7

Climate Change and its Effect on Water Availability and Mitigation Strategies

V.K. Choudhary, Manish Kanwat, P. Suresh Kumar and R. Bhagawati

Introduction

"Food insecurity is an enormous challenge at a global scale, with strong implications both for environmental management and for socio-economic development" (Rockstrom, 2003). This is exaggerated by persistent drought and uneven distribution of rainfall resulting in low crop yield. As the results, millions of lives are threatened with starvation caused by food shortages particularly in the arid and semi arid regions where majority of population still rely on rain-fed agriculture to secure food security (Ntsheme, 2005).

The majority of the affected population threatened with starvation resides in the rural areas with little or no income at all. It is projected that large number of population will be without food in coming years. This is exacerbated by slow economic growth and poor performance in the agricultural sector. It is likely that the increment of the food gap will occur in the near future intensifying the shortage of food in the region (Kundlande *et al*, 2004).

In this context climate change is playing crucial role in food and nutritional security with less availability of water. Climate change is arguably the most severe long term threat to development facing present and future generations across the globe. The past 50 years have witnessed unprecedented changes in the eco-system. Eco-system changes on global and regional scales have already affected natural resource base in diverse conditions and environments. It adversely affects not only the living conditions of people who depend upon these eco-systems for their livelihood but also influences the whole socioeconomic system at the macro level.

The natural resource base, including land and water, that support and sustain the livelihoods of masses is degrading at accelerated rates. Melting Himalayan glaciers pose a direct threat to the water and food security of 1.6 billion people in South Asia region as per recent estimates of Asian Development Bank (ADB). The situation is likely to worsen in the water scarce regions in terms of severe drought and floods. Such conditions are likely to disrupt the balance in the pattern of water supply and demand for water across agriculture, domestic and industry sectors. This will lead to reduction in the choice of crops and cropping system, posing threats to food security and increasing frequency of water induced disasters (Anon, 2009).

Assessment of climate change in South Asian countries

The climate change can be easily visualized by analyzing table 1, that how temperature and precipitation are changing and even shifting of the vents over the period of time. Though the average annual rainfall is almost with no change, but the numbers of rainy days shows drastic changes. The numbers of rainy days are getting few in numbers which is clear indication that in few day high volume of water are poured. This is main cause for flood and even for prolonged dry spell.

Table 1. Summary of key observed Past and Present Climate Trends and Variability (IPCC, 2007)

Country	Change in Temperature	Change in Precipitation
India	0.68°C increase per century, increasing annual mean temperature	Increased extreme rains in north-west in recent decades, lower number of rainy days along east coast
Nepal	0.09°C rise per year in Himalaya, and 0.04°C in Terai region, more in winter	No distinct long term trends in precipitation records for 1948-1994
Pakistan	0.6°C-1.0°C rise in mean temperature in coastal areas	10-14% decrease in coastal belt and hyper arid plains, increase during summer and winter over last 40 years in Northern Pakistan
Bangladesh	Increasing trend of about 1.0°C in May and 0.5°C in November during 1985-98	Decadal rain anomalies above long term averages since 1960s
Sri Lanka	0.016°C increase per year between 1961-90 over entire country, 2°C increase per year in central highlands	Increasing trend in February and decreasing trend in June

contd...

Impact of climate change in South Asian countries

The impact of climate change can be visualized from the table 2 with the data presented of the socioeconomic damages caused due to flood events in South Asian countries. Due to climate change flood situation are more common and are causing heavy losses in terms of deaths, injuries, loss of house etc.

Table 2. Socio-Economic Damages caused due to Flood Events in South Asian Countries (1960-2008)

Damages	Bangladesh	India	Nepal	Pakistan	Sri Lanka
Deaths	52033	55656	5637	8877	1050
Affected	304628928	763986965	2977703	37687043	7957127
Homeless	4219724	13210000	84925	4234415	2746601
Injured	102390	1561	1072	1981	1002
Total Affected	308951042	777198526	3063700	41923439	10704730
Estimated Cost (US$ '000)	12038400	29417188	977213	2865178	374364

Flood Disaster in South Asia (Anon, 2009)

Climate change scenario

In parts of India, temperature increases and decreases in precipitation, along with increasing water use, have caused water shortages that have led to drying up of lakes and rivers. Similarly, water shortages have been attributed to issues such as rapid urbanization and industrialization, population growth and inefficient water use, which are all aggravated by changing climate and its adverse impacts on demand, supply and water quality.

Water availability in India

The gross per capita water availability in India is projected to decline from about 1,820 m^3/yr in 2001 to as little as 1,140 m^3/yr in 2050, as a result of population growth. Another study indicates that India will reach a state of water stress before 2025, when the availability is projected to fall below 1,000 m^3 per capita. These changes are due to climatic and demographic factors. The relative contribution of these factors is not known. The projected decrease in winter precipitation over the Indian subcontinent would imply less storage and greater water stress during the lean monsoon period. Intense rain occurring over fewer days, which implies increased frequency of floods during the monsoon, may also result in reduced groundwater recharge potential. Expansion of areas under severe water stress will be one of the most pressing environmental problems in India in the foreseeable future, as the number of people living under severe water stress is *likely* to increase substantially in absolute terms.

Potential impact of climate change

Impacts of climate change on agriculture which are: (a) Increase in CO_2 to 550 ppm, this will increase yields of rice, wheat, legumes and oilseeds by 10- 20%; (b) A 1°C increase in temperature may reduce yields of wheat, soybean, mustard, groundnut, and potato by 3-7%; (c) Productivity of most crops to decrease marginally by 2020 and 10- 40% by 2100. Increased droughts, floods and heat waves will increase production variability; (d) Length of growing period in rainfed areas is likely to reduce, especially in peninsular regions and southern India; (e) the availability of water will be come down; (f) the soil fertility of hilly region will decrease due to decrease in potential organic carbon; (g) considerable effect on microbes, pathogens, and insects; (h) Possibly some improvement in yields of chickpea, rabi maize, sorghum and millets; and (i) Less loss in potato, mustard and vegetables in north-western India due to reduced frost damage.

Adoption strategies

Some of the potential strategies are started to follow to cope up with the sudden change, and by using traditional wisdom, location specific technology, participatory research and development, capacity building, proper governance, sharing of information at various levels the impact of climate change may be normalize.

Table 3. Guiding principles for adaptation to climate change

1. Sustainable Development	Adaptation must be addressed in a broader development context, recognizing climate change as an added challenge to reducing poverty, hunger, diseases and environmental degradation
2. Resilience	Building resilience to ongoing and future climate change calls for adaptation to start now by addressing existing problems in land and water management
3. Governance	Strengthening institutions for land and water management is crucial for effective adaptation and should build on the principles of participation of civil society, gender equality, subsidiarity and decentralization
4. Information	Information and knowledge for local adaptation must be improved, and must be considered a public good to be shared at all levels
5. Economics and Financing	The cost of inaction, and the economic and social benefits of adaptation actions, calls for increased and innovative investment and financing

Relationship between water supply and crop yield

Agriculture is important to our economy, culture, and environment but is subject to mounting pressure from uncontrolled urbanization, global market pressures, and threats to the reliability and availability of fresh water. Actions are needed to both ensure a sustainable agricultural sector and to reduce the amount of water required for it.

Water conservation and efficiency improvements can reduce water use and improve water quality while maintaining or increasing crop yield. Yet these improvements often entail significant investment which can be a barrier to implementation. Smart policies can reduce this barrier.

Crop water requirements vary throughout the crop life cycle and depend on weather and soil conditions. Irrigation scheduling provides a means to evaluate and apply an amount of water sufficient to meet crop requirements at the right time. While proper scheduling can either increase or decrease water use, it will likely increase yield and/or quality, resulting in an improvement in water-use efficiency. It is likely that further incremental of water supply above the required water supply units to achieve maximum crop yield might cause decline in crop yield and eventual decrease in water productivity this can be clearly visualized from figure 1 & 2 (Zhang, 2003).

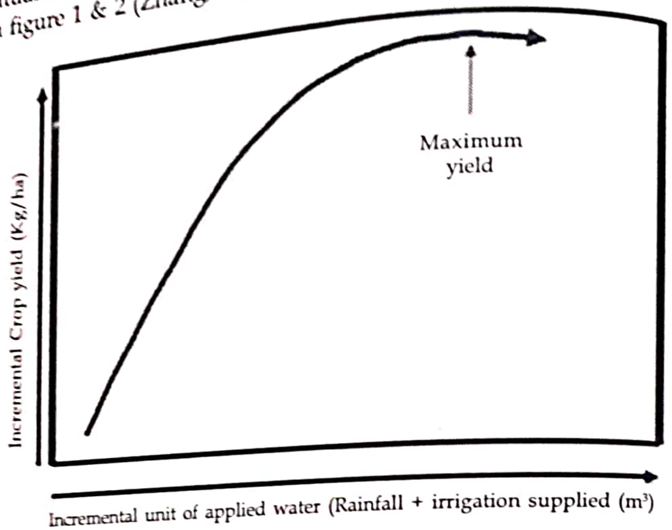

Figure 1. Crop yield and applied water relationship

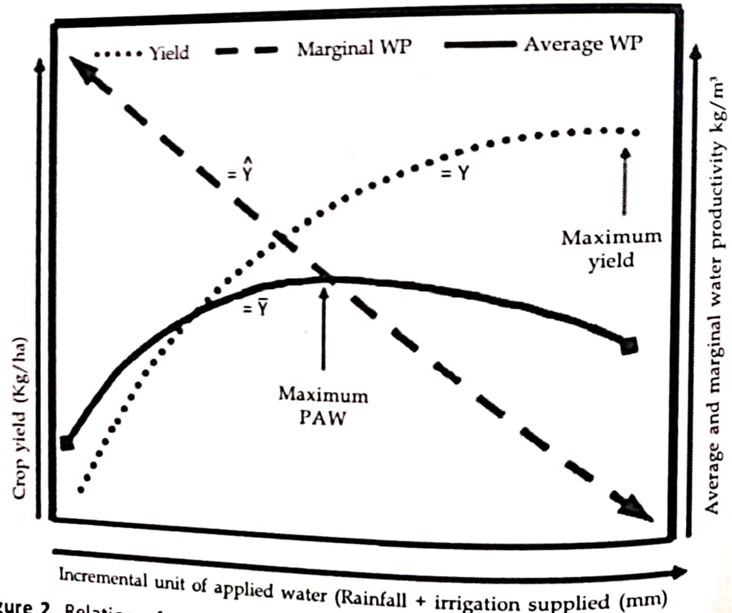

Figure 2. Relation of crop production, productivity of applied water (PAW) and marginal productivity to the crop water supply

Rain water harvesting systems to increase water productivity

The challenge is to solve the problem of food insecurity by exploring the impact of rain water management on improving food security. On average, less than 30% of rainfall in rain-fed agriculture contributes to crop growth, while at least 70% is lost to the crop as evaporation, interception, drainage and surface runoff". While large proportion of rainfall is lost to run-off, evaporation, and drainage, the inter-seasonal prolonged dry spell causes crop failures. The rainwater management can provide the potential to increase crop yield (Figure 3). Rainwater harvesting can help to improve soil moisture especially during the period of the increased dry spell in the growing season (Rockstrom, 2003).

Micro-catchment systems (Within field/internal catchments systems)

Rain water harvesting systems

In-situ water conservation (Tillage and cultural practices)

Runoff-based systems (Catchments and/or storage)

Direct application systems (Runoff diversion into cropland where soil profile provided moisture storage)

Storage systems (Distinct storage structures for supplemental irrigation and other uses)

Small catchment systems (Runoff generated from small external catchments and diverted to cropland)

Macro-catchment systems (flood diversion and spreading i.e.spate irrigation)

Adaptation and mitigation strategies

Adaptation and mitigation of climate change impacts through community mobilization and capacity building of communities on planning and management of water resources through innovative technologies which can save energy and water.

Low cost water saving technologies

Immediate application of appropriate eco-friendly low cost technologies and management practices for saving water at national, regional and community and household level is an imperative need. Various such technologies have been designed to cope-up with the water crises. For example;

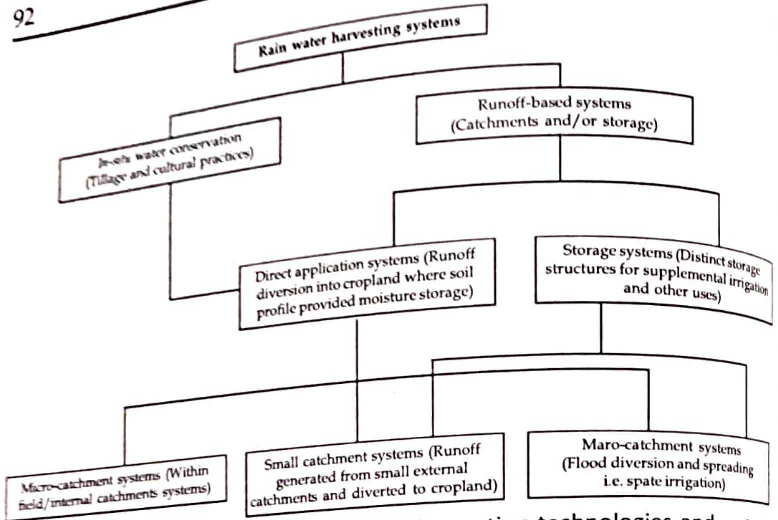

Figure 3. Adopted classification of rainwater harvesting technologies and systems (Ngigi, 2003).

A. *Land shaping technology* is an improved agro technology (Figure 4). The benefits of this technology are; (a) three dimensional (land, water, air) crops; (b) Option for integration of agriculture; (c) Aquaculture with duck rearing; (d) Introduction of double and triple crops; (e) Additional crop in pond & land embankment; (f) Harvested water utilized in 2nd and 3rd crops; (g) Conservation of ground water; and (h) Energy saving module.

B. In Gangetic plains of Eastern India, *moisture conservation technology* has been used to enhance and sustain farm production. The other technology is Micro Level Water Resource Development through *Tank-cum-Well Technology* designed by Water Technology Centre, Bhubaneshwar. The technology involves a system of tanks and dug wells in sequence. While tanks store run-off water which is recycled for irrigation, the open dug wells harvest water seeped in from tanks.

C. In Arunachal Pradesh, bunds which used to demarcate plots are raised and broadened and used for finger millet and vegetable cultivation. Similarly, in compartment bunds plot may be used for rice cum fish culture by following the traditional wisdom of *Apatani* plateau.

D. Community level check dams/water distributaries/ Nallas needs to be constructed to store flowing water during rainy season. The

stored and harvested water may be used for, irrigation, domestic, small scale industries, navigation etc. with proper allocations.

E. Need to follow efficient and water saving irrigation techniques as per the topography, soil types and crops allocated. By this water utilization efficiency can be improved and saved water may be used for other important work.

F. Drip irrigation is one of the important tools to cope up from water scarcity during climate change. This technology has potential difference from conventional use of water for irrigation on various crops. For example; the percentage yield of Banana crop using conventional method would be 57.5 t/ha, while by using drip irrigation, it will be 87.5 t/ha resulting an increase of 52% yield and water saving to the tune of 45%. Adoption of drip irrigation will solve the problems of energy security, water security, food security and rural to urban migration in global change and population resource imbalance scenario. But drip irrigation has also some limitation that this can only be used for wide spacing row crops. The details can be visualized from Table 4.

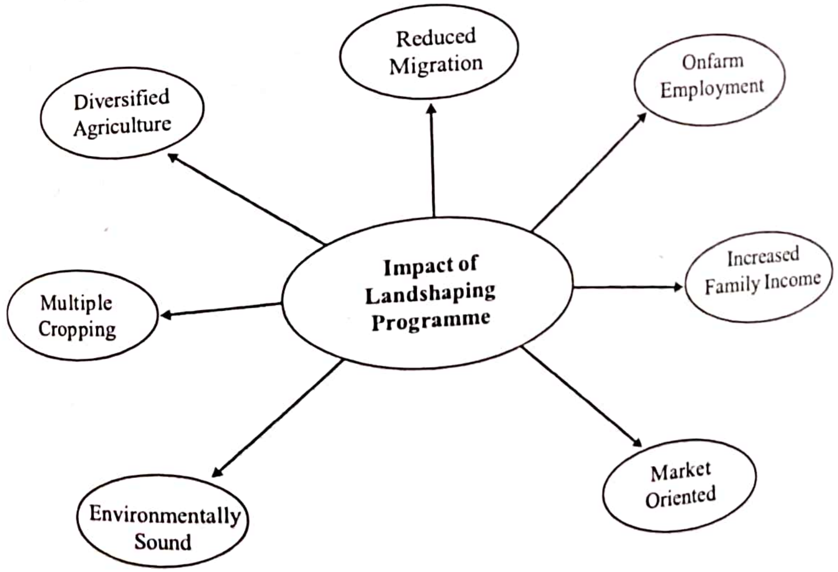

Figure 4. Impact of land-shaping programme

Table 4. Benefits of Drip Irrigation over Conventional Use of Water for Irrigation

Crop	Conventional (Yield [t/ha])	Drip (Yield [t/ha])	% yield increase	Water savings (%)	Increase in water use efficiency (%)
Banana	57.5	87.5	52	45	176
Grapes	26.4	32.5	23	48	136
Sweet Lime	100	150.0	50	61	289
Pomegranate	56.0	109.0	98	45	167
Tomato	32.0	48.0	50	31	119
Watermelon	24.0	45.0	88	36	196
Chillies	4.2	6.1	44	63	291
Sugarcane	128.0	170.0	33	56	204

It is well aware that already 80.0 per cent of basins with 60.0 per cent of the farm area are facing physical water scarcity. Projecting the food demand in 2050 at 400 million tonnes requires an additional irrigation of 60 mha, and this would create livelihood opportunities but will also demands huge investment initiatives. In the present context, the approach for climate change adaptation should be through promotion of National and local institutions, integrating integrated water resource management (IWRM), focusing on supply management-infrastructure, demands management-institutions, etc. However, the present institutions, management system, and infrastructure are inadequate to deal with the exigencies of climatic change. Thus, in addressing potential water shortages, as much attention should be given to managing demands as to increasing supply, by introducing more efficient technologies as well as simply promoting a culture of conservation (Anon, 2009).

To increase the water use efficiency by proper water management following things need to be followed, those are:

(i) Comprehensive water data base in public domain and assessment of the impact of climate change on water resource; (ii) Promotion of citizen and state actions for water conservation, augmentation and preservation; (iii) Focused attention on over-exploited areas; (iv) Increasing water use efficiency by 20%; and (v) Promotion of basin level integrated water resources management.

Efficient water use efficiency

Water savings achieved through conservation and efficiency improvements are just as effective as new, centralized water storage and

are often far less expensive. Many proven technologies and practices can improve water-use efficiency. Strengthen and expand efforts to promote the use of these technologies and practices.

- Revise and expand "Efficient Water Management Practices" for agricultural water agencies.
- Make agricultural "Efficient Water Management Practices" mandatory and enforceable by the State Water Resources Control Board.
- Develop institutional mechanisms to increase the reliability of agricultural water deliveries to users meeting high standards of water-use efficiency.

Expand water-efficiency information, evaluation programs, and on-site technical assistance provided through Agricultural Extension Services and other agricultural outreach efforts. Four scenarios for improving the water-use efficiency of the agricultural sector are evaluated:

Modest Crop Shifting – shifting a small percentage of lower-value, water-intensive crops to higher-value, water-efficient crops

Smart Irrigation Scheduling – using irrigation scheduling information that helps farmers more precisely irrigate to meet crop water needs and boost production

Advanced Irrigation Management – applying advanced management methods that save water, such as regulated deficit irrigation

Efficient Irrigation Technology – shifting a fraction of the crops irrigated using flood irrigation to sprinkler and drip systems

Water conservation and efficiency scenario

Today, the challenge is to envision an agricultural sector that continues to supply food to the state and nation, to support rural livelihoods, and remains consistent with the goal of long-term sustainable water use for the state as a whole. There are many different ways for irrigators to use water productively. Farmers have long shown themselves to be flexible, dynamic, and innovative in response to water constraints. But rapid and unplanned changes in water availability can result in labor dislocations, debt, and production losses.

Water is only one of many constraints and incentives farmers must balance; constraints that may indirectly affect water use include fluctuating market conditions; agricultural policies; local soils and climates; and previous investment in irrigation technologies, farm equipment, and processing machinery. In general, farmers make economically rational decisions to maximize profits. Farmers also make choices independent of profit maximization: experience, family traditions, and community values all factor into their decisions.

There is an urgent need to give the full support in decision making at water user groups to set the decision about crop type, irrigation method, and management practices. Regular monitoring is required to correct the problems coming across and also facilitate them to improve their capability by capacity building programme. Support the water user to keep coordination between different catchment management group and efficient implementation of policies.

Sprinkler Irrigation Systems

Sprinkler irrigation, introduced in the 1930s, delivers water to the field through a pressurized pipe system and distributes water via rotating sprinkler heads, spray nozzles, or a single gun-type sprinkler. The sprinklers can be either permanently mounted (solid set) or mounted on a moving platform that is connected to a water source (traveling). Although they have the poorest overall water-use efficiency among the sprinklers, traveling sprinklers are well-suited to irregularly sized or shaped fields and can be easily moved between fields (Evans *et al.*, 1998). Low-energy precision application (LEPA) and low elevation spray application (LESA) sprinklers are an adaptation of center pivot systems that use drop tubes that extend down from the pipeline to apply water on the ground or a few inches above the ground. LEPA and LESA systems can conserve both water and energy by applying the water at a low-pressure close to the ground, which reduces water loss from evaporation and wind, increases application uniformity, and decreases energy requirements.

Sprinklers provide a number of important advantages. If managed properly, they can improve water-use efficiency. Sprinklers often result in less ineffective runoff than a surface system, thereby reducing erosion, pollution of downstream water sources, and the economic cost of dealing with drainage. In addition, sprinklers tend to require less labor, thereby reducing labor costs and vulnerability to labor shortages (Burt *et al.* 2003).

Drip/Micro-irrigation Systems

Drip irrigation refers to the slow application of low pressure water from plastic tubing placed near the plant's root zone. Drip systems

commonly consist of buried PVC pipe mains and sub-mains attached to surface polyeth lateral lines a less expensive, but also less durable, option is drip tape. Water is applied through drip emitters placed above- or below-ground, referred to as surface and subsurface drip, respectively. Micro-irrigation systems are similar to drip systems with the exception that water is applied at a higher rate (5 to 50 gallons per hour) by a small plastic sprinkler attached to a stake (Evans *et al.* 1998).

Drip irrigation has been in use since ancient times when buried pots were filled with water that slowly seeped into the soil. Modern drip was facilitated by the advent of plastics during World War II and was first introduced in Israel. Although traditionally applied to specialty crops such as vegetables and grapes, drip irrigation systems are increasingly applied to row crops, and there are examples of use on field crops such as cotton, corn, alfalfa, and potatoes Drip irrigation allows for the precise application of water and fertilizer to meet crop needs and can increase crop yield and/or quality.

In recent past growers that with drip irrigation, "We consistently use less water, less fertilizer, and find tillage and ground preparation less costly. In addition, yields are higher and the quality of the product we grow is better. Drip irrigation pays, it doesn't cost!" (AWMC 2006a). Furthermore, "the potential for improved water and chemical management can benefit water quality, reduce potential runoff, and reduce potential leaching of nutrients and chemicals" (Evans *et al.*, 1998). Drip systems can be automated, thereby reducing labour costs. With drip systems, diseases are less likely to develop because water does not come into contact with crop leaves, stems, or fruit (Shock, 2006). Drip systems can be used on oddly shaped or hilly terrain.

Comparison of irrigation technologies

In the present context it is very much required that as per the crop, we can use the various type of irrigation methods, to save water. The methods may vary with crop to crop but we need to use or recommend such methods which can be easily used with higher efficiency. Here some of the important methods along with their efficiencies are presented in table 5 so that growers and extension functionaries can promote the different methods and water can be saved for other uses.

Table 5. Irrigation System Efficiency

Type of Irrigation System	Efficiency
Flood	
Basin	85%
Border	77.5%
Furrow	67.5%
Wild Flooding	60%
Gravity	75%
Average	**73%**
Sprinkler	
Hand Move or Portable	70%
Center Pivot and Linear Move	82.5%
Solid Set or Permanent	75%
Side Roll Sprinkler	70%
LEPA (Low Energy Precision Application)	90%
Average	**78%**
Drip/Micro irrigation	
Surface Drip	87.5%
Buried Drip	90%
Sub irrigation	90%
Micro Sprinkler	87.5%
Average	**89%**

Source: Salas *et al.*, 2006

Adoption

Adaptive capacity and adaptation related to water resources ... considered very important. Historically, migration in the face of droug... and floods has been identified as one of the adaptation options. Migratio... has also been found to present a source of income for those migrants who are employed as seasonal labour. Other practices that contribute to adaptation include traditional and modern water-harvesting techniques, water conservation and storage, and planting of drought-resistant and early-maturing crops. The importance of building on tradition... ...water harvesting and use has been highlighted...

one of the most important adaptation requirements, indicating the need for its incorporation into climate change policies to ensure the development of effective adaptation strategies that are cost-effective, participatory and sustainable.

Generally, the frequency of occurrence of more intense rainfall events in many parts of country has increased, causing severe floods, landslides, and debris and mud flows, while the numbers of rainy days and total annual amount of precipitation have decreased. However, there are reports that the frequency of extreme rainfall in some areas has exhibited a decreasing tendency.

However, with climate change, an array of serious threats is apparent.

- Sea-level rise could impact on the river basin and on people living in the delta and other coastal areas.
- Temperature rises will be *likely* to reduce the productivity of major crops and increase their water requirements, thereby directly decreasing crop water-use efficiency.
- There will probably be a general increase in irrigation demand.
- There will also be a high degree of uncertainty about the flow of the various rivers.
- North East of India will be *likely* to experience an increase in water stress, with a projected decline in precipitation by 2050. This will increase water stress in all sectors.

In some parts of India, the conversion of cropland to forest (grassland), restoration and re-establishment of vegetation, improvement of the tree and herb varieties, and selection and cultivation of new drought-resistant varieties could be effective measures to prevent water scarcity due to climate change. Water saving schemes for irrigation could be used to avert the water scarcity in regions already under water stress. There are urgent needs to recycling and reuse of municipal wastewater and increasing efficiency of water use for irrigation and other purposes will be *likely* to help avert water scarcity.

Various parts of India to minimize the impacts of climate change on water resources, several of which address the existing inefficiency in the use of water:

- Modernization of existing irrigation schemes and demand management aimed at optimizing physical and economic efficiency in the use of water resources and recycled water in water-stressed areas;

- Public investment policies that improve access to available water resources, encourage integrated water management and respect for the environment, and promote better practices for the sensible use of water in agriculture;
- The use of water to meet non-potable water demands. After treatment, recycled water can also be used to create or enhance wetlands and riparian habitats.

Impact and Vulnerability

- The imbalance of species loss and replacement leads to an initial loss in diversity.
- Species most affected by warming are restricted to the uppermost parts of mountains. For other species, the effect will mainly be upward migration.
- Species affected by cooling are those at lower altitudes.
- Changes will directly affect the indigenous biota. An even greater threat is that a warmer climate will increase the ease with which the islands can be invaded by alien species.

Conclusion

There are urgent needs to implement some of the important practices in any area to have higher irrigation water use efficiencies:

(1) adopt a water management plan; (2) designate a water conservation coordinator; (3) support water management services such as mobile irrigation labs, irrigation scheduling, and water quality testing; (4) improve communication and cooperation among water suppliers and users; (5) identify institutional changes that will improve the potential for more flexible water deliveries and storage; and (6) improve pump efficiency to reduce operational costs.

The greatest challenge is to achieve food security in climate change scenario, through increased productive use of water used for agriculture, thereby leaving more water available for other users in the basin. The integrated approach to water management can improve rural livelihoods and simultaneously increase water productivity. The improved land and water management will lead to rainwater use efficiency, leaving more water available in the storage dams that can be used beneficially for crops grown in winter.

References

Agricultural Water Management Council (AWMC) (2006). A Smaller Footprint: Managing Our Resources. Retrieved July 15, 2008 from http://www.agwatercouncil.org/Publications/menuid-86.html.

Annonymous (2009). Report of the Round Table Conference On Water, Livelihood and Adaptation to Climate Change in South Asia November 05-06, 2009 (ed: Dr Veena Khanduri) conference organized by India Water Partnership.

Burt, C., D. Howes, and G. Wilson (2003). California Agricultural Water Electrical Energy Requirements: Final Report. Prepared for the California Energy Commission by the Irrigation Technology Research Center, California Polytechnic State University, San Luis Obispo, California.

Evans, R.O., K.A. Harrison, J.E. Hook, C.V. Privette, W.I. Segars, W.B. Smith, D.L. Thomas, and A.W. Tyson (1998). Irrigation Conservation Practices Appropriate for the Southeastern United States. Georgia Department of Natural Resources Environmental Protection Division and Georgia Geological Survey. Project Report 32. Atlanta, Georgia.

Kundhlande, G., Groenewald, D.C., Baiphethi M.N., Viljoen, M.N., Botha J.J., van Rensburg, L.D., and Anderson, J.J. (2004). Socio-Economic Study on Water Conservation Techniques in Semi-Arid Areas, Water Research Commission Report, WRC Report No. 1267/1/04.

Ngigi, S.N. (2003). What is the Limit of Up-scaling Rainwater Harvesting in a River Basin? Physics and Chemistry of the Earth 28: 943–956.

Ntsheme, O.P. (2005). A Survey of The Current On-farm Agricultural Land And Water Management Practices In The Olifants Catchment-A Diagnostic Of Quaternary Catchment B72A, Unpublished MSc (WREM) report: University of Zimbabwe.

Rockstrom, J. (2003). Resilience Bulding and Water Demand Management for Drought Mitigation, Physics and Chemistry of the Earth, Volume 28, Pages 869-877

Salas, W., P. Green, S. Frolking, C. Li, and S. Boles (2006). Estimating Irrigation Water Use for California Agriculture: 1950s to Present. California Energy Commission, PIER Energy-Related Environmental Research. Sacramento, California.

Shock, C. (2006). Drip Irrigation: An Introduction. Oregon State University Extension Service. Retrieved July 31, 2008 fromhttp://extension.oregonstate.edu/umatilla/mf/sites/default/files/Drip_Irrigation_EM8782.pdf.

Zhang, H. (2003). Improving Water Productivity through Deficit Irrigation: Examples from Syria, the North China Plain and Oregon, USA, CSIRO Plant Industry, Wembley, Australia.

□□□