five crops makes 92 % of the water requirements depicted in the following table-1.4.

Table - 1.3: Area under important crops in South Asia (million ha)

Country	Wheat	Rice	Coarse grains	Cotton	Sugar cane	Pulses	Oil seeds	Beans	Total
Bangladesh	0.85	10.50	0.00	0.00	0.17	0.67	0.50	0.00	12.69
India	27.40	44.80	29.40	9.00	4.15	25.30	10.50	9.90	160.45
Nepal	0.64	1.52	1.10	0.00	0.00	0.30	0.00	0.04	3.60
Pakistan	8.30	2.40	1.80	3.00	1.10	1.71	0.90	0.25	19.46
Sri Lanka	0.00	0.82	0.00	0.00	0.00	0.05	0.00	0.03	0.90
Total	**37.19**	**60.04**	**32.30**	**12.00**	**5.42**	**28.03**	**11.90**	**10.22**	**197.10**

Table - 1.4: Water Requirements of Important Crops.

Crops	Area	Water Requirements	Total	% Share
Unit	*Million ha*	*Acre inches**	*MAF*	
Wheat	37.19	15	114.9	9.8
Rice	60.04	60	741.8	63.6
Coarse grains	32.3	12	79.8	6.8
Cotton	12.00	16	39.5	3.4
Sugarcane	5.42	60	67.0	5.7
Pulses	28.03	10	69.3	5.9
Oilseeds	11.90	12	29.4	2.5
Beans	10.22	12	25.3	2.2
Total	**197.1**	**29**	**1166.9**	**100**

** By Pakistan standard*

COUNTRY PROFILE

The ware resource profile of the South Asian Countries is as follows:

BANGLADESH

The cultivated area of Bangladesh is 8.8 million ha. The country has a high density of population of 834 inhabitants per $km^{2.}$ The average holding per farm household in 1983 was 0.9 ha. Nearly 24 per cent of farm households own less than 0.2 ha and another 46 per cent own up to 1.0 ha. Agriculture is mainly carried out under conventional subsistence-farming practices. Rice is the main crop, occupying an area of 10.5 million ha, which makes 90 % of the area under cereal crops. Other important crops grown in the country are pulses, oilseeds, jute and sugar cane. Recently a plan has been prepared to introduce and expand cotton-production in the country to meet domestic requirements and to sustain the exports of garments and other textile made ups.

Bangladesh has a tropical monsoon climate. About 80 per cent of the total rainfall occurs in the monsoon and the average annual rainfall over the country is 2320 mm. Being a deltaic country, cyclone cause heavy damage to the agricultural economy and structures. Floods, cyclones and droughts are a common feature of the climate pattern in Bangladesh . There are wide annual variations in rainfall and temperature throughout the country.

Ganges, Brahmaputra and Meghna, and their tributaries cover the flood plains of Bangladesh. The total dam capacity is 17.3 MAF. In addition, there are three barrages across the Teesta, Tangon and Manu rivers that are used as diversion structures for irrigation purposes only. In 1990, the total water withdrawal for agricultural, domestic and industrial purposes was estimated at about 12.4 MAF. ,of which agriculture makes 86% , the domestic industrial sectors make 14%. The requirement of navigation and fisheries is estimated at 8.5 MAF. Approximately 73 per cent of the total water-withdrawal comes from groundwater.

In Bangladesh, irrigation through major canals covers only 6 per cent of the total irrigated area, the remaining being classed as minor irrigation consisting of low lift pumps, shallow tube-wells, deep tube-wells. Government's main emphasis in Bangladesh is the expansion of small-scale irrigation.

At present, irrigation is practiced for rice (71 per cent) and wheat (9 per cent), which together occupy 80 per cent of the irrigated land. Irrigation is mainly used in the dry season.

Because of its low-lying topography, about 22 per cent of the area of the country are flooded each year. Flood control and drainage are used to reduce the depth of flooding or eliminate, through 'controlled flooding' high and untimely floods in order to provide greater security for crop production.

Water-management and flood-protection occupy a pivotal position in the planning

process of Bangladesh. The major emphasis in Bangladesh is on the following issues:

- Improving use efficiency of existing facilities with an effective O&M;
- De-Silting of rivers and channels;
- Integrated flood control / drainage;
- Participation of water-users in the planning and design of new irrigation/drainage projects.

BHUTAN

Bhutan is a Himalayan country with a rugged mountain terrain. Climate ranges from hot and humid subtropical conditions in the south to the incessant ice and snow in Himalayas.

The only dam in the country is the Chukka hydropower dam. Most rivers are deeply incised into the landscape, a fact that greatly limits the possibilities for run-of-the-river irrigation. The total water-withdrawal was estimated at 16.2 thousand-acre feet in 1987.

The cultivated area in Bhutan is 160 thousand ha. Out of this, about 1 thousand ha are irrigated and rest is dependent upon rains. The irrigated area is mostly under rice crop.

The irrigation-management strategy mainly focuses on:

- Sustainable improvements in water-delivery and use-efficiency;
- Diversifying the range of irrigation from mono-cropped rice system to multi-crop system;
- Increasing the role of water-users and the private sector, and to reduce recurrent government investments in irrigation schemes.

INDIA

The total cultivable area of India is estimated at 169.5 million ha, or about 57 per cent of the land area. The cropping intensity is 130 per cent. The major cereals grown in India are wheat, rice, and coarse grains. Ninety one per cent of the farmers have land holdings less than 4 ha. The average farm size is estimated at 1.57 ha.

The rainfall in India is brought about by the monsoon system and western disturbances. The average rainfall is 1170 mm. There are places, which get world's highest rainfall of 12,500 mm. On the other extreme, there are places like Rajasthan, Gujarat, Saurashtra and Kutch, which get less than 150-mm rainfall. Most of these areas have undergone extensive drought conditions, with massive human and livestock migration. This called for an intervention from the Government to address the drudgeries of masses in these areas. Temperature variations are also marked.

The major sources of water in India are rainfall and the glacier melts. The total surface flow, including groundwater is 1570 MAF. Out of this 587 MAF are utilized. The total water-storage capacity constructed up to 1996 was of the order of 212 MAF. In 1990, the total water-withdrawal was estimated at 425 MAF, of which 92 per cent was for irrigation purposes.

India has the largest irrigated area of the world, size of the irrigated area is 59 million ha. Irrigation is mainly concentrated in the north of the country, along the Indus and Ganges rivers.

Uttar Pradesh (22 per cent of the irrigated area), Rajasthan (9 per cent) Madhya Pradesh (9 per cent) and Punjab (8 per cent) Liberal subsidies on electricity and its abundant supplies has helped to foster both production and productivity of crops. This situation has resulted in huge inefficient use of water at the farm.

The average overall water-use efficiency in canal irrigation systems is estimated at 40 per cent. Water-rates are uniform throughout the state in Andhra Pradesh, Gujarat, Kerala, Madhya Pradesh and West Bengal. However, in Bihar, Haryana, Maharashtra, Punjab, Rajasthan, Tamil Nadu, Tripura and Uttar Pradesh, the rates vary within the state from region to region or project to project.

The water-rates are higher for storage-systems than for flow-diversion schemes. Similarly, the rates for canal-lift irrigation are generally higher (double) than flow-irrigation when water lifting is undertaken by the Government bodies. The development of sprinkler and drip-irrigation is likely not to pick up in various states of India particularly in view of free or subsidized electric tariff. However, India is providing subsidy to promote drip irrigation.

A number of Indian states in recent years are cutting down or partially withdrawing

subsidies. This is likely to promote the efficient use of pressurized irrigation systems. However since India does not have compulsion from the donor-agencies, it may take considerable time before the efficient use of water accelerates. The area under drip-irrigation is mainly concentrated in Maharashtra, Andhra Pradesh and Karnataka. The drip-irrigation is mainly followed on high-value horticultural crops/orchards.

Drainage works have been undertaken on about 5.8 million ha, which is 12 per cent of the irrigated area. In addition, 3.1 million ha are affected by salinity and about 0.24 million ha by alkalinity. These figures however seem gross under estimates.

Indian irrigation is dominated by the public sector. The O&M of most schemes require public sector involvement. India adopted a national water-policy in 1987 for the planning and development of water-resources. It emphasizes the need for river basin planning. Water allocation priority has been given to drinking water, followed by irrigation, hydropower, navigation and industrial or other uses in the order. All the states are required to develop their state water-policy within the framework of the national water-policy and, accordingly, set up a master plan for water-resources development.

All rivers in their upper reaches have good quality of water. Like elsewhere, the deterioration in quality of water starts downstream through domestic, industrial and agricultural pollutants. These pollutants also affect groundwater. The mining of groundwater in drought-hit states has resulted in lowering of water-table in large number of Indian States to very low levels. This is mainly because of the conditions of non-recharging of water in current drought conditions that forced a large number of the farming communities to migrate from water-starving areas to water sanctuaries. Indian policy of providing heavy subsidy on electric tariff has also been responsible for this situation.

MALDIVES

The total cultivated area of Maldives is estimated at 3000 ha. Permanent crops as coconut and aeronaut are grown on an area of 2000 ha and annual field-crops as maize, sorghum, cassava, onion and chilies are grown on an area of 1000 ha.

The islands have a tropical climate with two monsoons, which are:

- The southwest monsoon from May to September;
- The northeast monsoon from November to March.

The precipitation is uniformly distributed between April - December. The January – March is a dry period. The mean annual rainfall is 1883 mm. The islands do not have any rivers. Rainwater is collected through water-harvesting on a small scale and used for drinking purposes. Maldives finds it extremely difficult to obtain suitable drinkable water. Three desalination plants are in operation, with a total production of 1000 m^3/d.

NEPAL

Nepal is a land locked Himalayan State located entirely in the Ganges basin. The cultivable area of Nepal is estimated at 2.96 million ha. One third of this area is in the Terai plain, 8 per cent in the Siwalik, 48 per cent in the mountain and hill region and 10 per cent in the high Himalayas. Agriculture contributed 40 per cent of GDP in 1996 and employed more than 93 per cent of the economically active population of the country. The main agricultural exports are rice, pulses and jute.

The mean annual rainfall is 1500 mm. There are two rainy seasons in Nepal: one in the summer (June to September) when the southwest monsoon brings more than 75 per cent of the total rainfall, and the other in winter (December to February) accounting for less than 25 per cent of the total. The summer monsoon-rain first falls in the southeast of the country and gradually moves westwards with diminishing intensity. This results in more rainfall in the east of the country. During winter, rainfall is brought about by westerly disturbances.

All rivers in Nepal drain into the Ganges River. The country is divided into five river basins, which are from west to east. The seasonal distribution of flow is extremely variable. The flows in rivers, both from rains and snow-melt greatly recede during January – March period. This situation improves during July – August period as snowmelt and rainfall picks up.

The surface-water resources produced internally are estimated at 168 MAF water. The groundwater-resources have not been fully assessed. The Terai and some parts of

the Siwalik valley have sweet-water aquifers. A rough estimate is made by assuming a groundwater-resource equivalent to ten per cent of surface-water, i.e. approximately 17 MAF. This makes Nepal one of the Asian countries with the highest level of water-resources per inhabitant.

The total dam-capacity of Nepal is 69 thousand-acre feet. This is a small fraction of the potential dam-capacity of 117 MAF. The irrigated area in Nepal is 1.14 million ha. Irrigation is mainly done by flooding. Ninety one per cent area is dependent on surface-water and 9 per cent on groundwater. The Department of Irrigation is responsible for the management of the irrigation programs. The main irrigated crop is paddy in summer, followed by wheat crop in winter.

PAKISTAN

Rainfall activity over Pakistan occurs mainly in two distinct periods, namely summer (June to September, the monsoon season) and winter (December to March). More rains fall during the monsoon season than during the winter season.

The annual flow of water in the Indus River system, on an average, is 140 MAF. The flow during summer is 118 MAF (84%) and in winter is 22 MAF (16). Indus is the Main River contributing 65% of water supplies, with Jhelum giving 17% and Chenab 19%. In the light of Indus-Basin Water-Treaty, Pakistan has built a series of link canals to divert water from the western rivers, to provide water to the Southern Punjab. Pakistan has built a reservoir capacity of 18 MAF water to cater for the needs during periods of scarcity, mainly winter crops. About 4 MAF capacity has already been reduced through sedimentation. The alluvial plains of Pakistan have a sweet-water aquifer of 50 MAF. Out of this, 40 MAF is being exploited through 600,000 tubewells mainly in private sector. The availability of water in Kharif is 77 MAF and Rabi 56 MAF, making total water supplies at 133 MAF.

Under On-Farm Water-Management Program, 45 thousand watercourses have been improved, out of a total of 120 thousand watercourses. A follow-up program, pursuant to improvement of watercourses to improve water-use efficiency was carried out at farmer's fields. Technologies are disseminated to Farmers on laser-leveling of fields, sowing of crops on beds and furrows, zero tillage, inter-cultural practices and balanced application of fertilizers. This helps to raise the productivity of crops and living standards of the farming community. The pressurized irrigation system e.g. sprinkler and trickle irrigation system, were introduced for high-value crops viz. orchard and vegetables. This system is particularly good for areas with an uneven topography, particularly in rainfed areas. The initial investment is very high/prohibitive and poor farming-communities, especially in drought hit Balochistan and other places, cannot afford such a high capital investment. Another problem with the pressurized irrigation system is that most of the materials are imported. Local initiatives have been taken recently, which are of infinitesimal nature. There is a need for inducting the private-sector in this area, assuring competitive and cost-effective supplies of the pressurized-irrigation materials to the interested farmers.

Rod Kohis are hilly valleys, where hill-torrents move at a rapid pace and result in soil erosion and damage to standing crops. Primarily, the structures in these areas are built to slow down the speed of the torrents. Research is underway to investigate practices and package of technology to minimize the farm-losses to soil and crops.

As water-resources are under high pressure, the Ministry of Food and Agriculture is in the process of promoting cropping pattern/production practices that minimize the requirements of irrigation-water, without compromise on farm-productivity/profitability.

A flow of 10 MAF is required to maintain ecology in the deltaic region and to avoid intrusion of sea water. There was not much water available for the purpose during the drought encountered over the last three years. As a result, the seawater intruded, causing damage to farmlands.

SRI LANKA

Sri Lanka receives rainfall mainly through two monsoons. The rainfall-intensity varies markedly across the island. Based on rainfall, several agro-climatic regions (wet zone, intermediate zone, dry zone and arid zone) can be recognized. There is considerable variation around the mean annual rainfall of 2000 mm. The highest rainfalls are in the central highlands.

Groundwater resources have been extensively used. Sri Lanka's largest aquifer extends over

200 km in the northwestern and northern coastal areas. There are about 15000 tube-wells in the country. The quality of the groundwater is generally fairly good and relatively constant throughout the year. However, in some parts of the country (northern and northwestern coastal areas) excessive concentrations of iron and nitrates (due to agro-chemicals and fertilizers) have been reported. Furthermore, due to uncontrolled extraction of groundwater for domestic and agricultural uses, intrusion of brackish water has occurred in the coastal areas.

Groundwater is an important source of water for irrigation and domestic use. It is increasingly used as drinking water, especially in small towns and rural areas. The total water-demand is estimated to be 9.3 MAF. Of this, 90 per cent is for agriculture, 7 per cent for domestic purposes and 3 per cent for industrial purposes.

The total cultivated area of Sri Lanka is 1.9 million ha. Out of this 0.7 million ha are irrigated and rest is dependent upon rains. Of this cultivated area, 1 million ha are under permanent crops such as tea, rubber and coconut. Annual crops viz. paddy, sugar cane, maize, green gram, green chilies and cowpeas, are grown on 0.9 million ha.The irrigation systems in Sri Lanka are designed mainly for paddy (0.8 million ha) cultivation. Other irrigated crops are chilies (15000 ha), sweet potato, banana and green gram.

In Sri Lanka, irrigation-schemes can be classed as minor, medium or major, depending on the area they serve. Minor schemes provide facilities for less than 80 ha. In 1995, they served about 200 000 ha. Medium schemes provide facilities for areas of 80-400 ha. In 1995, they served 61 000 ha. Major schemes provide facilities for more than 400 ha. In 1995, they served 309 000 ha.

Storage schemes have two purposes: storage and flood control. Water is impounded in these tanks by building dams across valleys, and then released when required to service downstream areas.

Diversion weirs, commonly called anicuts, are constructed in perennial streams in the wet zone, to convey water to the fields below. In the wet zone, flood-control and drainage schemes have been incorporated into the irrigation-system mainly in the lower reaches of rivers. In the coastal areas, saltwater exclusion schemes have been commissioned where water salinity affects the agriculture. Flood bunds and pumps are the main features in flood-protection schemes, whereas gated regulators are adopted in saltwater-exclusion schemes.

Lift-irrigation schemes, with mechanically or electrically operated pumps, have been introduced recently to irrigate the highlands. It is estimated that around 1000 ha are irrigated by groundwater-wells.

In 1980, an attempt was made to establish a water-tax. However, this attempt failed because of the political unrest in the 1980s. Irrigation development, O&M and rehabilitation have been predominantly state activities. The participation of water-users has been adopted in irrigation schemes in recent years. A Water Resources Council has been established in Sri Lanka, to oversee the implementation of the action-plan of water management.

ISSUES AND OPPORTUNITIES FOR SOUTH ASIA

Climate

The climate is the biggest factor affecting availability of water. The South Asian Region has two distinct rainfall systems. In summer, the southwestern system brings rainfall to this region. In winter, Bangladesh and adjoining areas of India get rainfall from the North Eastern monsoon system. Pakistan and other parts of the region get rainfall from the western weather system. La-Nina (dry spell) and El-Nino (wet spell) are the two distinct phenomena that effect the availability of water extraordinarily. The details are as follows: -

a. La-Nina This is a situation of low or no rainfall resulting in drought. The South Asian Region suffered from this phenomenon during last 3-4 years resulted in a drought in the region, severely affecting the economy of the countries in the region.

The effects of drought are of universal nature, affecting vast areas in a country or the region. There were areas in the region, particularly in arid and semi-arid climate, where there was acute shortage of water. In these areas, the crops were damaged. The pastures dried up. Even drinking water became a problem. There was massive human and livestock migration. The damage to the livestock was substantial. A large number of crops, especially in rainfed area were damaged, affecting the GDP. The

farmers' incomes were also affected and the ambit of poverty widened.

The farmers in these areas, where feasible, pumped excessive quantities of water from the sub-surface, disturbing the ecosystem. This lowered the water-table depth to dangerously low levels, as there was no recharging system available to recoup the aquifer. This chain of events led to a vicious cycle of poverty. The countries of the region are massively involved in mitigating the effects of drought from the destitute and poverty stricken masses in the affected areas. The following short and long-term measures are proposed for drought hit areas:

Short-Term Measures

- The Governments should assess the extent of damage/likely damage and declare affected areas as calamity-hit, to cope with the extra-ordinary situation.
- The Governments should provide a relief package, providing food for the human being and feed/fodders for the animals.
- Vaccination programs may be carried out for livestock.
- The elite animals of good breeds of livestock may be taken to sanctuaries, to avoid the risk of loss of such breeds.
- Governments may provide credit-line, to enable the farmers to buy seeds, fertilizers, bullocks, farm machinery and farming inputs.

Long-Term Measures

- Governments should undertake to build up water-supply schemes in the desert/ affected areas, through arranging pipeline supplies in remote water-deficit areas.
- Build up a network of roads, to facilitate the movement of goods and relief supplies in the drought-stricken areas.
- The scientists should come up with a package of crop-production practices and technologies that are low water-requiring, particularly crop-varieties that have less thirst for water.

b. El-Nino: This is a situation of high rainfall, often resulting in floods. The effects of floods are localized in nature and show a corridor effect, around the inundating creeks and rivers. The coverage of floods is not of the same large dimension as in droughts. The floods are quite common in the countries of the region and damage standing crops, households, farms, irrigation structures and communication links. The opportunities for a solution to this type of situation are proposed as follows:

- On short-term basis, the Governments may provide relief to the affectees and take other appropriate measures, as reported earlier.

- On long-term basis, the Governments should plan for mitigating the effects of floods, through building of structures and reserviors to pond the water overflowing from the banks of rivers and creeks. Sri Lanka has successfully diverted floods through building such structures.

River System

The region has a network of rivers and streams in almost all the countries. The rainfall and the snowmelt from the glaciers are the two sources of water-supply in these rivers.

There is a wide fluctuation in the river-flows during wet and dry seasons of the year. The supplies peak up generally in monsoon and during snowmelts (July- September) while the flows recede in dry season, particularly in winter. This situation calls for a judicious management of water-resources for raising crops during periods of scarcity, particularly winter crops. The rivers need to be tamed through construction of control-structures and water-reserviors to offset the shortages in times of scarcity.

Water-Reservoirs

To tame the rivers, there is a necessity to build up water-reservoirs on the river systems. A large number of such reservoirs have already been built in various countries of the region, with a reservoir capacity of 248 MAF. These reservoirs are useful for a regular supply of water during periods of scarcity, for sustained production of crops.

In addition, these reservoirs have provided an important opportunity in hydel-power generation, fishing and a ground-water recharge of the adjoining areas. The situation has helped to raise farm-incomes and eradicate poverty.

The region has a huge potential for building additional storage-capacity. However, there are inter-country conflicts on building of these reservoirs. Even within countries, many a times, there are problems in construction of these reservoirs. There is a growing feeling

that the reservoirs result in displacement of people/farming community, create environmental problems and, some times, lead to politicization of the issues. High initial capital investment is another issue. Most of the reservoirs have watershed-management programs in the catchment areas. However, sometimes the catchment is in adjoining countries, which makes it impracticable to launch watershed programs. Once the reserviors are built, the rapid sedimentation is a big issue and calls for appropriate policy and action plans.

Groundwater

The groundwater involves aspects of quantum and quality of subsurface water for human use and agricultural purposes. The South Asian Region has a good sweet-water aquifer. In addition, it has a large brackish subsurface-water profile.
Almost in all countries of the region, the supplementation of canal-water irrigation through subsurface water supplies is quite common. This water is pumped through shallow wells or deep tubewells or turbines for industrial, potable and agricultural purposes. A large number of these irrigation-programs are in both public and private sector. Some countries of the region have already handed over the public-sector tubewells to the benefiting water-users.

Recharging of the subsurface water-aquifer is highly important to keep the pumping of water continued from this subsurface layer. However, the countries of the region in some areas have suffered in water-recharging programs on the following accounts:

a. Drought affected the rainfall and water-balance.

b. Subsidies in some countries on electric tariff and irrigation-equipment promoted in efficient use. There is a need to minimize/withdraw these subsidies, to optimize water-use efficiency and to ensure that (inefficient) mining of water does not continue.

Water recharging is important for the countries of the region, especially in the arid and semi-arid areas where water depth has been lowered substantially, in much case to 40-50 feet deep. In some places, the farmers have been mining fossilized water from depths of 800-1000 feet. This water has been used to grow crops which unfortunately did not fetch good prices in some years, inflicting huge losses to the farm economy. This is a classical case of onion-production in Balochistan, Pakistan. Such situations are quite common in other countries of the South Asian Region. Governments of the region need to make policies for conservation of water-resources that optimize use efficiency.

INSTITUTIONAL DEVELOPMENT

There is a need to assure that proper institutions are in place to carry out the various activities concerning water-resource development, distribution and on farm water management.

a. Water-Resources Development

The countries of the region in general, has already established, agencies that have complete water-mapping of surface-water available in various parts of their country. These agencies have already done useful work in water-resources development, through construction of a network of water-structures, such as reservoirs, dams, barrages, canals, link canals, lakes and ponds. These agencies in the regional countries, in many cases have information on potential sites to meet a century's requirements of building water-reservoirs.

The estimation of subsurface water and water-supplies from glacier-melts, however, have not been adequately quantified in some countries and this need to be carried out for better planning and utilization of water resources. The responsible institutions for development of resources need to be strengthened through providing financial and technical backstopping.

b. Water Distribution-System

A number of the countries of the region have established a scientific water-distribution system to meet requirements of water for crops. The drought over the last 3-4 years has given very good learning experiences on judicious water-use system. The Agricultural and Irrigation Departments were able to develop schedules for water-distribution system, depending upon crop-needs. This has helped to mitigate the ill affects of water-supplies, without much effect on productivity of crops. One classical example is the wheat crop of 21 million tons in Pakistan during 1999-2000 and 19 million tons in 2000-01, despite a water shortage of 40% during the early period of wheat crop and 60-70% during

earring and grain formation stages. At the beginning of the wheat-crop season, Pakistan Irrigation Department, in consultation with Agricultural Departments, was able to rotate the water-supply in canals. In spring 2001, when shortages further worsened, the canal-supply was restricted to areas that had subsurface brackish water, so that farming/ rural communities may get drinking water. The strategy has helped Pakistan. Despite a very bad year, Pakistan has sufficient stocks of wheat for domestic consumption. It has already exported 0.7 million tons of wheat and has in pipeline, a supply of additional one million tons of wheat for export. This is a lesson repeated in some other countries of the region also that a judicious management of water-resources can help to avert disasters in agricultural sector, particularly crops.

c. Water Conservation

The Governments should aim at conserving the soil and water-resources to maximize the efficiency of use.

Water Delivery-System

The studies carried out by various institutions in Pakistan show that the water-losses in delivery from canal to watercourse outlets are about 40 % on an average. An equal amount of water is lost in the century-old watercourses. There is a need to minimize these losses in water-delivery through:

- Desilting of canals and minors.
- Renovation of water-courses, through brick lining and earthing improvement.

Pakistan and other countries of the region that are conscious of this situation have already launched on-farm water management programs, in the context of their farming situations. The countries of the region need to take up crash water-management programmes, so as to quickly renovate water-delivery system, to improve efficiency of delivery.

On Farm Programs

A large number of fields are so uneven that the result is unequal distribution of water applied, patchy germination and poor crop-stands. There is a need for improving water-use efficiency at the farm, to maximize productivity of crops. The following programmes are being followed in Pakistan and some other countries of the region, to optimize water at the farm:

- Precision leveling of land, in uneven fields.
- Sowing of crops on ridges and beds.
- Use of pressurized-irrigation systems for orchards, vegetables, floriculture and other high-valued crops.

Some countries of the region have used subsidies to promote use of drip and trickle-irrigation systems. This generally leads to more efficient utilization of the scarce farm-resources.

Cropping Patterns

South Asia mainly grows crops with high water-requirements such as rice and sugarcane. Out of a total cultivated area of 204.8 million ha area under crops in South Asia, 60.04 million ha are under rice crop alone. This far exceeds the area under any other crop. Some countries have almost one irrigated crop, rice. Another high water-requiring crop is sugarcane that covers 5.42 million ha in the region.

As drought is a frequent visitor to this region, it is advisable that regional agricultural institutions may focus on promoting cropping-patterns that minimize water-use for agricultural purpose. In Pakistan, the crop-substitution program includes persuading farmers not to grow rice in cotton zone. Similarly, the sowing of sugarbeet is being promoted to replace high water-requiring sugarcane.

Scientists in Pakistan are now focussing on reducing the sowing time of cotton from 150 days to 120 days. The curtailment in growing period will help to save one irrigation. The scientists also need to focus on other crops and should try to replace long period cultivars with short duration cultivars.

Water Pollution

Most of the rivers and creeks in their upper reaches have good-quality water. As water flows downstream, the industrial and urban effluents load this water with heavy metals, injurious chemicals and biological pollutants. The quality of ground-water is also deteriorating rapidly. Cases of ill effects of such industrial effluents have been reported in Pakistan and other countries of the region. In Sri Lanka, the pollution with iron and nitrates has been reported. The salinization of

subsurface water, through intrusion of seawater, has been reported in some countries of the region in coastal areas. This is an area, that needs the attention of the Governments in the region, in the context of appropriate legislation and implementation of sound environmental policies.

Participation of the Farming Communities

Over the last two decades, in the countries of the region, there is a growing involvement of the farming communities in water-resource development, distribution and on-farm-water management programs. Water users' associations have been organized and are actively involved in the planning and development programs of the water-sector in agriculture. These farmer organizations can be further involved in transformation of agricultural rural scenarios.

Pricing of Water

The studies carried out in countries of the region indicate that large O & M costs are being incurred on irrigation-networks by maintaining them in public sector. At least part of this expenditure can be minimized through participation of farmers in maintenance of these canals. The studies carried out by IWMI in Pakistan and other countries of the region indicate a successful experiment. It has been demonstrated that farmers can maintain canals and water-distribution systems, quite efficiently. This can be followed up further. The rebate on electric tariff and installation of tube-wells generally leads to their inefficient use. All such concessions and subsidies need to be withdrawn, for conservation of water-resources and their efficient utilization.

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