

## RESEARCH PERSPECTIVES ON NATURAL RESOURCE MANAGEMENT IN INDIA<sup>1</sup>

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I take this opportunity to express my gratitude to the members of the Institute of Indian Geographers and the Governing Council for unanimously electing me President of the Institute of Indian Geographers (IIG) for 2011-12 and giving me the privilege to address the 33rd Annual meeting of the Institute of Indian Geographers at the Tripura Central University, Agartala. In particular, I express my deep gratitude to Professor K. R. Dikshit and Professor R. P. Misra for their constant encouragement and abiding interest in my work.

My interest in natural resource management is four decades old, i.e. going back to my graduate student days at the University of Waterloo in Canada during 1970-72. Late Professor Lorne Russwurm and my mentor Professor Bruce Mitchell at the University of Waterloo introduced me the basic concepts, theory and methods of natural resource management and planning. Much later, as a Reader in Geography at the Delhi School of Economics in 1980, I formalized my practice of natural resource management. I have learnt from my former teachers Professor P. Dayal, Professor Ashok K. Dutt, and Professor L. N. Ram and many colleagues like Professor Savitri G. Burman, Professor R. Ramachandran, Professor V. K. Verma, Professor Gopal Krishan, Professor H.S. Sharma, Professor Surinder Agarwal, Professor N. Mohammad,

Professor Suryakant, Professor Jayamala Diddee, Professor P.P. Karan, Professor Kalpana Markanday, Professor Nina Singh, Professor G.K. Panda, Dr. Anu Kapur, Dr. S.K. Chattopadhyay, Professor P.R. Sharma, Dr. R.V. Verma and Dr. R.B. Singh. I have honed my skills in natural resource management through constant interaction with my graduate students (Dr. Inderjeet, Dr. Punyatoya Patra, Dr. Krishna P. Poudel, Dr. R. Thakur, Dr. Narendra Rana and Rajesh Kumar Abhay) and colleagues at the Ranchi and Patna University, University of Delhi, and at the Universities of Akron, Kent State, North Dakota in the USA and York University in Canada and also from critical discussions with colleagues both in India and abroad. Last but not the least, my family is a repertoire of geographic engagement through my sons and daughter in-law who are all faculty in Geography and Business Administration at various US universities.

Resource management is a rapidly emerging sub-field within geography in India which integrates physical and human geography. Embedded within the notion of resource management is the idea of decision making which provides insights into resource management strategies and inputs into the planning process. Prudent management of natural resources is one of the key elements in trading the path of sustainable development. Surplus

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generated through proper management of natural resources can be utilized to develop secondary and tertiary sectors. Location, allocation, and reallocation are important components in devising natural resource management practices. This approach is based on how individuals perceive resource management problems and issues, and has developed as a vital research agenda based on years of systematic research (Thakur 2003, 224). It is also noteworthy that proper decision making improves the efficiency and productivity of resource use but also clarifies the understanding of the man-environment interaction (O'Riordan 1971, 109). Further, resource management is a decision making process by which resources are allocated over space and time according to the needs, aspirations and desires of mankind within the framework of innovations and political economy. Decision making emphasizes rationality, ethics and ecology which are a substitute for conservation. Thus, resource management implies strategic planning. According to Mitchell, decision making implies "control, strategy, handling or direction in which resources could be developed" (Mitchell, 1979, 3).

In the Indian context, resource use and its management are rapidly becoming the driving force of research among the academics. Such studies have significance in quantifying the depletion of natural resources, arresting resource degradation, promoting quality of life and management for a sustainable future by developing rational resource policies. Thus, research in resource management is increasingly tied with overall economic and social development of India. Therefore, this review examines the resource management

dimensions of development in India with a focus on research trends, paradigm shifts, methodological developments, research questions, institutionalization, integrated resource development, challenges and opportunities for synergy.

## **FROM NATURAL RESOURCES TO NATURAL RESOURCES MANAGEMENT**

India is fortunate with relatively diverse natural resources. However, these resources are not distributed equally and the country is cursed by the uneven distribution of natural resources and spatial variations in their development (Thakur, 2007, 3). The massive quantitative expansion in population size and concomitant pressure on natural resources along with lesser awareness of our natural wealth have resulted into loss of arable lands, disappearance of forests, land degradation, energy crisis, pollution hazards, regional water shortage and deterioration of water quality (Thakur, 2007, 3). Such consequential trends are blighting our natural resources and decreasing its productive potential for current and future generation.

Teaching and research in this rapidly emerging sub-field is gaining ground in many universities, research institutes and grassroots initiatives in India. Its origin and growth started as a part of Commercial geography and later on Economic Geography during the 1940s and 50s under the guidance of George Kurian, S. P. Chatterjee, R. N. Dubey, P. Dayal, Savitri Burman, O. P. Bharadwaj, H. P. Das, Kazi Ahmad, Tahir Rizvi and P. P. Karan. In this period, under the leadership of the above mentioned stalwarts, the emphasis was

mainly on the study of economic activities of man, agriculture and land use, industrial patterns and occurrence and utilization of minerals.

Resource studies also appeared as a part of regional geography in the works of O. H. K. Spate's (1954) *India and Pakistan*, R. L. Singh's (1971) *India: A Regional Geography* and many state geographies produced by the National Book Trust of India. A major contribution of regional geographers in dealing with natural resources emerges from their attention to the inter-relations of associated phenomena in particular regions. They have been able to bring broad perspective to problems of economic productions, trade and resource use planning. One of the more active participants in this work in the last fifty years has been the efforts made by research institutes like National Atlas and Thematic Mapping Organization (Kolkata), National Remote Sensing Agency (Hyderabad), Indian Remote Sensing Agency (Dehra Dun), Central Arid Zone Research Institute (Jodhpur) and National Bureau of Soil Survey and Land Use Planning (Nagpur) on the inventory, appraisal and conservation of natural resources. Apart from research institutes, researches in universities have also contributed significantly to the individual resources and their overall appraisal in which the changing significance of resources in specific areas have been analyzed and documented.

### **Books, Atlas and Monograph**

Books are classified themewise which contribute significantly to the growing importance of natural resources management in India. Dagli (1971) in his book *Natural Resources in Indian Economy*

suggests that any significant economic activity is based on various types of natural resources drawn from a number of states and whatever viability Indian economy has today is due to the fact that all its natural resources are used in a coordinated manner in the framework of national economy. Valdiya (1987) in *Environmental Geology: Indian context* attempts to weave the diverse components of the ecology into the fabric of geology and brings out the interlinkings and interdependence between various environmental factors. The book highlights the environmental stresses, the land in India is being subjected to elucidating not only the natural and anthropogenic causes of land and soil degradation, but also the implications of resource depletion. The problems of India have been portrayed in the background of its resources and potentialities and the future prospects have also been visualized (Dutt, 1972). Ramesh (1984) has brought out a comprehensive geography of India's resources in the background of its development. Singh, Kumra, Singh, Singh, Bilas and Singh (2005) in *Sustainable Management of Natural Resources (Land, Water and Forest)* have brought to forces some dimensions related to identification of interlinkages among resources, technology, development and environment; assessment of various natural resources: their availability, utilization, constraints and potentials; ascertaining the role of modern technology in monitoring natural resources; and sustainable management policies. Raza (1990) in *Renewable Resources for Regional Development: The Indian Soviet Experience* provides a treatise on rational utilization and conservation of renewable resources for regional development. The book argues that the development

of methods and techniques for planning, management, monitoring and control of natural processes for their optimal utilization may be regarded as the strategic aims of scientific research in this field. The book on Earth System Sciences and Natural Resources Management by Ravindra Kumar and Subhash (2004) highlights the work done by the Centre for Earth Science Studies (CESS) scientists, incorporating mitigation of natural hazards, assessment of natural resource potential, impact of exploitation of resources on environment, evolution of beaches, ocean pollution and environmental impact due to over-exploitation of dwindling natural resources. Tiwari (1995) in *Natural Resources and Sustainable Development in Himalaya* investigates the status and utilization pattern of natural resources, analyzes the structure and dynamics of human resources, analyzes the impact of existing resource use pattern and anthropogenic transformation process on the geocological system, and evolves an integrated resource management framework for the ecologically sustainable development in the Upper Kosi catchment in the central Himalayas. The book by Krishnan (1994) on *Growing Numbers and Dwindling Resources* explores the relation between problems of population explosion and natural resource depletion and examines the worsening situation as forests disappear, fuel reserves shrink, water tables drop, and the ozone layer depletes. Singh's (1994) book *Managing Common Pool Resources: Principles and Case Studies* combines both theoretical and empirical approaches to CPR development and management and comprises nine case studies of different forms of CPR management from parts of India. The author

argues in favour of an eclectic approach and underlines the need to maintain an appropriate balance between different systems of management. Finally, a coherent and environmentally sound policy for development and management of CPR is synthesized. In another, scintillating study, Singh and Ballabh (1996) in their book *Co-operative Management of Natural Resources* offers alternative ways to restore the productivity of the country's degraded natural resources. The book argues for collective or co-operative management as the most politically and socially suitable method for the management of natural resources. It brings together experiences from diverse regions of India, such as wastelands, forests, groundwater, surface water, and fisheries and also provide practical guidelines on how to organize resources users and enable them to manage common pool resources more efficiently, equitably and sustainably. Kapoor, Singh, Ali and Gehlot (2004) provide critical information to improve the immediate as well as long-term possibilities of resource development and create awareness for the protection and conservation of Indian desert environment. The book covers areas of soil and water management, irrigation and cropping systems, horticulture and afforestation, forage and pasture development, flora and fauna and management of insects, pests and weeds.

Resource utilization, degradation and management continue to be the focus of much effort by Indian geographers, economists, ecologists, geologists, foresters and hydrologists. It is a subfield where researchers in India have attained a high degree of success in achieving the synthesis, describing the spatial patterns

of resource use, processes responsible for resource depletion, degradation and policy development. However, model building is in its infancy stage and conceptual and theoretical developments are weak. Research on the above themes has been diverse, dispersed and challenging. The thirteen volume book on Perspectives in Resources Management in Developing Countries, focusing on India, has made substantial inroads into some of the problems faced by Indian resource managers (Thakur, 2003-2012, Vol. 1-8 are published and 9-13 are in press). Vol 1: Resource Management: Theory and Techniques gives the practioner access to the most practical and recent thinking on the subject of natural resources management including theories, models and paradigms. It elaborates the concepts of renewable and non-renewable resources, ecology and sustainable development and emphasizes on approaches to resources management. Vol. II: Population, Resources and Development addresses the complex interrelations between population, resources and development, including massive quantitative expansion in population size and their concomitant pressure on natural resources, penultimate problems of human survival and development opportunities and constraints. Vol. III: Ecological Degradation of Land provides series of essays on various facets of land degradation, focusing on wasteland identification, distribution, mapping and remedial measures. It gives special attention to environmental conditions and trends in desertification and takes into account of critical issues and problems emerging thereof. Vol. IV: Land Appraisal and Development is a

collection of empirical studies focusing on methodological approaches to land appraisal of mountainous, desert and deltaic areas. It provides a comprehensive and in-depth analysis of the dimensions of agricultural development and production potential for poverty alleviation. Vol. V: Soil Deterioration and Conservation deals primarily with contemporary patterns of soil utilization, estimation of magnitude and extent of soil deterioration, erosion control and conservation policy. Vol. VI: Water Supply and Quality is significant in the context of current urban water supply and quality problems because of increasing demand for water in the face of rapid industrialization, growing population and urban migration. The chapter centers around water supply and demand, impact of agricultural, industrial activities and waste disposal on water quality, spatial pattern of drinking water quality, eutrophication and water balance. Vol. VII: Water Utilization and Management presents empirical evidence on the environmental, bureaucratic and socio-economic constraints in water resources utilization and management. It offers specific strategies for water management in health resort town, metropolitan city, canal irrigation, disaster prone region and watersheds. Vol. VIII: Groundwater Assessment and Development focuses on groundwater exploration and development in hard rock and alluvium areas including the determination of durable and efficient setting of wells, assessing the groundwater potential of the aquifers for management, delineation of fresh-saline water boundary, rates and magnitude of groundwater depletion and local subsidence. Vol. IX: Bioresource Depletion and Conservation

contains a wealth of information on the patterns and processes of bioresource depletion. It provides unique insights into the underlying economic, social and political forces that encourage forest conversion to other less valuable uses. The book offers an extensive discussion of the ways to conserve biodiversity, educate the public and contribute to sustainable development. Vol. X: Environmental Hazards provides a balanced perspective on the occurrence, causes and impact of environmental hazards on society and natural resources. They include resource utilization and managerial problems arising from flood, drought, landslip, landslide, riverbank erosion, tropical cyclone, volcano and earthquakes. Vol. XI: Scenic Resources and Tourism focuses on scenic resources and tourism development at macro-level. It examines the theories in its full diversity and manifestation including scenic sites, pilgrimage-based tourism, ecotourism and agro-tourism, structure of tourism development, and tourism planning. Vol. XII: Energy Resources and the Environment examines distribution, production and utilization of both conventional and non-conventional energy resources. It provides insights into energy demand and problems, and prospects and focuses on energy policies and programmes for sustainable development. Vol. XIII: Integrated Watershed Development presents an inventory of watershed resources, their utilization, development and management with particular emphasis on river basins. It also establishes mechanism for community participation in decision-making and in formulating strategies for integrated development of resources to bring enhanced resource productivity.

The following section presents books on individual resources.

*Advances in Land Resource Management for 21<sup>st</sup> Century* by Gawande, Bali, Das, Sarkar, Das, and Narayanaswamy (2000) covers a wide range of issues relating to the sustainable and equitable management of land resources. The volume provides insights into some of the problems that face land resource managers, including soil erosion, water-logging, salinization, alkalization, acidification, fertility depletion, physical and biological deterioration affecting about fifty per cent of our land area. Chadha, Sen and Sharma's (2004) book *Land Resources* presents trends in the pattern of land utilization at the national and state levels, cropping intensity and its determinants, impact of urbanisation and land prices on utilization of agricultural land, diversion of land from agricultural to non-agricultural uses and the varying trends of under-utilization of agricultural land across regions and economic and social groups. It analyzes the extent of land degradation across agro-climatic zones and factors causing degradation and its consequences. It also examines structure of tenancy relations, consolidation of holdings, computerization of land records and the need for re-parameterising land policy during post-reform challenges. In India, an estimated 175 m ha of land is subjected to various kinds of degradation, namely, soil erosion by water and wind, salinization and alkalization, water-logging, ravines and gullies, and shifting cultivation (Valdiya, 1987; Khoshoo and Deekshatulu, 1992). Due to increasing population pressure, food shortage and other socio-economic compulsions, marginal and fragile land is being brought under cultivation in India.

Bhushan, Abrol and Rama Mohan Rao (1998) emphasized need to understand degradation process, consequences and rehabilitation strategies.

Although water requirements in all the sectors- agriculture, domestic, industry are going to increase, but their proportionate share in each of the sub-sectors is going to change drastically in India and water conservation in all its uses is the focus of the study by Bansil (2004) in *Water Management in India*. Mandal's (2006) book *Water Resource Management* addresses issues pertaining to water utilization and management and presents water supply problems for the purpose of irrigation, drinking and industrial uses. Water utilization is of the order of 540 cubic kms of which 360 cubic kms is from surface water and 180 cubic kms from groundwater. Out of this, 470 cubic kms is used for irrigation and 70 cubic kms for other uses. Irrigation accounts for 87 per cent of the total water use of the country. The extension of irrigation facilities has been a central feature of India's agricultural development strategy since independence (Vaidyanathan, 2006, 9). The last five to six decades have witnessed investments on a historically unprecedented scale. Singh (2006) through her book *Use and Misuse of Land and Water Resources* throws light through case studies from Uttaranchal, Uttar Pradesh, Deccan region, Andhra Pradesh, Rajasthan, Haryana and Goa on the problems of utilization and their management. Prasad (2003) in *Water Resources and Sustainable Development* emphasizes on issues related to sustainable development of water resources impinging on socio-economic, institutional and environmental aspects that face India, with particular reference

to the prevailing controversy on large and small dams, appropriate institutional framework for resolution of international and intra-national conflicts in the water sector, farmers participation in irrigation management, and water related natural disasters like flood and drought.

The determinants of groundwater depletion in eastern Haryana is quantitatively measured by the help of multivariate statistics and their management techniques proposed (Inderjit, 2001). Lahiri-Dutt and Wasson (2008) in *Water First: Issues and Challenges for Nations and Communities in South Asia* sketch issues and challenges that confront South Asian region, particularly India, where control over water has been a symbol of social and political power. Chaturvedi (2012) in *India's Waters: Environment, Economy and Development* provides a study of the current study of development of the major river basins- the Indus, and the Ganges- Brahmaputra- Meghna basins, as well as Central, Peninsular and others followed by watershed, groundwater, command area development and inter-basin water transfer. Some of the important water-related researches with which geographers have been concerned over the last decade, ranging from groundwater availability, quality to investigations of watershed development, water resources management and sustainable agricultural development are contained in Chandrasekharan, Sharma and Sundaram (2004). Mollinga (2000) in *Water for Food and Rural Development: Approaches and Initiatives in South Asia* establishes the crucial relationship between the multiple uses of water resources on the one hand and food security and rural development on the other, and suggests innovative approaches and methodologies

that can help resolve the deadlock in water resources development and management in South Asia. A wide range of issues related to policy and research challenges of water use efficiency and institution identification are not yet settled. On the other hand, urbanisation has created a new set of water-related issues; also, increased recognition of the role of ecological services provided by ecosystems provides a challenge at research frontier (Chopra, Rao and Sengupta, 2003). Water is examined in *Waterscape* by Baviskar (2007) in fast changing terrain by using the analytical framework of cultural politics to examine questions of power and inequality, conflicts and compromises around water. The book reflects the growing recognition that managing land, water and biomass is going to be a critical challenge for future economic growth and ecological sustainability. Politics arising out of water conflicts play an important role in water management. Wood's book (2007) is about the politics of water resource development and management in India, with special reference to the Narmada river water dispute in the context of Indian centre-state and inter-state relationships. The book reflects the constitutional and legal mechanism for resolving disputes among riparian states, and the upstream-downstream politics between downstream Gujarat and Rajasthan versus upstream Madhya Pradesh and Maharashtra. It also examines the struggle between pro-versus anti dam forces over the construction of the gigantic Sardar Sarovar dam. Joy, Gujja, Paranjape, Goud and Vispute (2008) bring together eight types of water conflicts in India through sixty-three case studies. They are: (a) Contending water issues, (b) equity-access-allocations, (c) water quality, (d) sand excavation and mining, (e) micro-

level conflicts, (f) dams and displacement, (g) transboundary conflicts, and (h) privatization. The typology makes important contribution through a new discourse on water in general and water conflict in particular.

Mirza, Ahmed, and Ahmad (2008) in *Interlinking of Rivers in India: Issues and Concerns* deal with inter-basin water transfer in India which is one of the important techniques for water management: "India's plan to interlink its rivers and to transfer water may generate positive benefits through improved and expanded irrigation and may also contribute to flood and drought hazards mitigation for India, although the magnitudes are debatable. However, there is opposing views that the interlinking plan is economically prohibitive, fraught with uncertainties and has potential for disastrous and irreversible adverse after-effects. Water deficit can be reduced through improved water management without large-scale engineering interventions. Moreover, many of the rivers involved, particularly in the Himalayan component are international and, therefore, the scheme has major implications for other riparians. Indeed, the planned transfer of water from the Ganges and Brahmaputra rivers will adversely impact Bangladesh socially, economically and environmental- unless arrangements are made to maintain historical flows, which is unlikely. Any multipurpose storage reservoirs in upstream countries, such as Nepal and Bhutan, would facilitate energy generation and other benefits but will also cause adverse environmental and social impacts to these countries. Therefore, ILR plan will further complicate existing water sharing and management problems between India and other co-basin countries".

Iyer (2007) in *Towards Water Wisdom: Limits, Justice and Harmony* argues for an urgent and radical transformation of our thinking on water. The author redefines the projected water crises as one of mismanagement rather than scarcity and calls for a more equitable, harmonious and sustainable management of water. Verma, Sahu and Lal (2009) in *Water Resource Management* present the latest methods and technology that has been developed for water management. Crase and Gandhi (2009) in *Reforming Institutions in Water Resource Management: Policy and Performance for Sustainable Development* provide a new approach for the analysis and design of water institutions that govern the use and development of water resources, particularly for agriculture which is the largest user in India. Ballabh (2008) in *Governance of Water: Institutional Alternatives and Political Economy* makes a case for reforming water governance through not only re-orienting policy priorities and approaches, but also restructuring the institutional framework away from the state and dichotomy. The book also explores the issue from neoclassical and institutional economics, deliberative democracy, public administration, collective action and political economy perspectives. Because of the importance of groundwater in irrigated agriculture and as a source of drinking water geographers (Jeet, 2005) and other resource analysts (Kumar, 2007) have been interested in the individuals and institutions that manage its allocation, development, use and protection. The book is characterized by new methodologies, analytical procedures and criteria to analyze groundwater use in agriculture. Athavale (2003) in *Water Harvesting and Sustainable Supply in India*

deals with traditional practices of rain and surface water harvesting as well as check dams. Jeet (2010) in *Rainwater Harvesting* provides scope for this method especially in those areas which have registered decline in groundwater levels.

Some of the books on natural resources are mixed in approach as well as in treatments. For examples, Ramesh (1984) *Resource Geography* demonstrates that the study of resource utilization, evaluation, management and conservation occur in a material context and the book looks at these problems from the point of view of material conditions as against natural conditions. Sinha (1985) throws light on the problem associated with the multiple growth of resources for social justice and economic prosperity of the society under differential environmental conditions. Agarwal and Narain (1989) in *Towards Green Villages* argue to hand over control of resources to villages community, which supports community-based approach. Kothari, Singh and Suri (1996) in *People and Protected Areas: Towards Participatory Conservation* suggests the mass involvement. Kothari, Pathak, Anuradha and Taneja (1998) in *Communities and Conservation* make a shift away from the top-down approach that has characterized such efforts in the last few decades. It constitutes the first comprehensive treatment of recent community-based conservation efforts in South Asia and explores policies, practices, strategies and issues related to participatory conservation. Thus, while ownership and management of natural resources rest with the state, the government failure is visible with respect to excessive exploitation for development and environmental degradation. It is suggested that natural

resources cannot be managed properly without involving rural communities which derive their sustenance from the natural resources (Mishra and Bajpai, 2001). Beberta (2002) provides comprehensive account of principles and methodology of preparing forest management plan for a forest division. Menon, Singh, Shah, Lélé, Paranjape and Joy (2007) examine the theory and practice of NGO-driven community-based natural resource management keeping in mind the existing critiques of dominant discourses of development, the micro-politics of decentralization and the protectisation of community development. Much of wildlife and biological diversity is located in less developed part where there is intense competition for resources between people and wildlife (Saberwal and Rangarajan, 2003). Should the state or should local communities manage natural resources? Should 'western science' or 'local knowledge' form the basis of national park management? Saberwal and Rangarajan (2003) argue for the need to involve villager and stress the value of local participation in conservation.

The book by Mollinga, Dixit and Athukorala (2006) on Integrated Water Resources Management: Global Theory, Emerging Practice and Local Needs tracks the emergence of IWRM as a central notion in water debates and argues that in India this concept is in search of a constituency. It is also argued that understanding and implementing IWRM requires interdisciplinary analysis and frameworks. The IWRM concept as promoted in the global water policy has entered Indian vocabulary, but is not yet a very strong force. Its successes, failures and constraints as one of the most popular paradigms in South Asia has been examined by Biswas, Varis and

Tortajada (2005) to make water management more efficient in the future.

An atlas is a assemblage, compilation or group of maps. In atlas, the maps are represented by various ways and methods which help the readers or users to understand the spatial and regional dimensions of physical and human characteristics. The late 1950's to till today marked an era of cartographic production and resource mapping. The last five decades have witnessed a growing interest in the history of Indian Cartography in general and resource mapping in particular. Analytical cartography, remote sensing and geographic information system have always data sources, data manipulation methods and output techniques spatial analysis has been at the core of map making. In the 1950's the notable achievement was the establishment of National Atlas and Thematic Mapping Organisation by the Government of India in 1956 in Calcutta with S.P. Chatterjee as its first Honorary Director. Professor Chatterjee rendered a signal service to Indian geography by starting this organisation. Its main purpose was to prepare an inventory of physical, economic and cultural resources of the country. This organisation produced many thematic maps of high value including National Atlas of India in 8 volumes in 1957. Under the direction of Chatterjee the activities of the organisation multiplied and its status elevated to such a mapping organisation employing perhaps the largest number of geographer under one roof of the world (Nag, 2003, 43).

1. The Planning Atlas of Damodar Valley Region was published in 1968 by the Founder Director.
2. Irrigation Atlas of India was published in 1972 and second edition in 1990's.

3. Land Resource Atlas of India, edited by Nag (1996). This atlas encompasses 12 multi-coloured plates each showing a specialized theme of land resources on the scale of 1:6 million. NATMO took up onerous job of compiling several atlases depicting the basic resources of the country.
4. Water Resources Development Atlas of India was published in 1996 as Nag being the editor.
5. Hydrological Atlas of India (2005) under the editorship of Nag, on the scale of 1: 1000,000 is an attempt to transfer the knowledge so far collected by different concerned departments to the users and researchers through a set of thematic maps showing hydrological set up of the country along with all the interrelated elements of geology, physiography, climate, soil, natural vegetation and land use. It provides an overview of the water potential of both the surface and groundwater and their quantity, quality and availability. According to Nag, each of the map shows different aspects of water for a better understanding of natural environment, its interaction with the social and economic activities.
6. District Planning Map published by Nag in 1997 and onwards emphasizing resources and economy.

Using satellite data, coupled with computer cartography and geographic information systems. The National Remote Sensing Agency has prepared and published maps showing the spatial distribution of wastelands on a scale of 1: 3,500,000 and 1: 1000,000. The Agency has also completed wasteland mapping at the 1: 50,000 scale for 237 severely affected districts in 19

states in India (Nagaraja and Gautam, 1996, 145-154). On the other hand, the National Wasteland Development Board has also published districtwise extent of wastelands in the country.

The Central Water Commission (CWC) is engaged in flood forecasting on inter-state river basins through 134 river level forecasting and 25 inflow forecasting stations on major dams and barriers over the country.

The Central Arid Zone Research Institute (CAZRI) was established by the Government of India in 1952 in Jodhpur, a city in the state of Rajasthan. It was previously known as Desert Afforestation Research Station until it was renamed in 1959. The objectives of the Institute are to find ways to stabilising shifting sand dunes, establishing sili-pastoral and firewood plantations, planting windbreaks to reduce wind speed and subsequent erosion, rehabilitating degraded forests and starting afforestation of barren hill slopes.

Desertification is a term that refers to the processes of land degradation that ultimately leads to transformation of productive land into an ecological desert. It is a process, involving a continuous change, from no degradation to very severe degradation (Sharma, 1993). In India systematic studies on desertification were initiated by the scientists of Central Arid Zone Research Institute (Ghose and Singh, 1965; Ghose, Pandey, Kar, 1977). Later on Dhabria (1984) and Sharma (1988, 1993) drew attention about the problem of desertification in Rajasthan. Under the auspices of UNCCD (United Nations Convention on Combating Desertification in India, Space Application Centre (ISRO) has been identified by the

Ministry of Environment and Forests, Govt. of India as the focal institution to coordinate and implement Thematic Programme TPN-I. In order to realize the objectives of TNP-I, pioneer study on Desertification Status in India (DMS) was initiated in 2001 by SAC involving 15 important organizations of India including University of Rajasthan, Jaipur. The mapping was done on 1:50,000 and 1:500,000 scales using Remote Sensing data products. The results of this study were presented through the Atlas on Desertification (Ajai, 2007). The atlas has brought out that nearly 32% of the total geographical area of the country is under serious threat of desertification. After publication of this atlas, several research papers on desertification have been published by Sharma, Ajai, Bindu, and Arya (2008), Sharma (2011), and Ajai (2011).

Centre for Earth Science Studies (CESS) from its inception in 1978 considered natural resource management as one of its thrust areas. One of the first projects was Resource Atlas of Kerala completed and published in 1984. The maps were in 1:1,000,000 and 1:2,000,000 scale with districts and talukas as the lowest mapping units. It covered various themes under the sections of natural resources (23 maps), human resources (20 maps), infrastructure (20 maps), resource development (60 maps) and regions and regional development (7 maps). In 1989, at the instance of the State Planning Board, Kerala, a series of resource maps were prepared for Kasargod District plan in a scale of 1:250,000. Panchayat resource mapping was initiated by CESS in 1991 (Chattopadhyay, 2004). Subsequently, there were several projects on NRM covering district data base, river basins, Blocks and

Panchayats. It continues to be an important area, particularly for societal application. Currently, there were 27 projects dealing with various issues ranging from terrain, land quality, geochemistry to environmental remote sensing. Four projects addressed issues related to water resources, three on terrain and landuse, 11 on environmental management, two on atlas preparation and one on coastal zone management. Besides, there are another six projects dealing with various other issues including active remote sensing, rural energy, heat islands and neural network. The action research programme on rain water harvesting and groundwater recharge in Chadayamangalam block warrant special mention as it directly addressed societal concern (CESS 2012).

Government of India established All India Soil Survey Organisation in 1956 with the Headquarters at the Indian Agricultural Research Institute, Nagpur with five Regional Soil Correlation Centres at Bangaluru, Delhi, Kolkata, Jorhat and Udaipur. Later in 1958, this scheme was integrated with the Land Use Planning Scheme of the Central Soil Conservation Board, primarily, to carry out detailed soil surveys in the catchment areas of major River Valley projects, with setting-up the organisation, "All India Soil and Land Use Survey".

In 1969, it was re-organized and the research aspects of soil survey, classification and correlation were transferred to the Indian Council of Agricultural Research (ICAR) and the developmental activities was retained under the Department of Agriculture, Ministry of Food and Agriculture. In 1976, it became an independent Institute of ICAR named as National Bureau of Soil Survey and Land Use Planning (NBSS&LUP) and continued to function at the IARI, New

Delhi. In June 1978, the Headquarters of the Bureau, was shifted to Nagpur. The NBSS&LUP is one among the chain of ICAR Institutes. In line with the recommendations of the Task Force on Land and Soil Resources (1972), which suggested the need for soil correlation, uniform nomenclature and proper soil mapping and also the presidential notification on December 15, 1973, the duties with respect to research, training, correlation, classification, mapping and interpretation were allotted to the NBSS&LUP. The Bureau has successfully completed the soil resource mapping of the whole country at the scale of 1:250,000 and district soil mapping of 83 districts at the scale of 1:50,000 in the country.

Three monographs of small size have been published on land and water resources in the country. Thakur (2008) investigates and highlights the spatio-temporal changes in the depletion and degradation of land resources in the country and evaluates development challenges and management strategies. Qureshi (2005) has critically examined the Indian scenario of water resources, both surface and groundwater, in a spatial perspective; the strategy for managing regional abundance and ameliorating scarcity, the regional patterns of water demand and scarcity, and conservation of water resources. Kayastha (2000) states that water resources of India are unevenly distributed and despite the large competitive demands and its uses, all the available water in the country cannot be utilized owing to various topographical and hydrological factors. Floods, droughts and pollution are the major problems. The monograph suggests a number of management strategies.

Kayastha and his students at the Banaras Hindu University have shown keen interest in the growth of this sub-field by initiating studies on urban pollution, flood plain management and human adaptation, impact of development on environment and resource policies. Similarly, Burman and her students at the University of Delhi have evinced keen interest on methodologies of resource development and their impact on the ecology in the Himalayan region (Burman, 1990). She also emphasized on the inter-linkages of natural and human resources together with their economic uses in the Himalayan watersheds (Kapur, 1999). Raza and his students at the Aligarh Muslim University stressed on man-land relationship in prehistory, ecological analysis of tribal societies, ecological impact of different land use practices and pollution stress on river ecosystems.

Mountain regions have received considerable attention and it has been noted that they are being subjected to population pressures. A most welcome addition to the literature on mountain environments is the book by Karan (1984). This book discusses patterns of economic and social development in Sikkim Himalaya and addresses questions, such as what kind of economic patterns can a small mountain territory develop and what are the environmental consequences of the development of mountain areas? The work by Ives and Ives (1987) was devoted to an analysis of the theory of Himalayan environmental degradation and explored whether current mountain land use practices produce the downstream destruction, and if so, what mitigation measures can be pursued. Ives and Messerli (1989) have also stressed that the various processes of

environmental degradation were due to the cumulative effects and practices, and with better technology and improved agricultural and forestry practices, development can be reconciled with management in the Himalayas.

Rapid population growth and indiscriminate application of technology especially in the past few decades have had far reaching impact on the ecological balance. Owing to the fragile character of their ecology, the impact of such activity has been severe in many parts of the country especially in the Himalayas, desert and coastal areas. Among the issues taken up for research were the environmental impact of road construction, growth of highland tourism, eutrophication of Dal Lake, mining and derelict land and inadequate impact of human activities on climate.

At a smaller scale, geographic research on resources has been diverse. Studies are associated with natural resource endowment and inventory and appraisal of useful environmental products, resource development and utilization, regional framework of resource development on environment, economy and society and resource conservation and management (Shafi, 1972, 51-62; Ahmad, 1979, 9-20; Kayastha, 1984, 51-63). Geographers for the past five decades have been involved in particular resource studies (Dayal, 1977 and 1984; Gautam and Narayan, 1988; Thakur, 2010; Chadha, Sen and Sharma, 2004). Geographical analysis of the impact of resource development has been completed both at a macro-economic level and also with reference to individual sites. Such studies are in tune with nature-society relationship.

Resource studies have also been conducted to identify regional units or planning or regionalization for purposes of planning. This continued from the mid-50's to the late 60's. Studies at the Indian Statistical Institute, Town and Country Planning Organization, Planning Commission and Census of India carried out among others, by Learmonth and Bhat (1960 and 1962), Prakasa Rao and Bhat (1964), Sengupta and Sdasyuk (1968). Sengupta (1966) also promoted and refined techniques of regionalization, and also provided formats for regional resource appraisals.

### **Paradigm Shifts**

Since the early 1960's geographers and resource analysts have made widespread use of paradigm concept. Paradigms are generally accepted set of assumptions and procedures defining both subjects and methods of scientific enquiry. The terms such as ecological, economic, institutional, integrated, behavioral, community-based and information system paradigms have become common, which have been employed to provide directions in research. They reflect sub-fields interdisciplinary nature which has been developed to provide a framework for the rational use and management of natural resources. They have been developed to protect/safeguard natural resources against their reckless exploitation and misuse by human and animal population (Thakur, 2003, 6).

### **Ecological Paradigm**

The ecological paradigm finds solutions to the problems of resource management by the measurement of physical attributes of ecological system. The study of the

interrelationships that exist between organisms and their environment is known as ecology. The ecological environment, although infinitely varied and complex, is a dynamic and organic whole. It is characterized by the dynamics of a number of interacting elements. In order to attain the required goal, resource development and management takes full account of the dynamics and interdependencies. Therefore, this paradigm is shared by geomorphologists, climatologists, hydrologists and bio-geographers, who attempt to understand ecological processes as a basis for the implementation of resource management schemes.

This paradigm has three directions which are competitive to each other. First, ecological interlinkages throw light on the connection between physical system, natural resources and human usages of these resources. This looks at resource degradation or resource use not the result of a single activity but of a combined effects of all the economic activities in the locality and its neighboring regions as well as the physical character, capabilities and interlinkages of the locality itself (Thakur, 2003, 10). Burman (2003) draws attention to the interlinkages between different physical parameters of the ecological system which are utilized as natural resources either directly as land, mineral, biotic, etc. or indirectly in the processing and production of economic goods like, energy, air, water, etc. Second, the most significant influence of ecology on resource management is the concept of biosphere reserve developed within the framework of UNESCO's MAB program as a multifunctional tool to protect biodiversity, promote sustainable resource development

and ensure local people's participation. It includes national parks, biological reserves and other protected areas with an objective to provide the scientific knowledge for sound and sustainable management of land resources. It aims at the conservation of ecosystem by preserving representative samples of significant ecosystems, original habitats of domesticated plants and animals and populations of rare and endangered species. Thus, the concept has been used in India to maintain biological diversity, for field research and monitoring activities and for environmental protection and land resources development. Third, political ecology approach has emerged as a research agenda especially in Third World to understand the political sources, conditions and ramifications of environmental change (Bryant, 1992, 13). It is an interdisciplinary approach which connects politics and economy to problems of resource management. The dominant narratives of political ecology are degradation and marginalization thesis, environment conflict thesis, conservation and control thesis, and environmental identity and social movement thesis (Robbins, 2004, 13-15). Degradation and marginalization offer an explanation of why environmental system change, environmental conflict explains access to resources and conflicts arising from, conservation and control explains conservation failures and political economic exclusion, and environmental identity and social movement seeks to explain why social system change (Robbins, 2004, 13-15). Some of the researches conducted by Robbins in the field of political ecology in India are common property resources in Rajasthan (2004, 142-146), the biogeography of

power in the Aravalli: a classic case of conservation and control (2004, 166-171), gendered landscapes and resource bottlenecks in the Thar (2004, 182-186) and pastoral polities in Rajasthan: agrarian alliances and traditional technology as resistance (2004, 199-201). Birkenholtz (2012) argues for a rethinking of water supply development programs through a political ecology approach that focuses on the emergent capacities of water supply technologies to redirect existing socio-ecological association. Political ecologies are more complex in cities environments. It expands beyond simply identifying the unequal distribution of water supply and how these are produced and why these ecological networks look the way they do (Weber, 2006). The bases of water crises in Chennai of 1993 are explained by political ecologies in which political ideology and application of science and technology are thought to be instrumental.

### **Economic Paradigm**

The concept of economic paradigm is based on the assumption of resource allocation which rests upon the assumption efficiency and maximization of net returns. Economists have been involved in resource allocation research and have made important contributions in understanding the processes operating to produce current resource and welfare allocations, in analyzing who has the power to determine the distributive patterns and in assessing the role and efficacy of public policy measures to affect change in the allocative system. Related to this paradigm is the concept of political economy which has been used synonymously to indicate the area of resource allocation and the

determination of aggregate economic activity. This has been guided by Marxist political economy, such as Smith, Ricardo, Malthus, Mill and Marx and has appeared in the studies of contemporary economies, politics, international relations and resource management. Its appearance in the field of resource management is recent and it illuminates key social factors that shape people's action. This emphasizes the recursiveness of the relation among socio-structural formations, economic forces and political-power relations that generally underlie and determine resource exploitation and development (Blaikie, 1985). With this it is possible to analyze societal factors influencing the farmer's practices rather than examine only physical processes of soil erosion like erosivity of rain, erodibility of soil, tillage methods or cropping patterns. Thus, this paradigm takes into view the historical-structural stance incorporating within its framework its structural- institutional forces and individual responses to such factors in the wider political economy (Thakur, 2003, 17). However, this paradigm has rarely been applied to Indian settings.

### **Institutional Paradigm**

Another paradigm biased to economics, political science, law and business administration is the institutional which emphasizes the role of social, political, and economic organizations, in determining economic events. In this paradigm the fundamental research need is the analysis of formation of institutional arrangements and the way they evolve in response to changing needs and existence of stress. Thus, the success or failure of resource management is tied up with institutional

structures- the pattern of agencies, laws and policies which pertain to resource issues. Institutional arrangements are defined as the composite of legal powers, administrative structures, and financial provisions (Mitchell, 282, 1989). Institutions include both formal and informal interactions between individuals and groups, legislation and regulation, policies and guidelines, administrative structures, political structures and processes, economic and financial arrangements and historical and traditional customs and values. Resource managers in India have become interested in institutional arrangements and their role in the management of natural resources (Robbins, 1998; Birkenholtz, 2009). In the desert grass and shrub lands of Rajasthan, where multiple, contending institutions govern village resources, the role of social institutions-rules, norms, and systems of authority and power are overwhelming. Robbins (1998) states that state political interventions vie against traditional common and semiprivate rule arrangements for control of pasture and forest resources. The study assesses the role of institutions in configuring resource extraction decisions made by producers and in creating distinct biotic conditions. It is also demonstrated that responses to authority differ along axes of gender, caste and class and so lead to varied decisions by producers.

Although Robbins was referring to forests, the same applies for dynamic groundwater dependent socio-ecologies in the Jaipur district of Rajasthan near its capital, Jaipur (Birkenholtz, 2009). The adoption of tube well technology sets in motion a recursive process of technological adaptation, social institution formation

and ecological change. Although this is leading to socioeconomic differentiation, the results suggest that these social institutions formed around the tube well are durable. Mukherji (2007) demonstrates that alternative institutional arrangements have superior equity outcomes than pure private water market transactions in West Bengal. Kumar (2000) suggests establishment of tradable private property rights in groundwater as a major institutional reform for communities to establish rights over the water they manage and to address the issues of efficiency, equity, and sustainability. However, the functioning of social institutions in India is full of problems (Robbins, 2000). The author offers the outlines of a theory of natural resource corruption, defines it as a special case of extra-legal resource management institutions, explores the challenges corruption poses for sustainable use of natural systems, and provides an example of corruption in the case of forest management in India.

### **Integrated Paradigm**

Integrated management paradigm has been very popular in India as this has attracted the geographer. The themes stressed in this paradigm are the integration of natural resources and this is possible only through a spatial approach. The meaning of integration is to unite parts or elements so as to form a harmonious whole and to coordinate diverse elements. As a concept, integration is well established in the field of management which leads to cooperation and coordination, and, in turn leads to improved effectiveness. Historically, the use of land, water, forest and other natural resources was viewed as separate issues; but

now, research has resulted in an increased awareness that they are integrated. In the process of integration, water plays critical role not only in developmental activities but also in the maintenance of ecological balance of the river basin. Integrated resource management implies the orderly marshalling of water resources of river basins for multiple purposes to promote human welfare (Thakur, 2003, 21). The river basin is a biogeographical system and is also called process-response system. It is dynamic in nature. The formal and functional regions are rejected as unit of study for development and management of resources, instead, river basin is selected as a unit because of its physical unity. The above characteristics make a river basin a suitable multi-purpose economic region where variety of multipurpose uses is made due to its engineering techniques. The river basin management is also called as “integrated resource management”, “integrated catchment management” and “total catchment management”. The creation of Damodar Valley Corporation in India by the Act of Parliament in 1948 became a great event in the history of the integrated resource management. The Damodar Valley Corporation is essentially a multi-purpose river-valley project designed by an American engineer, William Voorduin from the Tennessee Valley Authority in the United States. It was followed by other multi-purpose river-valley projects such as the Bhakra Nangal, Mahanadi Valley, Tehri Dam, and Narmada Valley. Saha’s (1979) study on the Damodar river basin planning is remarkable in its breadth and coverage which requires to be attempted elsewhere also.

## **Behavioral Paradigm**

Another most rapidly growing paradigm in resource management in India is behavioral. It is based on how individuals perceive resource management problems and issues and it provides insights into resource management strategies and an input into planning process (Thakur 2003, 224). This paradigm, based on the works of Burton, Kates, White, Mitchell, O’Riordan, Saarinen and Sewell, focuses upon individuals, lay public, and technical experts, private and public managers. This paradigm provides the definition of resource management as the decision making process by which resources are allocated. Therefore, this is behavioral base of the people. The task of resource management decision making has become more complex and multi-dimensional because it is based on components like perception, attitude, value and emotions (PAVE theory). Perception is the ability of mind to apprehend objects through the senses of sight, hearing, smell and touch. Attitude refers to belief or preference held by a person with respect to an object. Values are significant throughout the decision-making process and encompass goals, beliefs, attitudes, and traditions that have influence on the exercise of power. Emotions are a state of excitement that is characterized by strong feeling and with both mental and physical manifestations. It contributes to the ways people reason. During the 1960’s to 1980s a large number of studies appeared adopting perceptual and attitudinal variables focusing on floodplain and Himalayan resource decisions at Banaras and Delhi. They have increased our understanding of the decision-making

process through questionnaire survey but model building in resource management decision making is poorly developed.

### **Community-based Paradigm**

Community-based paradigm challenges the assumption that conservation is only possible through the exclusion of human activities. This is a new people-centered thinking in conservation and management which is gradually emerging quite important in developing countries including India, mainly derived from a political reaction against the environmental authoritarianism of the state (Udaya Sekhar, 2000, 123). This is a paradigm shift towards decentralization at the policy level in resource management. The centralized approach dominated natural resource management in India during the colonial period (Udaya Sekhar, 2000, 123). It stresses participation and decentralization of management in contrast to top-down approach currently practiced. Here, local institutions are given due recognition and decision-making is made open with equitable sharing of costs and benefits between the state and local communities. It is believed that local communities, especially those, with a long tradition of resource use in a particular area hold in-depth knowledge and experience of wild-life and habitats which can be invaluable for conservation efforts.

### **Information Systems Paradigm**

The information system is a methodological paradigm in natural resource management which has great potential as a tool to support decision-making. It is a ruling paradigm as it has the largest impact on

the thinking of managers in India. It is also known as geomatics or geoinformatics which has brought revolution in this field. It has proven as a powerful tool for studying natural resources and helps in locating features, extent of coverage, monitoring the resources and in generating models to probable scenarios, which assist in optimizing resource utilization (Rao and Herman, 2005). There are two advanced information systems-remote sensing and geographical information systems (GIS)-that are used to monitor and study resource processes and how human activities are affecting these processes. Today the amount of data gathered on natural resources from remote sensing satellites and many other sources is overwhelming. Tremendous amount of data are being generated through high resolution images. Inventory of land, water and biomass resources can hardly be conceived without satellite images. While remote sensing helps in data acquisition at regular intervals, GIS application has enlarged the horizon of data assimilation. There are no other effective and efficient measures to gather and disseminate and has also provided a test bed for assessing impacts of alternate use and create future use scenarios. Resource data are to analyze and present the information needed to develop sustainable resource management programs in India. Each year remote sensing world is obtaining larger and larger volumes of data. As a result, there is a growing interest in data management and disseminating technology within the community. The efficient data and information management system must be implemented to handle, store and disseminate data. Over the past 20 years, sophisticated computer-based information systems have evolved that are

proving to be essential tools in India in developing management strategies. The GIS that includes both the hardware and software components is utilized to store, analyze, overlay and map digital data in a geographically referenced format. They handle and process geographic information over high speed networks, such as the internet. Thus, GIS have become an essential link between the data collection technologies, such as remote sensing, and the policy makers such as bureaucrats and organizations. RS-GIS application is widespread in the field of natural resource management and the scope is enlarging over the years, although potential of these techniques are yet to be fully realizable. It is now widely used in areas of resource management, from ecology to geology, and from oceanography to Himalayan geomorphology and resources. As natural resource managers, biologists, botanists, ecologists, environmental regulators, geographers, hydrologists, petroleum engineers, planners and foresters are relying on analytical power of GIS for making critical decisions. GIS provides deeper understanding of the problem we face by giving accurate information. Decision makers need a complete picture of the issues before taking action, such as planting crops, drilling for oil, restoring habitats and monitoring endangered species. Therefore, it has always been fundamentally as application-led technology.

Internationally, the research on GIS started in the early sixties, however, in India it started towards the end of Sixth Five Year Plan (Singh, 2004, 156). The preparatory stage of GIS (1978-1980) began with the theoretical approach followed by software development, setting up research

groups and organizing some regional experimental researches and training programs. The Department of Science and Technology launched a comprehensive program in 1982 on the development of Natural Resources Data Management System by setting up computerized data bases at micro level taking district as the unit. The National Natural Resources Management System (NNRMS) project was started in 1988 by the Department of Space to adopt a holistic approach for rational management of natural resources of the country. The important achievement of National Remote Sensing Agency in 1986 was the survey and mapping of wastelands in India using landsat satellite data on 1.1 million scale. The Planning Commission has recognized GIS as “an invaluable planning tool in land use and wasteland development for identifying treatment areas” (Madon and Sahay, 1997, 47). The Survey of India has established the digital cartographic database for the country and National Remote Sensing Agency is collecting and disseminating satellite imagery. The GIS initiative started at National Informatics centre in the early 1990s where the primary impetus was the emergence of GIS of NIC (GISNIC) and the establishment of NICNET (high-speed telecommunications network) facilities at the district level (Madon and Sahay, 1997, 47). The Government of India has emphasized the development of a strong space program through the Department of Space at National Remote Sensing Agency, Hyderabad which used remote sensing for natural resource surveys (Madon and Sahay, 1997, 48). The management of wastelands is a priority area with respect to India’s development. In 1991, the

Ministry of Environment and Forests started an important project for wasteland management applying GIS technology on 1:50000 scale. This wasteland mapping was carried on for 147 districts in the country with a large area of degraded land. Other government agencies using GIS are Census Department, Geological Survey of India, Town and Country Planning Organization, Wildlife Institute of India and the Coast Guards.

The application of remote sensing and GIS at micro level is complex and diverse conducted by NGO's and universities. They play an effective role in natural resources inventory and, appraisal, land capability classification, land degradation, desertification, drought monitoring, agro-climatic zoning, rain use efficiency, regional water shortage, surface and groundwater quality, seasonal fluctuation of lakes, groundwater potential zone mapping, prioritization of wastelands, floodplain management, forest cover, decline of wetlands, assessment of soil moisture and flood coverage (Singh, 2004, 155-169; Singh, 2008, 22-27; Singh, 2008, 94-103; Singh, 2009, 203-257). Resource studies and management in desert areas with special reference to desertification status mapping and identification of hazard vulnerable areas have been conducted by Sharma and Binda (2006 and 2007).

Each state in our country has institutes specializing in applying RS-GIS for natural resource management and experiments are going on at various levels. Center for Earth Science Studies (CESS) in Kerala is experimenting with application of RS-GIS technologies at various levels. It has brought out resource maps on 1: 250,000,

1:50,000 and 12500 scales for districts, blocks, and Panchayats. Potential sources for groundwater resource development have been worked out in 1:50000 scale using LISS-III image. Cadastral level information was generated using Quick Bird Image of 2.5 meter with spatial data base and interactive decisions. Village resource centers proposed by ISRO and MSSRF would yield results provided plot level resource data are generated in time, updated periodically and the local people are involved in using those data interactively. RS-GIS application will facilitate such a process.

## **CHALLENGES**

The subfield of natural resource management is confronted with numerous conceptual and methodological challenges in the way of prudent management of natural resources. This brief review has highlighted many challenges.

1. Paradigms have been developed to protect and safeguard natural resources against their reckless exploitation and misuse by human and animal population and have been gleaned from a very large and varied literature.
2. Weakness in most research in resource analysis is the lack of understanding of basic processes and relationships.
3. There is unequal emphasis in the application of paradigms in resource management.
4. It is a recent field, therefore, lacks maturity and precision.
5. Integrated, institutional and information systems paradigms are popular in India than other paradigms.

6. It is now realized that there is a need to introduce precision management in natural resource management which warrants site-specific detailed information at regular time interval, so that impact of use can be assessed and lessons internalized in future management. Macro scale approach will not yield desired results.
7. Behavioral and systems inquiries are weakened by inadequate understanding of perceptual, attitudinal, emotional and ecological processes.
8. Political ecology, an internationally popular paradigm, is yet to gain acceptance.
9. The path of resource management decision making is full of uncertainties and conflicts, but, neither of the paradigms addresses means of conflict resolution.
10. A new people-centered thinking in management is gradually emerging, mainly derived from a political reaction against the environmental authoritarianism of the state, which stresses, local participation in the management process. But it is not clear as to what degree of public involvement is desirable and feasible? Which segments of the public should be consulted? At what points in the planning and policy processes should public inputs be sought? What are the components of a good public participation program?
11. The main focus of watershed approach is the socio-economic transformation of the entire region and improvement in the quality of life of all people based on the fullest use of available land and water resources, but, active participation of local people in these programs is critical.
12. There is lack of integrated techniques to quantitatively measure and analyze the resource quantity and quality.
13. There is disregard to traditional indigenous ecological knowledge (TEK) and practices of soil and water conservation.
14. There is a total lack of model building on the basis of indigenous experience and the sub-field itself is in infancy stage.
15. To a large extent, work is done in isolation and in traditional descriptive style without an adequate theoretical and conceptual framework.
16. Proper use of RS-GIS data is a great challenge for natural resource managers.
17. The rise of digital technology generates as much hope as fear.

## **DIRECTIONS FOR FUTURE RESEARCH**

The following section presents some research dimensions and frontiers which will have relevance to contemporary Indian society.

1. Toward an integration of paradigms: followed sequentially as integrated, ecological, community, economic, behavioral and institutional; analyzed by adopting Remote Sensing and GIS paradigm.
2. Impact of reforms and reclamation on the sustainable management of land resources.
3. Addressing uncertainty and conflict resolution.

4. The political ecology of water scarcity.
5. The political economy of resource depletion.
6. Institutional change and resource management in historical perspective.
7. Creating institutional landscapes for prudent management of resources
8. Institutionalizing common pool resources.
9. Traditional ecological knowledge and resource management.
10. Ecological, economic and social aspects of interlinking of rivers.
11. Institutional and environmental constraints in water resource management.
12. Spatial aspects of pollution.
13. Identification, development, and management of scenery resources in the Western Ghats and Himalayan region.
14. Detailed regional studies in understanding the distribution, utilization, and measures for rational use of resources for integrated resource development.
15. Energy efficiency: assessment of policy regimes and their impacts.
16. Water-stressed megacity: consumption and demand.
17. Development of rural electrification.
18. Dynamics of rural energy access.
19. Impact of groundwater markets on water use efficiency.
20. Patterns and processes of regional deforestation.
21. Community-based resource management in tribal, marginal and culturally diverse areas.
22. Climate change and land degradation.
23. Carrying capacity of Ganga basin agricultural resources to support human and bovine population.
24. Environmental change and sustainability of water in the hill towns.

## CONCLUSIONS

Natural resource management in India now encompasses a range of research perspectives including those relating to economic, political and cultural dimensions of resource management. Intellectually, the sub-field of natural resource management in India is well positioned to contribute to research perspectives emerging from paradigm shifts, methodological developments and institutionalization. In all this a set of challenges to research in natural resource management has emerged from an appreciation and an understanding of the linkages between the local to global scales, the debate between quantitative modeling versus predicting social trends and human futures emerging from power relations and equity and all these have spatial policy implications. Although there has been considerable progress in understanding different facets of natural resource management in India there are still many unresolved questions and several important new areas for research as has been identified from the future directions in this subfield.

I wish the Annual Conference of IIG at Agartala a grand success.

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