Integrated River Management in India – Challenges in Changing Environments

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Abstract
Global environmental changes and demands for multiple use of increasing population make river management a difficult task, especially in developing countries like India with exploding population, weak economy and several social issues such as disputes over transboundary rivers, resettlement and rehabilitation issues during project implementation, corruption and vested political and regional interests. With the increase in population, reliable water is becoming a scarce resource. The principal source of water for India is the southwest monsoon that undergoes wide spatial and interannual variations associated with global climate anomalies. Any further extremes in rainfall and changes in the frequency and intensity of severe weather systems due to a changing climate will have serious impact on water resources and agriculture, and it will be reflected in all facets of life. There are number of factors that affect the water quantity and quality in India including industrialisation, agricultural development, changing land use patterns, overuse of surface and groundwater, and after all the careless use and inefficient institutional mechanism for the management and conservation. Rapid urbanization and urban migration not only pollute the water tremendously, but also makes the water resource allocation very complex. Only 35% of the farm area is irrigated, when majority of the water runs off into the Seas unutilised. A comprehensive assessment of the water resources in the major river basins of India and the relelvance of the exisitng water policy in a changing environment is attempted in this paper. Results show a rapid decrease in the availability of reliable water in all parts of India in near future, highlighting the importance of the efficiet management of rivers in maintaining food security and national economy and also the life security of millions of poor that depends on agriculture.

Introduction

India has a total area of 3,287,263Km^2, divided into 29 states and 7 union territories. The country has a wide range of geography and climate. The Thar Desert cover the Western part of India, whereas in the eastern part, in the same latitudes lies the world's heaviest rainfall region. The climatic condition and geography influences to a great extent the water resources and its utilization.

Physiographically, India may be divided into seven well-defined regions.

1. The Northern Mountains, comprising the mighty Himalayan ranges;
2. The Great Plains, traversed by the Indus and Ganga Brahmaputra river systems. As much as one third of this lies in the arid zone of western Rajasthan. The remaining area is mostly fertile plains.
3. The Central Highlands, consisting of a wide belt of hills running east west starting from Aravalli ranges in the west and terminating in a steep escarpment in the east. The area lies between the Great Plains and the Deccan Plateau.
4. The Peninsular Plateaus comprising the Western Ghats, Eastern Ghats, North Deccan Plateau, South Deccan Plateau and Eastern Plateau.
5. The East Coast, a belt of land of about 100-130 km wide, bordering the Bay of Bengal land lying to the east of the Eastern Ghats.
6. The West Coast, a narrow belt of land of about 10-25 km wide, bordering the Arabian Sea and lying to the west of the Western Ghats, and.
7. The islands, comprising the coral islands of Lakshadeep in Arabian Sea and Andaman and Nicobar Islands of the Bay of Bengal.

Despite extensive efforts to conserve and manage water resources, water demands continue to rise, and availability continue to fall. In countries like India where the population is still rapidly growing, impending water crisis will be the major environmental problem in the coming years.

Table 1. Land and Water Resources of India

Particulars	**Quantity**
Geographical Area	$329*10^4 km^2$
Flood Prone Area	$40*10^4 km^2$
Ultimate Irrigation Potential	$140*10^4 km^2$
Total Cultivable Land Area	$184*10^4 km^2$
Net Irrigated Area	$50*10^4 km^2$
Natural Runoff (Surface Water and Ground Water)	$1869 km^2$
Estimated Utilisable Surface Water Potential	$690 km^2$
Groundwater Resource	$432 km^2$
Available Groundwater resource for Irrigation	$361 km^2$
Net Utilisable Groundwater resource for irrigation	$325 km^2$

India is rich in water resources, being blessed with a network of great rivers and vast alluvial basins to hold groundwater. Though the rainfall over India is slightly above global average, its uneven distribution leads to occasional floods and droughts, in different parts of the country. This disparity in rainfall is reflected in water resources and this is a permanent issue in water management in India. Under the pressure of rapid population growth, the available resources of water are being developed and depleted at a rate faster that replenishment. Integrated plans for protection, management and efficient utilization of rivers become important in this context.

Economy of India and life of majority of the population are closely related to agriculture, the largest consumer of water. Agriculture consumes nearly 70% of all available freshwater. Agriculture and related activities contributed nearly 27% of the total Gross Domestic Product (GDP) of India in the year 1999-2000 (TERI, 2002). Agricultural products account for 12% of total annual exports of the country (Ministry of Finance, 2005). However, 62% of the cropped area is still dependent on rainfall (MoEF, 2002) and Indian agriculture continues to be fundamentally dependent on the weather. Here lies the importance of the protection and management of rivers to envisage future challenges. According to Lonergan (1998), India's climate could become warmer by 2.33° to 4.78° under conditions of increased atmospheric carbon dioxide. The fast increasing number of vehicles and factories may create this condition soon. Rainfall frequency is also likely to change (IPCC, 1998). Any altered climate could have far reaching consequence on the water resources of India.

Exploding population, measures to maintain food security, urbanization and industrialization pose serious threat to the availability of reliable water. Population increase is expected to stabilise at 1.5 Billion, nearly 50% more the present level only by 2050. India is going to face a very serious water scarcity in two or three decades, unless new resources are identified and effective conservation and management measures are not resorted to in its major river basins (Fig.1). Two-third of India's available freshwater is lost due to evaporation and runoff into the Sea, while there exists a freshwater crisis in many parts at different times of a year (UN Newsletter, 1999). Measures of surface water conservation and exploitation are still inadequate. Overexploitation of groundwater leads to lowering of water table in many parts of India, especially in the coastal regions, putting even surface water resources into danger. Overdraft of groundwater today exceeds natural replenishment by at least 160 billion cubic metres a year. Heavy pumping for irrigation purposes has caused a drop in groundwater levels of 25 to 30m in a decade in the State of Tamil Nadu. According the report of 'The Guardian' (2006), "in much of India, the rivers have long-since dried up, and the only water is underground. In the last decade,

more than 20 million farmers have bought drills and cheap Yamaha pumps to bring water to the surface and irrigate their crops. As a result, water tables that were until recently only a few metres from the surface are now hundreds of metres down"

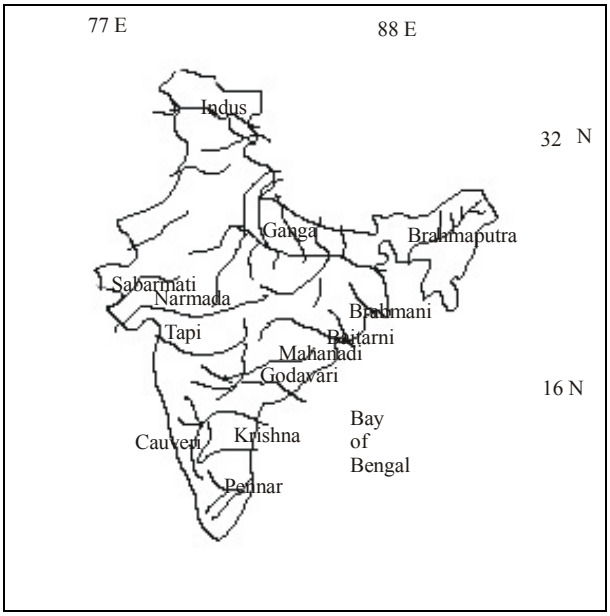

Figure.1. India - Major river systems

Water resources of India

Renewable water resources of India are about 4% of the global availability (IWRS, 1998). Government estimates in early 90's indicated that the per capita availability of freshwater in the country (if all water from rainfall made available) was only 2200m^3 per year.

Table 2: Major river basins

Basin	Length (km)/ Drainage area (km^2)	Surface water/ utilisable surface water/ present use (Mm^3)	Groundwater - replenishable/ available for exploitation (Mm^3)
Indus	1114/321289	73.3/46/40	40/26.49
Ganga	2525/ 861404	525/250/N.A.	170.99/96.37
Brahmaputra	918/861404	585.6/24/N.A.	26.55/21.8
Narmada	1312/98796	45.6/34.5/8	10.83/7.18
Tapi	724/65145	18/14.5/4.5	8.27/3.97
Brahmani-	799/39033	28.5/18.3/N.A	4.05/3.16
Baitarni	355/12879		
Mahanadi	851/141589	66.9/50/17	16.46/13.02
Godavari	1465/312812	110.5/76.3/41	40.65/24.94
Krishna	1400/258948	78.1/58/50	26.41/14.5
Pennar	597/55213	6.3/6.3/5	4.93/2.66
Cauvery	800/87900	21.4/19/18	12.3/4.67
Sabarmati	371/21674	3.8/1.9/1.8	N.A./N.A.

In few decades from now, the per capita availability may go down the required minimum of 1600m^3. This availability itself is highly varying and in the drier interior and northwest, it is always meagre. Today, around 83% of the population comes under the drinking water supply schemes. Only 35% of the cultivable land is irrigated, while 70% of the runoff wastefully joins the Sea. Water deliveries in India rarely correspond in quantity and timing of the true

requirements (Postel, 89). The annual precipitation in India is estimated to be 4000Bm^3, the southwest monsoon being the major contributor (3000Bm^3). This precipitation contributes to the formation of twelve major river basins and eight other basins formed by the combinations of medium and minor basins (Table 2). The major and medium river basins contribute over 90% of the total runoff in the country. The Indo- Gangetic planes have enormous amount of water, but the current method of utilization is not appropriate (Serageldin, 98). Of the total water potential of 1869Bm^3, only 1122Bm^3 can be put to beneficial use. Out of this, 690Bm^3 is surface water and 432Bm^3 is replenishable groundwater (Ministry of Water Resources, 1998). There will be a considerable gap between the water need and availability in various catchments in two or three decades from now. An in-depth study based of water balance and the expected changes in water resources become necessary to formulate measures to meet the challenges in future.

Rainfall and water availability

In general, monsoons and the local weather systems produce a mean rainfall of around 110cm over India, slightly above global average. Effect of orography results in up to 400cm rainfall in the extreme northeast region and in the southwest coast**.** Isolated regions in the northeast get more than 1000cm and in the west coast, up to 700cm. Rainfall is less than 20cm in the northwestern parts. The southwest monsoon (June - September) is the principal rainy season for the country. During the north-east monsoon period (October - December), the chief areas of rainfall is confined to the southern tip of the peninsula, the east coast and isolated areas in the north-east and the extreme north. The varying nature of rainfall and water resources produces different types of climate, ranging from arid to perhumid. Major part of interior India is semi arid, but rich agricultural lands and here if some more water becomes available by efficient water management it may help a lot in solving possible food crisis in future.

It is the temporal distribution of the rainfall, more than the total amount that affects the water availability of a region. A less seasonal (more distribution through months) rainfall permits more soil moisture retention and increases water availability in dry months. Though the rainfall is heavy in the west coast hill regions, most of it is highly seasonal and confined to two or three months. Water from the heavy rainfall flow fast wastefully into the ocean through the steep hill slopes, before it could be harnessed. Study of the seasonality of rainfall over India using the method suggested by Walsh & Lawler (1981) shows that rainfall is less seasonal in the southern tip of Peninsular India, as this region gets rainfall from both monsoons and local systems. Similarly, it is less in the northern parts also, due to the winter rainfall associated with the passage of Western Disturbances. Effect of the northeast monsoon and depressions and cyclones in winter produce a less seasonal pattern in the east coast. The seasonality of rainfall is always reflected in water resources availability.

Water balances in the major river basins have been computed using the data provided by the India Meteorological Department, based on the methods developed by Thornthwaite (1948) and modified by Thornthwaite & Mather (1955). The per capita availability of the surplus water from precipitation has been computed. Considering the rate of growth of population and the rate of increase in temperature and changes in precipitation pattern, the per capita availability have again been computed for the entire river basins by the year 2025 (Table 3).

The per capita water availability ranges from 13404m^3 in the Brahmaputra to 122m^3 in Brahmani-Baitarni**.** The average value is nearly 1700m^3. But, excluding Brahmaputra it is only 550m^3. Even today, availability on annual basis is less than requirement in many of the catchments, especially in the interior peninsular region. The study reveals that by the year 2025, at the current rate of growth of population and with the predicted increase in global temperature, the availability will be drastically reduced to 650 m^3 for the regions as a whole and to 250 m^3, excluding Brahmaputra. Situation remains still hopeful in the northeast Brahmaputra region. In almost all parts of India, seasonal water deficiencies show an increasing trend and the surpluses show a decreasing trend. According to WMO, rainfall increase may be considerable in

the north-west India, but, it may be very low in the south and north, where the increase in precipitation may not be able to compensate for the reduction in soil moisture due to rise in temperature (Bhalme, 1997). Northeast India has high values of per capita availability. But, the very high growth rate of population in these regions will reduce the availability up to one-fifth of the present level by 2025. Seasonality of rainfall is reflected in the water surpluses. If the rainfall is highly seasonal, there can be a seasonal surplus though the amount is small (needs for evapotranspiration and soil moisture recharge are temporarily met here). Therefore, change in seasonality may lead to more seasonal water crisis. In India, if considered separately, population increase is a more serious issue compared to the effect of global warming on water resources.

Table 3. Water availability in the major river basins

River	Per capita availability, year 2005	Per capita availability, year 2025
Indus	1313	694
Ganaga	1216	513
Brahmaputra	13404	4652
Narmada	1348	534
Tapi	281	114
Brahmani-Baitarni	122	51
Godavari	208	77
Krishna	224	113
Pennar	224	113
Cauvery	275	130
Sabarmati	285	127

Issues in management of rivers

The study points out that there will be a considerable shortage of water in all river basins of India by the year 2025. Government is planning to meet the estimated freshwater requirements from exploitable surface and ground water resources. In fact, any further need will have to be met with new resources to be explored or better management. Study of the World Watch Institute predicts that the Ganges and other rivers vital for farming in heavily populated India will run dry for a part or all of the dry season, 30 years from now (Science update, 97). Increased urbanization in India has stressed water use and water supply infrastructure beyond capacity. Recent statistics indicate that one-third of the urban population and one-twelfth of the total population live in 23 metropolitan cities and most of them are near major rivers. Growth of mega cities highly pollute rivers and add more stress on water. Mega-cities have to cope with intense competition from agriculture and industry to provide their expanding populations, especially the urban poor, with adequate water supply. Mega-cities also have to address the increasing pollution of their freshwater sources from growing volumes of urban waste and the increasing environmental risks from over-abstraction of groundwater resources, inadequate drainage and floods. If the present rate of migration to cities continues, not in far future, water allocation and planning will become complicated with no easy solutions. It is doubtful if the water consumption by the thousands of suburban inhabitants travelling daily to the cities for job is considered in the urban water planning.

Only a portion of the water surplus will be reliably available for human use due to deterioration of water resources, especially during dry months when the demand is more**.** Increased demands in agricultural, industrial and domestic sectors lead to considerable imbalances in the quantity and quality of river water. Climate change and variability are likely to worsen the existing situation by further limiting the water availability. Potential changes in temperature and precipitation pattern may adversely affect soil moisture condition, annual runoff and ground water recharge. Despite extensive efforts to improve the use and management of water resources, water demands continue to rise, contamination degrades water quality, and natural hazards, such as floods and droughts, disrupt human activities and cause extensive human suffering and economic losses. Population growth and urbanization are among the key factors underlying the enormous growth in the demand of water and the increase of environmental degradation.

Changing climate pattern is of serious concern for India. The Intergovernmental Panel for Climate Change predicts an increased recession of Himalayan glaciers and increasing danger from glacial lake outburst floods in an increased temperatures and increased seasonal variability in precipitation. Reduction in average flow of snow-fed rivers and an increase in peak flows and sediment yield would have major impacts on hydropower generation, urban water supply, and agriculture. Though almost all parts of India are vulnerable to floods or droughts, at present it is not severe in many States. But, in an altered global climate, change in such extremes can be catastrophic. Any change in the strength or seasonality of monsoons would lead to soil moisture deficiency or floods in the riverine environments and affect water availability and runoff rates. There can be tremendous increase in the transport of sediment load of the Ganges and Brahamaputra, which already carry an extraordinarily heavy sediment load and have a high, though irregular, rate of downstream deposition. The Ganges-Brahmaputra delta is one of the world's most densely populated areas, and the effects of climate change could cause serious drainage and sedimentation problems, in addition to bank erosion and land loss. These impacts clearly would have immense socio-economic costs.

Extreme water conditions and quality issues add to major problems in water resources management. The magnitude and severity of these problems vary from one basin to another. Increasing demand is characterized by increasing competition for available water. The social, environmental and political issues related to the rivers are worsening. There exists dispute over river water sharing, either national or international, around almost all major rivers. There are international treaties for water sharing of Indus with Pakistan and Brahmaputra with Bangladesh. In India, domestic water disputes are more severe and difficult to resolve compared to international, because of various political and social reasons. Dispute over the Cauvery waters among the southern states is more than a century old and it has become worse and violent recently. Similar dispute exist further north on the Godavari waters also. In the case of Narmada, the issue is about the huge Narmada valley project that needs evacuation of thousands of people and has severe environmental consequences. Water-related environmental problems are becoming transboundary in scope as local pollution problems spread across borders due to the pressure of population growth, increased fertilizer and pesticide use, more industries and inadequate pollution controls. When the availability decreases, existing disputes may worsen or new one may start around any rivers. Even the updated national water policy of India doesn't provide any clear solution for conflict resolution.

Shortage of surface water will increase dependency on groundwater. More water withdrawal for agriculture may lead to increased desertification, land degradation and loss of soil fertility. Substantial reduction in the area under agriculture and extensive damage to structures will not only affect the economy but also will create problems associated with shift in population to reliable river basins. Even now, overextraction of groundwater in some basins has resulted in reduction of summer runoff in rivers and lowering of water level in nearby minor open water bodies. Sand quarrying in rivers and catchments and the increased use of deep borewells in the State of Kerala has resulted in the depletion of groundwater level by more than one metre in ten years. In this State, deforestation and introduction of plantation crops in the watersheds in the Western Ghats hills where the rivers originate lead to large scale soil erosion and sedimentation, making seven once perennial rivers into seasonal in few decades. Another five rivers are in the same path.

Increased population and increasing demand in the agricultural, industrial, and hydropower sectors will put additional stress on water resources. Agriculture is the predominant water user in India and the gap between the need in the sector and availability will be widening, unless viable alternatives are not found. In addition to these, limited water management capacity, fragmented organizational structures, and inadequate water planning, management, and conservation are among the contributing factors to water crisis. Situation seriously underlines the need for taking up integrated plans for water conservation & utilization at basin level to meet

the increasing demands of irrigation, water harvesting, human & livestock consumption, expanding industry, hydro-electric power generation, recreation, navigation & other uses.

Changing government policies create new water issues. With globalisation, there has been a significant migration of manufacturing industries from developed countries to India and this trend is likely to continue. Along with increase in GDP and urbanization, there is a corresponding increase in river water use by the industrial and domestic sectors. Widening economic imbalance as a result of expansion in the IT sector creates a small group of rich people, 10% of them misusing water needed for the survival of 50%. Attempts to make changes in water allocation priorities invite new social issues. Destruction of wetlands, paddy fields and open water sources such as ponds and wells, make people more dependent on public water supply and thus on rivers. New roads and constructions create floods and demote groundwater recharge. Favoring industrialization over agriculture already has shown the impact. News report of the Ministry says unless food production is not increased by 4% in the coming year, there can be a famine after two years (Mathrubhumi, 2006).

Degradation of water resources has made reliable water a scarce resource in water rich regions. Almost all rivers in India are polluted far above limits, industries being the major polluter. Industries not only consume large quantities of water but also pollute it. According to the World Water Development Report 2003, in developing countries, 70 per cent of industrial wastes are dumped without treatment, thereby polluting the usable water supply. Therefore, the issue of industrial water use revolves around two crucial interlinked issues — water use and water pollution. Ganga Basin, the largest river basin of India that supports nearly 40 percent of the country's population is facing severe pollution problem from increased human and industrial activities, affecting human health and biodiversity. Even the famous Ganga Action Plan to control pollution and improve the river water quality (GAP), could tackle only about 35 % of the present pollution load. Human impact on rivers and river basins, and deforestation and land degradation in riverheads reduce runoff considerably, increasing vulnerability to floods and droughts. Rules and regulations often become farce in the peculiar social and political setup in India.

Another major environmental and social issue is gradually spreading with the starting of implementation of is 560 billion project (largest ever done in the world) to interlink rivers. Though the objective is control of floods and droughts by water transfer from one basin to other by interlinking rivers, the environmental consequences have not been considered seriously. Water rich States strongly oppose the implementation.

Corruption, misappropriation money, non-cooperation among different government departments, slow government machinery, and vested regional and political interests always retard major projects for river basin development, water conservation, irrigation and even public water supply.

National Water Policy

For the efficient utilisation of the water resources, though late, India developed a national water policy in 1987, which was updated in 2002. The policy recognises drainage basin as the basic unit of planning for development of water resources and calls for appropriate measures to optimise utilisation of this resource for the benefit of the people living in the basin, and for transfer of surplus water to meet the requirements of areas, which have shortage of water. The principal elements of the policy are: - 1) Governing water resource and its development by the national perspectives, considering water as a precious national asset, 2) Maximum utilisation of the available surface and ground water resources, 3) Planning for water resources on the basis of the hydrological unit such as a drainage basin or sub-basin. Establishment of appropriate organisations for the planned development and management of the river basins as a whole, 4) Transfer of water to areas where there is a shortage 5) Project planning for development of

water resources for multiple benefits based on an integrated and multi-disciplinary approach having regard to human and ecological aspects and special needs of disadvantaged sections of the society, 6) Prioritising water allocation in the order of drinking water, irrigation, hydro-power, industries, navigation and other uses, 7)Periodical reassessment of groundwater potential and its exploitation regulated with reference to recharge possibilities and consideration of social equity, 8) Promotion of the conjunctive use of surface and groundwater right from the project planning stage, 9) Ensuring the maintenance, modernisation and safety of structures through proper organisational arrangements, 10) Close integration of water use and land use policies and equity and social justice in the distribution of water, 11) Improved efficiency of utilisation in all the diverse uses of water and conservation consciousness promoted through education, regulation, incentives and disincentives, 12) Pricing of water to foster the motivation for economy in water use and to cover the annual maintenance and operational charges, 13) Involvement of farmers in the management of irrigation system, 14) Development of master plan for flood control and management for each flood prone basin. Strategy to reduce the intensity of floods by sound watershed management and provision of adequate flood cushion in water storage projects wherever feasible to facilitate better flood management of each flood prone basin, 15) Finding suitable cost-effective measures to minimise land erosion by sea or river and regulation of the indiscriminate occupation and economic activity in coastal areas and flood plain zones, 16) Priority for the needs of drought-prone areas in the planning of water resources development projects, making such areas less vulnerable through soil-moisture conservation measures, water harvesting practices, the minimisation of evaporation losses, the development of ground water potential and water transfer from surplus areas. Encouragement of pastures, forestry or other modes of development which are relatively less water demanding, 17) Establishment of a national information system on water resources with a network of data banks and data bases integrating and strengthening the existing Central and State level agencies, 18) Intensification of training and research efforts as an integral part of water resources development programmes. Unfortunately, many of the suggestions in the policy could not be implemented due to various social, political and economic reasons

Relevance of the policy in a changing environment

When the gap between demand and availability of water widens and environmental changes become significant, current management practices, rules and regulations become insufficient in protecting national interests and water based development activities. The existing National Water Policy needs to be reviewed and updated regularly in the context of current problems and emerging challenges and also in the light of past experiences. The updated policy in 2002 was based on facts collected in 1993. This itself is a major drawback, as so many changes have occurred through climate change and human interference in water resources during this period. In view of increasing population and needs, the greatest challenge India has to face is the amicable settlements of river disputes among different states, different regions and different users. In India, inter-state water disputes have held up water development for many years, affecting food production, power generation and industrial growth. But, the policy doesn't provide any proper guidelines for conflict resolution or for settling the issues such as rehabilitation, resettlement and wages. Untimely and politically motivated protests when a project is half completed leads to re-estimation and wastes millions of rupees.

To feed the fast rising population, agriculture itself will continue to be the user of major share of water. The green revolution that helped India survive after independence later affected the productivity of large farm area due to soil salinisation as a result of water logging and overuse of chemicals and fertilizers. Policy should address land and water management together, as severe efforts have to be made in maintaining food security. Policies in certain States that encourage the use of groundwater by providing large subsidies in power and necessary material are becoming serious environmental issues. Such States should keep a balance between the extraction and recharge of groundwater. Careless and inadequate management and deterioration of surface water creates water shortage even in heavy rainfall regions. Timely

maintenance of the delivery system alone can save huge amount of water. Domestic, agricultural and industrial pollution have affected both surface and groundwater. Current policies and measures are not adequate to control the deterioration. In the disputes between industries and administration, industries often win, utilising the loopholes in law. Growing number of cities near the rivers necessitates the development of an urban policy as part of the national policy to maintain urban water quality and to meet urban water demands. Water resources planning in units of drainage basin as suggested in the policy is difficult in heavy rainfall regions like the State like Kerala where it is difficult to demarcate one basin from another and basin wise projects give rise to unnecessary disputes.

Though the policy stresses special attention to the weaker sections of the society, the actual beneficiaries of the schemes are usually the undeserving people with some sort of influence. Politics, religion and caste play important roles when a particular section is to be included in the priority list. Poor always remain poor and their voices go unnoticed. If weaker sections continue to be neglected, growing unrest in communities may lead to violence in future. In most of the power and irrigation projects, the people displaced often belong to this class and proper attention is not given to their rehabilitation.

In the policy there is provision for a Master Plan for flood control. Consideration should be given to the fact that there is possibility of increased floods in future, as a result of climate change. As population increases, rehabilitation to safe area should be planned well in advance. The policy proposes establishment of a national information system on water resources with a network of data banks. But, the reliability of data, responsibility of staff and coordination among various States and departments are not satisfactory. The policy should give more importance to water related research and easy access to data for the researchers. There should be steps to include environmental aspects for resources management in the university curriculum. There is the lack of proper training for professionals and lack of research in water related programmes. Unfortunately, if a possibility arises, it is the influence and community, more than capability that is the criteria for selection and this is reflected in the quality of all development programmes. Equal opportunities, impartial selection and adequate funding for research will produce better results and this is very important in the technological advance in view of changing environment and of increasing needs and conflicts. The policy needs to be revised and updated frequently.

Guidelines for efficient management of rivers

Though water is becoming a serious and most challenging issue in the country, measures adopted to face it are inadequate and slow. What India needs is an appropriate and frequently updated water policy and a strong political will to implement it. Policy development should involve climate change impact on socio-economic conditions in different zones. Water management should be brought under a central control instead of the various departments making delays in decisions. Legal and institutional mechanisms are to be improved to cope with the need of the time. Even constitutional amendments become necessary to solve water problems in large and transboundary basins. At present, water is a state matter and the central government has only limited role in its control. Therefore, disputes over water among states continue to be a major hazard in water related development activities. There should be a consensus among major political parties.

Autonomous River Basin Organizations generally better coordinate basin welfare programmes. But, in the typical socio-political set up in India, impartiality should be ensured in its formation. It should have a role in demographic and socio-economic matters.

It is true that lack of government funds have haltered progress of many projects in India. An option is private sector participation. But, private sector financing should be seen to be complementary and in no way a substitute for the state's responsibility in providing basic necessities for all. Recent reports quoting the World Bank say private sector involvement is a

failure in India's basic requirements sector. Any development scheme cannot succeed without giving due care to the millions living well below poverty line. Water should continue to be provided free to the extreme poor and to the marginal farmers. Also, social situation in India may not permit pricing easily. Awareness in conservation and management is more important.

The fundamental right of access to safe water and sanitation with environmental protection is to be ensured. But, strict control is to be made to avoid overuse and wasteful use. Satisfactory water allocation with consensus among different users is a key factor in the development of society and in maintaining harmony. Involvement of non-governmental organizations and charitable organizations are better performed in India than the Government in providing basic necessities like water. Spiritual organizations such as 'Matha Amritanandamayi Math' and 'Satya Sayi Trust' have proved it. Because of the popular belief in such organizations in efficient, transparent, impartial and optimum use, funding from individuals and industries is easier for them. People's participation should be an integral part of all aspects of water resources management.

Rivers are to be used in an environmentally sustainable manner in order to maximize its economic and social benefits. It should not be overused or polluted. Addressing water problems requires an inter-sectoral approach that recognizes their links with land use, agriculture, technology and health. Reformation in agricultural sector is urgently needed in maximum and efficient use of water and in minimising input of pollutants. Policy packages using a mutually reinforcing mix of institutional and policy reform, and legal, economic and management instruments will be needed. Strong political decision by the state to implement the rules and regulations is most important.

Considering the water resources situation and socio-environmental factors in the river basins and the present status of the water resources development and management programmes in the country, some suggestions for future may be summarised as below:

- A comprehensive and frequently updated water policy and its effective implementation. Special reference to climate change and population expansion.
- Policies and management approaches based on socio-economic conditions of different regions
- Promotion of traditional, environment-friendly and cheap methods of water collection and conservation from domestic level
- Reduce water loss due to evaporation / leakage during conveyance (present loss is almost 50%) - encourage the use of concrete/PVC pipes instead of open canals and channels.
- Convert all existing dams multipurpose
- Modernisation of hydroelectric systems to get more power and to reserve more water.
- Maintain a minimum flow from the dams to prevent saltwater intrusion at lower reaches of rivers.
- Environmental impact assessment before planning water diversion from rivers or interlinking.
- Construction of spillways on river mouths where tidal effect is more, to avoid salt water mixing.
- Water conservation for agriculture - timely operation and maintenance of irrigation systems and deliveries in required quantities. Drip irrigation and microsprinklers in suitable locations save water. Include farmers in decision-making committees
- Use of recycled water for group farming in suburban locations. Individual responsibility makes things better.
- Control urban migration. Provide facilities in satellite cities.

- Sharing of potable water for domestic use and poor quality water for other uses like gardening, agriculture or sanitation in groundwater dependent places, where water quality differ from one location to another.
- Ensure max productivity from available water
- Ensure groundwater replenishment naturally or artificially and control sand quarrying. Finding a cheap alternative for gravel to reduce depending riverbeds and basins.
- Discourage deep bore wells in highlands and lowlands - safety and ensuring water downstream, preventing salinity intrusion in lower reaches
- Maintain water quality in open water bodies such as large ponds with co-operation from the public.
- Minimise pollution at all levels. Permission for new industries only in lower reaches of rivers where tidal effect is minimum. Industries should maximise the use of recycled water. Natural fertilisers and biological and natural pest control (eco-friendly) in agriculture can minimise the water pollution through drainage or by infiltration. Taxing for pollution.
- More importance in maintaining water quality in the water bodies joining rivers
- Protection of wetlands, the natural water purifier. Wetlands destruction has affected river runoff and water quality in some states.
- Control sand quarrying from water bodies and catchments to prevent lowering of water table.
- Control human interference in highlands where rivers originate, to reduce erosion and sedimentation
- Increasing tourism activities - Measures to keep environmental quality
- Collection of sufficient data from various sources and its easy accessibility to research community.
- More funding for research in water science.
- Inclusion of global water issues and river management in the school/college curriculum and introduction of training facilities in related subjects.
- Awareness campaigns for general public.
- Bring water resources under the direct control of Central Administration. No consideration to State boundaries in the distribution or inter-basin transfers. Solutions can be implemented only in such a situation.
- An impartial river basin organization representing different classes of the society to manage rivers, and to settle disputes over allocation, resettlement and rehabilitation.
- Involvement of NGO's and private sector in water conservation and distribution – for private sector price and quality should be controlled by the Government. Water should be supplied free to the extreme poor.
- Community-based approaches to water management
- Rational water pricing and water allocation should be different for marginal farmers and large farmers, and for commercial and non-commercial crops and for plantations – ensure water free to the poor
- Heavy taxing for misuse, overuse and theft of water

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