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Surviving with Climate Change: Adaptation, Vulnerability and Resilience: A Study of Wetlands Ecology and Culture of Doon Valley, Uttarakhand

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Abstract:

Swamps and wetlands are multi-functional landscape. It maintains one of the most productive ecosystems, regulates its ecological processes that contribute to a healthy environment. Wetlands have also influenced the development of human societies. It provides food, water and many more resources for the people. Many societies developed economy based on wetland resources and cultures, there in, set out direction for managing the natural resources for the benefit of its social, economic and environmental future. This interaction of ecology, economy, society and culture has given rise to a complex and sophisticated indigenous system of resource management.

The ecologically sustainable management of the natural resources – based on an integrated 'ecosystem approach' was part and parcel of social and cultural practices in India. The culture of management of the wetland areas of Doon valley represents a similar practice of ecologically sustainable management of the natural resources.

Today, wetlands as ecosystems stand on the fringes of our conservation policies and face the risk of being lost in the face of unplanned development and pressing resource needs. It is realized that in order to manage the wetland areas more efficiently and effectively, there must be the balance between ecological conservation and livelihoods of communities. The paper also intends to suggest the method of adaptation to climate change.

Key words: *Multi-Functional Landscape, Eco-Sensitive Culture, Impact of Climate Change, Conservation and Livelihoods, Adaptation to Climate Change, Regional Adaptation Programmes.*

Introduction

Swamps and wetlands are multi-functional landscape. It maintains one of the most productive ecosystems and provides habitat that supports great floral and faunal diversity. The transitional area between upland and deepwater aquatic systems, these wetlands regulates ecological processes that contribute to a healthy environment.

Wetlands, as vital ecosystems, have influenced the development of human societies since historical times. It provides food, water and many more resources for the people. The Socio-cultural practices were closely attuned and adapted to the conservation and management of the regional ecology. Societies developed economy based on wetland resources and cultures set out direction for managing the natural resources for the benefit of its social, economic and environmental future. This interaction of ecology, economy, society and culture has given rise to a complex and sophisticated indigenous system of resource management. The ecologically sustainable management of the natural resources – based on an integrated 'ecosystem approach' was part and parcel of social and cultural practices in India. The culture of management of the wetland areas of Doon valley represents a similar practice of ecologically sustainable management of the natural resources. The traditional social and cultural practices played an important role in achieving the goals of 'Shared interests: shared action' through community's strong 'land care ethic'.

Fresh water swamps of Dehradun are also susceptible to the impacts of predicted climate change. Climate change - water shortages - warmer temperatures are likely to increase. Spectrum of ecology, economy and society will be impacted by increasing temperatures, erratic rainfall, and various other vagaries of climate change. Societies and communities will find it difficult to adapt to. This may cause a more extensive damage in future as climate change will make condition worse in some regions, particularly in the agro based densely populated areas. Warmer temperature as a result

of climate change will likely to reduce river runoff. It will have negative impact on water sensitive systems (ecology and economy). Sudden collapse of environmental and economic system may occur and it will aggravate the environmental crisis. A vicious cycle where by each problem will exacerbate other problems which will feedback into each other.

The objective of the study :

The main objective of the present study is to examine the vulnerability of freshwater wetlands, marshy swamps and waterlogged areas to the changes in the landscape of Doon valley. The paper also intends to suggest the method of adaptation to climate change and gives geo-environmental information on freshwater swamps and wetlands of Dehradun. The paper evaluates the impact of ecological degradation on wetland ecology, more particularly to the climate change and its geo-ecological implications.

The study aims to :

- Prepare a geo-environmental information system of freshwater swamps and wetlands of Dehradun.
- Evaluates the impact of climate change on wetland ecology, more particularly its geo-ecological implications.
- Assist in formulating an integrated strategy for the conservation of wetlands and method of adaptation to climate change.
- Prepare guidelines for wetlands conservation, 'regional adaptation programmes.'
- Create a wetlands management knowledge base, 'the local adaptation programmes.'

Research methodology :

This research avoided looking only at the wetland ecology, or any single dimension for that matter. Instead, it has strived to pay attention to the complexity of, and linkages between, ecology and social systems through an interdisciplinary approach combining ecological and social science methodologies, both qualitative and quantitative. If anything, that has been stressed upon is social science methodology and particularly qualitative research above other approaches.

Study Area :

Of the six conspicuous 'DUNS' between the Lesser Himalaya and the Siwalik the Dehradun Valley is the biggest Doon in shape. size and morphology. Sprawling between 29 55 and 30 30 N latitudes and 77 35 and 78 20 E longitudes with an area of about 2265 km2 and altitude of 315-2500 mts. from mean sea level. This longitudinal, tectonic synclinal valley is an irregular parallelogram in shape with its longer axes parallel to the Lesser Himalaya in the north and the Siwalik in the south. The axes are transversely closed by the rivers Yamuna and Ganga in NW and SE respectively. This valley is drained by the spring fed perennial rivers – the Suswa and the Asan and other tributaries. The Doon Valley has temperate climate. May-June are the hottest (35C – 42C). December – January are the coldest (5 - 4C to 13 - 9C) and annual rainfall is 215.9 cm. The soils includes coarse sand, sandy and silty loam in the Lesser Himalayas, sand and sandy loam in the Siwalik and sand, clay, sandy and silty loam and sandy clay in the central synclinal trough. Vegetation classes as identified includes – (i) Tropical moist deciduous forest, (ii) Low alluvial Savannah woodland forest, (iii) Tropical dry deciduous forest, (iv) Dry deciduous forest and (v) Himalayan moist temperate forest. The little more than half of the population lives in eight urban centres namely Herbertpur, Doiwala, Vikasnagar, Dak Pathar, Raiwala, Rishikesh and Dehradun. Economy of the valley is diversified encompassing agriculture, mining, horticulture, industries, sericulture and tourism.

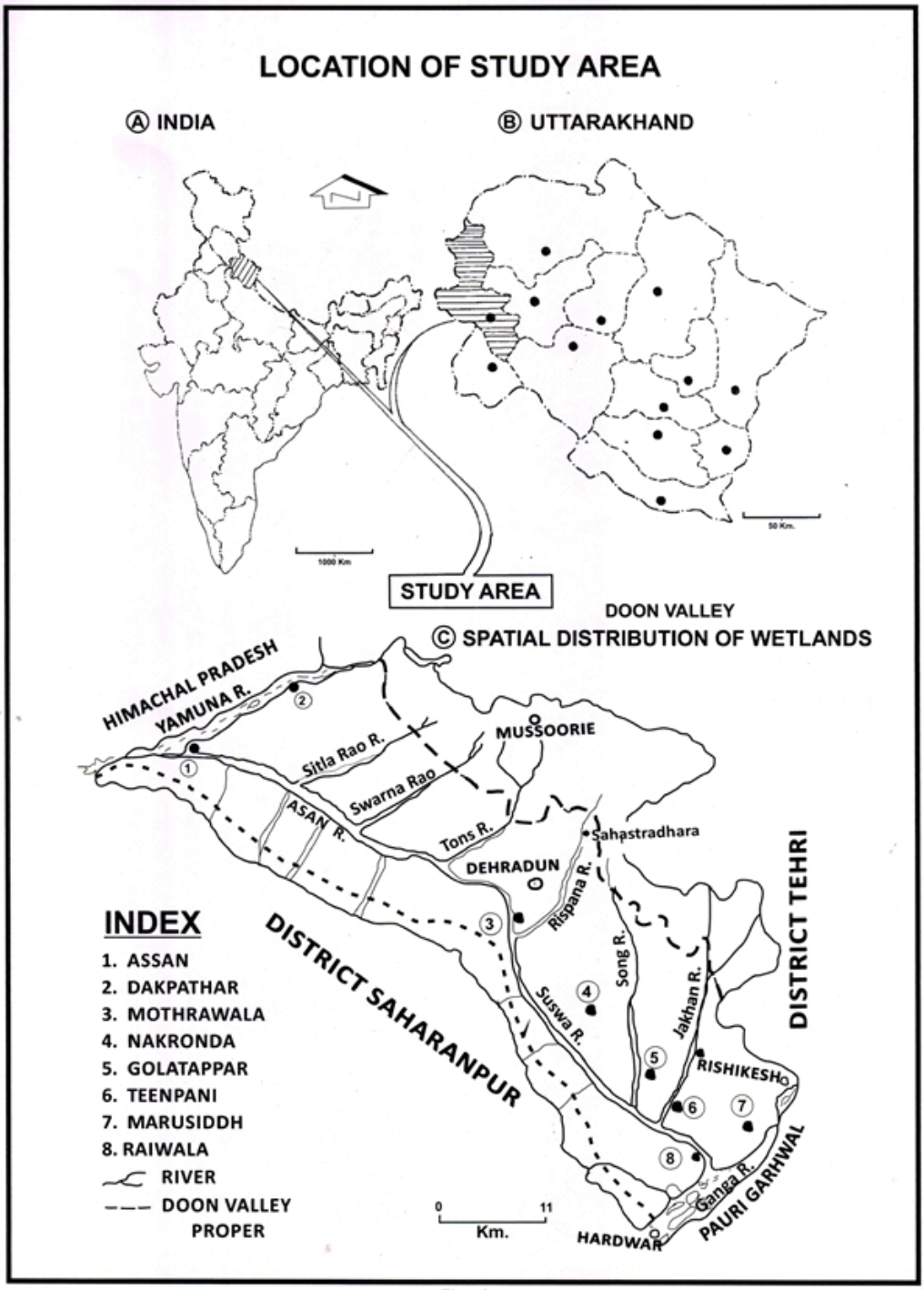

LOCATION OF STUDY AREA
Ⓐ INDIA
Ⓑ UTTARAKHAND
1000 Km
50 Km.
STUDY AREA
DOON VALLEY
Ⓒ SPATIAL DISTRIBUTION OF WETLANDS
HIMACHAL PRADESH
YAMUNA R.
Sitla Rao R.
Swarna Rao
ASAN R.
Tons R.
MUSSOORIE
Sahastradhara
DEHRADUN
Rispana R.
Song R.
Suswa R.
Jakhan R.
RISHIKESH
DISTRICT SAHARANPUR
DISTRICT TEHRI
PAURI GARHWAL
Ganga R.
HARDWAR
INDEX
1. ASSAN
2. DAKPATHAR
3. MOTHRAWALA
4. NAKRONDA
5. GOLATAPPAR
6. TEENPANI
7. MARUSIDDH
8. RAIWALA
RIVER
DOON VALLEY PROPER
0 11
Km.

Fig - 1

Spatial Distribution of Wetlands :

Location	Characteristics	Types of wetland
Assan	[illegible]	Riverine
Dakpathar	Developed through several processes, stream action forms oxbow lakes; manmade lakes.	Lakes
Mothrawala	Wetlands dominated by trees or shrubs. A wide range of vegetation types from grasses, herbs, shrubs, trees. They are often forested.	Swamps
Nakronda	Periodic flooding of land between a river channel and raised land on the edge of a valley; areas of low-lying flat ground over which rivers flood during high water.	Floodplains
Golatappar	Wetlands with predominantly grassy vegetation. A frequently or continually i nundated wetland characterized by emergent herbaceous vegetation adapted to saturated soil conditions.	Marshes
Teenpani, Laltappar	Periodically flooded forests, woody formation on ground that is totally submerged during the high - water season, can be found on low, poorly drained lands adjacent to watercourses or swamps.	Flooded forests
Maru Siddh	Characterized by aquatic plants, their growth is encouraged by the presence, for a large part of the year, of shallow stagnant water (in the case of a swamp) or muddy waterlogged soil (in the case of a marsh), both never fully dry out.	Swamps and marshes
Raiwala	Periodically flooded grasslands, herbaceous formations growing on soil that is completely submerged during flooding.	Flooded grasslands

Fig. 1(c)

Culture and Ecology :

Wetlands have a special historical and cultural importance in Doon valley. Traditionally, socio-cultural and agricultural practices in the Doon valley were formulated to manage wetlands in participation with local people and community. The conceptual framework for the management of

wetland area was directed towards a 'geo-ecological cultural model', one which revolved round the institution of 'Sidhh'. These Sidhh have important roles in shaping the past, present and future of the Doon valley. The name of the 'Sidhh' is perhaps derived from the Sanskrit word 'sidhha' meaning "the achiever of perfection". As per the Hindu tradition four Sidhh at four different locations of Doon valley were established by Maharshi Dattatreya. The Socio-cultural practices associated with these 'Sidhh' were closely attuned and adapted to the conservation and management of the regional ecology. Societies developed economy based on wetland resources and cultures set out direction for managing the natural resources for the benefit of its social, economic and environmental future. This interaction of ecology, economy, society and culture has given rise to a complex and sophisticated indigenous system of resource management. The ecologically sustainable management of the natural resources – based on an integrated 'ecosystem approach' was part and parcel of social and cultural practices. Focus of Sidhh was around a central concept of catchment management as the basis for wise use of wetland ecosystems. The approach was complex but the practice was simple. It required community participation to define and lead the developmental activities with 'shared interests and shared action'. Commitment to environmental conservation was enshrined in the institution of Sidhh. Management of natural resources was achieved by a common regional vision and community participation. Partnerships and collaborations were keys to success. This common vision and a collaborative ethos for a sustainable resource management led to the economic development. It focused on four central concepts: recharge, recycle, regenerate and reuse. All of them made significant contributions to 'Landscape Ecology'. People's participation helped in the fulfillment of aims and objectives of all these noble management policies.

Historical approaches to water management have been, and still are for the most part, based on an integrated 'ecosystem approach', which requires that ecological units be managed in their integrity. Focus of Sidhh was around a central concept of catchment management as the basis for wise use of wetland ecosystems and support for the conservation of natural resources. Activities were selected for resource management and for the generation of multiple goods and services that humans depend on, besides the social aspects, including community organization, villager's way of life, and the relation between people and community with the ecosystem. Regional wetlands are integral parts of larger landscapes; their functions depend upon the characteristics of the landscapes; the topography, climate and rainfall pattern; their extent and their location, the ecological and hydrological processes etc. Each wetland thus is ecologically unique. The functional and biological attributes of the wetlands are linked with the landscape ecology and the land-use patterns.

Shared Vision for Natural Resource Management :

The most important values of wetlands for human use in the Doon valley include water retention, replenishment of underground aquifers, and water quality improvement by removing or retaining nutrients, processing organic wastes, and reducing sediment before it reaches open water. Wetlands are crucial for food production - rice and several types of vegetables; for the occurrence of medicinal plants, wild food, etc.; and for the wild genetic sources of agro-biodiversity. As rightly and vocally expressed by people, water is the single most important resource for sustaining any form of life. It is crucial for sustaining biodiversity and for the livelihoods of the people. The recognition of water as a scarce resource, due largely to its highly variable seasonal and geographical distribution across the region, highlights the role of wetlands as water stores. Many of the wetlands of the region have no perennial source of water and they depend solely upon the monsoon rains. The draining of these wetlands, often to provide irrigation leads to rapid drying out of wetland. Thus, the management of scarce water flows was extremely important. Focus of Sidhh was around the central concept of catchment management as the basis for wise use of wetland ecosystems.

Resources in the wetland were held to be common property. The resource access rights come from the rights for basic livelihood; it included the duty for resource co-management within a framework of community rights. This implied that the communities regarded the wetlands more as

public resources than individual. It was controlled by traditions and morality. The philosophy of Sidhh constituted a form of community's capital which underpins an extensive knowledge system and forms of local wisdom developed specifically for resource management and utilization. The system of Sidhh also established a framework for ongoing learning in a 'plan, act, learn, improve' cycle. The knowledge the community regarding natural resources and environment management, was a form of knowledge reproduced from generations of experience, and one which offered a viable approach to mediating relations between humans and their natural environment. The approach cannot be classified as either production or conservation oriented, but rather an integrated approach to balance short-term production goals with sustainability concerns.

Wetland degradation :

Wetlands are undergoing rapid degradation due to increased anthropogenic pressure. An analysis of the major causes of wetland degradation reveals that reclamation of wetlands for cultivation to feed the growing population as one of the degradation pressure of landscape ecology. Another important cause is the rampant deforestation in the upper reaches of rivers augmenting heavy siltation in the lower areas, which in turn has reduced the flood absorption capacity of the wetlands. Reclamation of wetlands, destruction of a forest, or conversion of a specific land area anchors on the economic values or immediate monetary gains of the respective resource, but causes degradation of wetland. Water pollution and eutrophication is also taking. It has caused extinction of several native fish species. Over fishing, indiscriminate hunting of water birds, siltation etc. is serious threats faced by these unique wetlands.

Fresh water swamps of Doon Valley are also susceptible to the impacts of predicted climate change. Climate change - water shortages - warmer temperatures are likely to increase in near future. Spectrum of ecology, economy and society will be impacted by increasing temperatures, erratic rainfall, and various other vagaries of climate change. Societies and communities will find it difficult to adapt to. Warmer temperature as a result of climate change will likely to reduce river runoff. It will have negative impact on water sensitive systems (ecology and economy). Sudden collapse of environmental and economic system may occur and it will aggravate the environmental crisis. A vicious cycle where by each problem will exacerbate other problems which will feedback into each other.

Key Indicators of Climate Change:

Key Ecosystem Indicators	Impacts
Change in Vegetation composition	**Change in hydromorphic complexes; decrease in biological potential, increasing pressure upon wetlands and forests, upset the entire ecosystem as it will break the delicate balance of these sensitive ecosystems.**
Change in Habitat and Biodiversity.	**Habitat destruction and degradation, loss of ecosystem integrity, depletion of species abundance and diversity, increasingly degraded and fragmented, affect on food chain. Change the unique aquatic biodiversity.**
Change in Ecosystem Function	**Alterations of landscapes and ecosystem functioning. Changes in sensitive ecosystems, living condition, food chain etc. The unique ecosystem that contains fresh water species will be affected.**

Vulnerabilities to Climate Change :

There will be an increase in temperature. Higher temperatures will lead to Heat stress - the implications? "Recent scientific assessments indicate that, as the global temperatures continue to warm leading to climate change, the number and intensity of extreme events might increase." The joint effects of climate change will be either higher or lower precipitation, rise in temperature, and increased evapo-transpiration. It will alter the amount of available water by magnifying the differences between the rainy and droughty periods, drastically decline the ground water recharge. Potential drought and various other vagaries of climate change. Longer spells of dry heat will cause water scarcity in the long run. Water, essentially, one of the most important elements for life, will be most heavily impacted and degraded. Intensity of extreme events might increase, leading to over-use of fresh water resources and projected future increase. The water resources in any form and at any location will be affected.

(a) Water: Climate change - water shortages - warmer temperatures are likely to increase. Spectrum of ecology, economy and society will be impacted by increasing temperatures, erratic rainfall, and various other vagaries of climate change. Societies and communities will find it difficult to adapt to. This may cause a more extensive damage in future as climate change will make condition worse in some regions, particularly in the agro based densely populated areas. Warmer temperature as a result of climate change will likely to reduce river runoff. It will have negative impact on water sensitive systems (ecology and economy). Sudden collapse of environmental and economic system may occur and it will aggravate the environmental crisis. A vicious cycle where by each problem will exacerbate other problems which will feedback into each other.

There is constant anthropogenic pressure on water resources; demand for water will continue to increase, placing additional pressure on water resources. It will lead to rapid drying out and loss of all sources of water. It is not surprising that the impact of this will be very fast. What is alarming, however, is that the consequences of this change are still unclear as well as the rate at which this process is advancing. Increased demand for water will lead to over exploitation of water resources. It will led to dramatic alterations of landscapes and ecosystem functioning. It will further, result in increasing pressure upon wetlands and forests that have become increasingly degraded and fragmented. The abuse of wetlands – their unwise use – reduces their ability to perform useful functions such as water retention and flood control and other ecological function.

(b) Temperature: As temperatures rise, it would lead to major changes for sensitive ecosystems, thus the living condition will be affected. The unique ecosystem that contains fresh water species will be affected. The disturbances and threats can be broadly categorised as habitat destruction and degradation, loss of ecosystem integrity, depletion of species abundance and diversity. Even minor changes in water level may have major impact on these sensitive ecosystems. Habitat loss may aggravate the situation which could upset the entire ecosystem as it will break the delicate balance of these sensitive ecosystems. Species' habitats will decrease, thus the chances for various ecosystems to adapt naturally will diminish. At the level of ecosystem a large number of creatures in the food chain will be affected due to changes in the climate. It might pose serious threats – not only to the continued maintenance and functioning of ecosystems and their biological diversity, but to its well-being.

Impacts of Climate Change :

Key Indicators	Impacts
Increase in Temperature, Heat Stress and Potential Drought.	**An increase in temperature, higher temperatures will lead to heat stress; longer spells of dry heat will cause water scarcity in the long run.**
Climate Change	**Decreasing annual rainfall, increasing rainfall variability and temperatures, increasing intensity of both rainfall and drought, increasing temperatures, erratic rainfall.**
Increased Frequency of Extreme Events	**Increased frequency of extreme events. Increase in the number and intensity of extreme events, more frequent, longer natural disaster- flood, drought, and water scarcity.**
Impact on the Freshwater Resources	**Increased evapo-transpiration, alter the amount of available water by magnifying the differences between the rainy and droughty periods, over-use of fresh water resources and projected future increase, drastically decline the ground water recharge and availability of water.**
Loss of Biodiversity	**Loss of biodiversity, severe stress on biological potential due to climate change, potential drought and various other** 
Loss of Life and Livelihood	**Loss of life, crops and infrastructure, loss of livelihood due to increased storm activity, flooding etc. Decreased food production will cause problems for livelihood and food security**
Socio-Economic Impact	**Collapse of environmental and economic system, impact on agriculture, fisheries etc. Socio-economic impact, impact on human health. Resource related conflicts, potentially aggravating social and environmental conditions.**

Climate Change Risk Management :

Climate change is really a big challenge for fresh water and wetland ecosystem. There is no single solution to these threats. The solutions involve much more than addressing individual actions and reactions. To save the Earth for future generations and life, there is need to focus on bringing

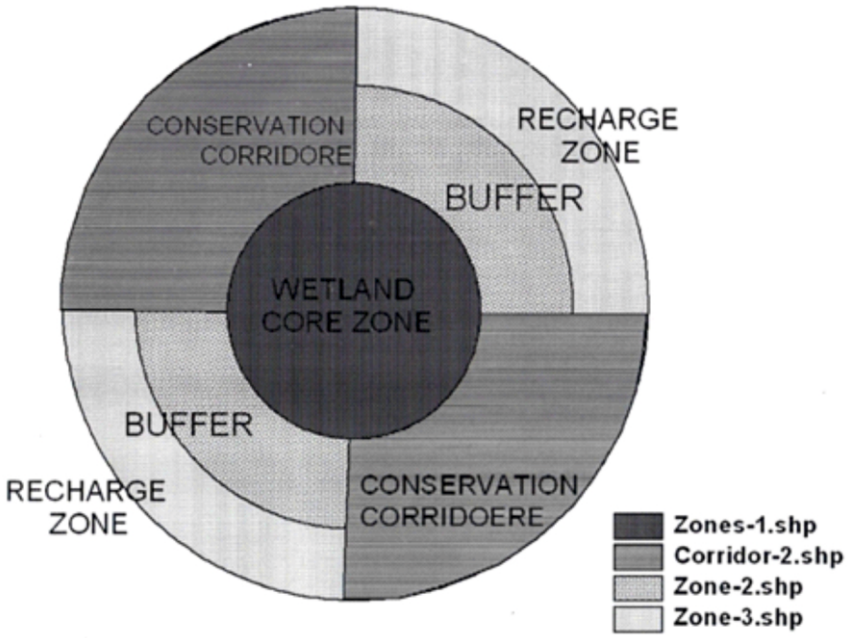
conservation and management requirements more in line with development activities, and vice versa, so that the two can focus on mutually obtainable goals. Adaptive responses to climate change; conservation and development will add to risk management.

The water resources require risk management and adaptive responses to climate change. There is need to ensure adequate recharge, as fresh water is the natural resource that underpins much of life on Earth and is an integral part of almost every living creature. Improved water harvesting and storage and rehabilitation of vegetation cover and grasslands, in particular, require urgent attention if condition suitable for existence and survival is to be maintained. The solution is not to be found in a single response. It requires a concerted, multifaceted approach to manage natural fresh water ecosystem and its resources. To minimize negative effects of climate change, ecosystem restoration is required. Involving local communities to explore possibilities of effective action and finally possibilities for action that can help contain the threat of climate change with local-level adaptations and management will prove to be an effective means of meeting local needs in terms of subsistence with conservation goals and goals of sustainable development. Sustainable approaches such as landscape management are slowly gaining recognition but, in the long-term, it is likely that these will have the most to offer – as long as there is still enough water to go around. There is need to give priority to raising public awareness on environmental issues, to mitigating the adverse effects of loss of all forms and all sources of water on the environment (ecology economy and society), control unsustainable use and to the conservation of water.

Micro-Catchment Development Model (MCDM) :

The integrated wetland management included the management of water body, adjacent marshy lands and watershed in a consolidated, integrated and participatory ways, entirely community-based and inclusive, involving every section of the community. Emphasis was given to the conservation of locally available floral and faunal species in the wetland and watershed areas. The wetland and its surrounding area are critical for the management of wetland. Conservation measures were taken regularly to rehabilitate the degraded catchment and forests. It was required to conserve and manage the landscape and ecology of this area.

The landscape ecology and land-use patterns were designed to maintain the functional and biological attributes of the wetlands. It included well demarcated zone of the wetland with a water inundated core zone that was maintained exclusively for wetland and a buffer zone around it. It was maintained as biodiversity conservation zone, with restricted access to significant areas. Encroachment, exploitation modification, manipulation and change in and around wetland areas were controlled by creation of wetland buffer across the region. It ensured adequate recharge, conservation and development. Maintenance of natural hydrology for storage and recycling, groundwater recharge, natural flood controlled and flow regulation was essential part of wetland conservation. Conservation of riparian and wetland vegetation; enhancement or protection was also required to maintain the functional and biological attributes of the wetland. There is need to Identify and protect significant areas for conservation of native flora and fauna. Habitat conservation / rehabilitation of this area demands for enhancement or protection of plant cover with native vegetation.



Micro-Catchment Development Model (MCDM)

Wetland and surrounding catchment is special environment zone. It is significant for habitat conservation and rehabilitation of wetland function. It has its natural significance in erosion control, maintenance of biological and genetic diversity and maintenance of ecosystem stability. It should have tree-plant-bush-grass composition with native plant diversity. It decreases the impact of runoff, minimises erosion into the wetland, supports the water filtration properties of the wetlands and decreases the impact of pollutants. Recharge zones is the catchment area, part of watershed that determines the water availability in the wetland region. Recharge zone or upper catchment maintains the natural hydrology to support native flora-fauna and wetland habitat. The intricacy of the hydrological cycle in wetland area is governed by landscape ecology appreciative of the relationship between the surface cover (vegetative cover) water yields and groundwater recharge. The natural precipitation enters the ground and adds to the groundwater reserves that feed the natural seepages around the valley slopes in the hills. The quantum of the rainwater entering the ground is a function of the duration of time for which the water gets opportunity to percolate. This retention time is decided upon by the nature of vegetal cover and physical resistances to the flow of water on ground.

Buffer- it is a special ecological zone around the wetlands (referred to as a filter/cushion for land development impacts on wetlands). It acts as buffer zones between land use and the wetlands reserves, with areas of restricted or no access. It also serves as habitat to several threatened flora and fauna species and provides suitable conditions for growth of native animals and plants, particularly threatened species. Conservation Corridor or wildlife corridor in buffer area connects wetland and surrounding catchment and provides barrier free passage or corridors for animal migration; ensure access, remains open to the wildlife where appropriate.

It is very significant for enhancement or protection of functional and biological attributes of the wetlands. Changes in ecological parameters lead to changes in the composition of flora and fauna. Hence, management landscape ecology is needed to manage a productive and reproductive environment. The management of wetlands is needed to mitigate the threats and sustain the assets of

these significant wetland areas.

Climate Change Adaptation Measures :

Key Areas	Adaptation Measures
Risk Management	**Risk management through; control of GHG emissions, technological upgradation, emphasis on energy conservation. Technological change has resulted in substantial energy savings and reduction in emissions through greater use efficiency and fuel substitution. Emphasis on energy conservation will prevent the risk of CC.**
Preventive Measures	**Promotion of renewable energy through various renewable energy sources, namely, wind farms, micro-hydroelectric plants, biomass & cogeneration power plants, biomass based gasifiers systems and solar photovoltaic systems.**
Adaptive Responses to Climate Change	**Adaptive responses to climate change; find, develop and exploit nonconventional energy sources, as well as energy development, both conventional and renewable.**
Mitigation and Adaptation Strategies	**Environmental quality and limit human health hazards from air pollution. Apart from energy conservation and efficiency improvements, resource minimizing cultural traditions, Encouragement to conservation and good practices**
Alleviatory Measures Carbon Sequestration	**Carbon sequestration through improving the quality of forests and regreening wastelands. Deforestation is arrested and the vast potential of afforestation is achieved**
Conservation and Management	**Conservation, efficiency improvements and development; improve energy and economic efficiency of the production capacity; bringing conservation and management requirements more in line with development activities, and vice versa,**
Curative Measures-Restoration of Economic And Environmental System	**Restoration of economic and environmental system, improved water harvesting and storage, needs to ensure adequate recharge of water and rehabilitation of vegetation cover and grasslands.**
Locally Relevant Measures	**Targeted adaptation to climate change; introduction of crops better suited to changed climate conditions. Introduction of new heat and drought tolerant plant varieties, Innovative farming water management.**
Capacity Building Generation of Knowledge and Awareness	**Capacity building measures - Generation of knowledge and Awareness, Development of monitoring and forecasting capacity, creation of an early warning system for increase disaster risk management.**

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