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Vulnerability to Climate Change and Adaptation : A Case Study of Fresh Water Swamps and Wetlands of Doon Valley and Siwaliks

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ABSTRACT

Unique freshwater wetlands, swamp forests, marshy and waterlogged areas are found on both flanks of Siwaliks by virtue of its location, topography (ranging from the lowlands to mountain regions and rolling plains of Doon valley) and high rainfall. These wetlands are considered to be important for regional geo-environmental conditions. Wetland provides a wide variety of habitats harboring unique biodiversity, helps to recharge water and stores the flood waters and storm waters. The region maintains significant areas of relatively intact ecosystems. Despite this, terrestrial ecosystems are at risk from desiccation, fragmentation and inappropriate water regimes due to increasing human interference. Freshwater swamps of Siwaliks are also susceptible to the impacts of predicted climate change. The major issues are rainfall changes, with the predicted reduction in average rainfall, increase in rainfall variability and drought frequency, higher temperatures and evaporation. It is also related to fire ecology changes and biodiversity. This paper gives geo-environmental information on lesser-known freshwater wetlands of Siwaliks and changes in the Siwalik landscape accompanied by ecological degradation in the region. The main objective of the present study is to examine the vulnerability of freshwater wetlands, marshy and waterlogged areas and swamps to climate change. Itevaluates the changes and their geo-ecological implications and suggests the method of adaptation to climate change.

Key Words : Wetlands, Doon Valley, Siwaliks, Vulnerability to Climate Change, Adaptation to Climate Change

INTRODUCTION

Tropical freshwater wetlands, marshy and waterlogged areas and swamp forests of Siwaliks once formed an important part of the Himalayan environmental system and extended all along the base of the Himalayas from Assam to Peshawar. By virtue of its unique location, topography and high rainfall, freshwater swamp forest ecosystems are confined to Siwaliks. The landscape around Dehradun has freshwater wetlands found on both flanks of Siwaliks. It also includes marshy and waterlogged areas (which store the flood waters and storm waters). These wetlands are considered to be important for regional geo-environmental conditions. It provides a wide variety of habitats harboring unique biodiversity.

The region maintains significant areas of relatively intact ecosystems. Despite this, terrestrial ecosystems are at risk from desiccation, fragmentation and inappropriate fire regimes due to increasing human interference. Degradation of the environment is impacting the condition of many wetlands. It is affecting downstream flow regimes and downstream ecology. Change in hydrological processes leads to significant reductions in stream flow, especially in drier years. In addition, native vegetation clearance in the upper catchments of many streams has increased flooding and significant in-stream erosion. Soil erosion risks have also increased significantly.

Fresh water swamps of Siwaliks are also susceptible to the impacts of predicted climate change. The major issues are rainfall changes, with the predicted

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reduction in average rainfall, increase in rainfall variability and drought frequency, and higher temperatures and evaporation. It is also related to fire ecology changes and biodiversity. Wildfires may become more common, with greater prevention and abatement costs. Biodiversity may be at risk from changes to rainfall and fire regimes with limited scope for adaptation by migration or dispersal. Primary production will become more challenging as rainfall variability increases.

Aim and Objective:

The primary objective of this study is to assess the vulnerability to climate change on the ecology of the wetland; the main aims of the study are to suggest the method of adaptation to climate change, conservation and management;

– To document the ecological profile of the areas; give geo-environmental information of freshwater wetlands of Siwaliks,

– To assess changes in the Siwalik landscape accompanied by ecological degradation in the region; the ill effects of human interference on the ecology of the wetland,

– Study the vulnerability of freshwater wetlands, marshy and waterlogged areas and swamp to climate change, evaluates the changes and their geo-ecological implications,

– To provide management recommendations for the conservation of the wetland; suggests the method of adaptation to climate change, suggestions for the conservation and management of wetland.

The study aimed at providing a geo-database based on Remote Sensing and Geographic Information System (RS & GIS) and also provide feedback for the effectiveness of environment and biodiversity conservation programs:

Case study of Swamps and wetlands of Siwaliks:

A case study approach is used for the impact assessment of climate change and to analyze the risk management of swamps and wetlands for environmental sustainability. A case study is a preferable approach when research questions are 'why' and 'how'. It is useful in examining and explaining contemporary events. In this research, the main question is how the predicted climate change will affect the swamps and wetlands of Siwaliks and how the vulnerability to climate change can better be managed for environmental sustainability. Therefore, a case study approach is appropriate.

Study area:

The landscape on both flanks of Siwaliksis selected as a study area for a number of reasons;

– The landscape has freshwater wetlands found on both flanks of Siwaliks. It has various types of wetlands including a wide range of habitat consisting of swamps, marshes and fresh water bodies, whether natural or artificial, permanent or temporary, static or flowing, such as riverine wetlands.

– This landscape has undergone drastic transformations due to expansion of agriculture, replacement of natural forest with commercial plantations of exotic species, industrialization and urbanization. As a result, natural habitats have fragmented and degraded causing local extinction of several species.

– The region has the highest percentage of wetland losses over the past few decades. The population of the wetland birds is also declining. This phenomenon is an indication of many environmental changes and possibly the degradation of the wetlands.

– The reason for selecting both flanks of Siwaliks as study area is that until recently this area has been neglected in terms of ecological studies and biodiversity assessments, no serious attempts were made to evaluate the long-term impacts of the change on the ecology and environmental degradation.

Therefore, these wetlands have high representativeness that can enable the generalization of the vulnerability of freshwater wetlands, marshy and waterlogged areas and swamps to climate change. It will significantly add to the baseline study (geo-environmental information) of the ecology of lesser-known freshwater wetlands of Siwaliks. It will evaluate the changes in geo-ecological condition, and their implications and suggests the method of adaptation to climate change.

Study sites:

A detailed inventory of wetlands is not available, except few wetland sites present in the Doon valley. Five research sites are selected for the present analysis. These study sites are all located relatively close to each other in the same eco-region. These locations represent the variety of physiographic conditions found within the region composed of fans of the Siwaliks, and yet remain similar enough to each other. Site selection was further done so that each site comprised of at least one wetland in each

physiographic zone, the Doon, the inner Terai and the river valley plain. Ecological sustainability with respect to the environment and biodiversity is an important factor in determining the choice of sites. Sites are also identified so that the clustering of sites is minimized.

Use of remote sensing and GIS in wetland management:

Wetlands are highly dynamic systems compared to terrestrial ecosystems. Remote sensing data in combination with Geographic Information System (GIS) are effective tools for assessment and monitoring of the environmental impacts of desiccation of wetland. The application encompasses wetland conservation and management also. Remote-sensing data paves way for monitoring and management of water bodies due to improving spatial, spectral and temporal resolution. Satellite data in association with the geographical information systems provide a cost and time-effective tool for identification, mapping and formulating conservation projects.

Studies have been made to delineate the vulnerable zones for environment management, using visual interpretation techniques to identify and delineate various geomorphological features. Temporal data helps us to obtain correct ground information about the status of ongoing changes over space and time. Satellite data has been used for the interpretation and delineation of flood-inundated regions.

IRS data having high spatial resolution and high temporal repetitiveness has helped in delineating the zonation of flooding areas. It has been used as input for the formulation of conservation and management plans for the development of land and water resources. Water resource mapping has been done for the delineation of temporal changes in the water spread. Various thematic maps on the hydro-geomorphological characteristics, drainage, surface water bodies and land use have been generated and integrated. The integration of remote sensing and GIS is thus helpful in conducting environmental impact assessments and evolving management plans.

Geo-environmental Appraisal of Swamps and wetlands of Siwaliks:

The Siwalik Landscape is one of the distinct eco-climatic zones parallel to sub-Himalayan tracts in north India. It is delimited by the Lesser Himalaya to the north and Indo-Gangetic Plain to the south. It includes; the Doon, Siwalik Hills and foothill rolling plain. This landscape is among the important ecoregions of the world, well known for its unique biodiversity and high productivity.

Physiographically, it is composed of fans of the Siwaliks. It is delimited by the Lesser Himalaya to the north and Indo-Gangetic Plain to the south. The fans of the Siwaliks are a long belt of the undulating, fairly sloping plain. (The landscape around Dehradun has fans on both flanks of the Siwalik range.) It can be divided into three distinct units, viz. the Doon, Siwalik Hills and foothill rolling plain, in descending order. The general elevation ranges between 300 and 600 m, adjoining the Siwalik range.

The Doon is a distinct eco-climatic zone parallel to sub-Himalayan tracts. The Siwalik Hills comprise of a mosaic of highly dissected nature of terrain with steep slopes and escarpments. It is located parallel to sub-Himalayan tracts in a north-west, southeast direction. Terai Landscape is subdivided traditionally into two units, namely, Bhabhar and the Terai; the Bhabhar is rather narrow and relatively dry having low water table, while the Terai is much more extensive and wet. The region is heavily traversed by the major river systems of the country. The Ganga and the Yamuna drain the region from the east and the west respectively.

This eco-climatic zone exhibits a tropical-type of climate. The climate of the region is characterized by a very hot and dry summer, a southwest monsoon season and a bracing cold season. The mean temperature in the area is more than 12°C during the coldest month (December-January) and the mean temperature ranges from 23°C to 30°C during the hottest month (June - July). The annual precipitation ranges from 1,000 to 2,500 mm.

This landscape comprises of fluvial sediments, which were deposited as a result of Neo tectonics of the Himalayas. As a whole, the stratigraphic succession shows the coarsening-upward (e.g., mudstone, sandstone and conglomerate) which reflects the rising Himalayas, while each fluvial succession shows the fining-upward succession. The soil of the region is a part of alluvial-Gangetic plains including the Bhabar region and the alluvial fans of the Siwaliks.

The natural vegetation is mainly of forest growth. The forests in the Siwalik zone are of the following types: dry Siwalik Sal forests; northern dry mixed deciduous forests and their sub-types and dry bamboo brakes. This landscape comprises a mosaic of cultivation, human

habitation and natural vegetation that has been heavily used by people. There has been extensive migration into the Terai after malarial eradication in the 1960s. As a result, there has been far greater recent deforestation. The natural vegetation is broadly divisible into four categories *viz.,* grasslands, secondary scrub and forests.

Wetlands of Siwaliks:

Regional wetlands are integral parts of larger landscapes, their functions and values to the ecology of the landscapes depend on both their extent and their location. Each wetland thus is ecologically unique.

The threats to wetlands may be divided into two broad categories: natural threats and anthropogenic threats, which may be direct or indirect. Natural threats include eutrophication, erosion, storm damage, drought or biotic interference other than by man, which may lead to the destruction of wetlands. Human intervention stops them to play their usual ecological roles. Ecological degradation of wetlands results in the loss of flora and fauna.

Case study -1 Shakumbhari Devi Wetland

Geo-Environmental Appraisal

This is a unique wetland being located in the lap of Siwaliks Foothills. The wetlands of Terai region have no perennial source of water and they depend solely upon the monsoon rains.

It is characterized by Swamps and marshes, aquatic plants (emergent or submerged vegetation, plants with floating leaves). Their growth is encouraged by the presence of shallow stagnant water or muddy waterlogged soil. It never fully dries out.

This wetland is an important ecosystem for waterfowl and has great potential for wildlife, besides serving an important role in ecological and hydrological functions.

Ecological Change Disturbances and Threats

The Disturbances and threats can be broadly categorized as habitat destruction and degradation, loss of ecosystem integrity, and depletion of species abundance and diversity.

There is constant anthropogenic pressure on Wetlands, demand for the modification of wetlands to agricultural land, particularly paddy fields, will continue to increase, placing additional pressure on wetlands. It leads to rapid drying out; at best they undergo vegetation changes and at worst are encroached upon for grazing or reclaimed for agriculture.

It has Further, resulted in increasing pressure upon wetlands and forests that have become increasingly degraded and fragmented. This fragmentation has the effect of fragmentation of habitat and reducing previously extensive wildlife populations into genetically isolated subpopulations, which is now at risk.

Vulnerabilities to Climate Change

There will be an increase in temperature. Higher temperatures will lead to Heat stress. The implications? Potential drought. As temperatures rise, the life cycle of wild animals and birds will be affected. They will find it difficult to adapt. A large number of creatures in the food chain will be affected due to changes in the climate. A spectrum of creatures will be impacted by increasing temperatures, erratic rainfall, and various other vagaries of climate change.

Climate Change Risk Management

Give priority to raising public awareness on environmental issues, to mitigating the adverse effects of wetland loss on the environment, and to the conservation of rare fauna and flora, and controlling unsustainable use, and over-harvesting of plant and animal products.

Case study -2 Mothoronwala Wetland

Geo-Environmental Appraisal

Mothoronwala wetland is a bog and swamp complex on Siwaliks foothills of Dehradun. It is humid and fairly green.

A continually inundated swampy area, Mothronwala wetland, is characterized by

emergent herbaceous vegetation adapted to saturated soil conditions. They are fed by monsoon rains flowing through natural water courses. This wetland supports rich biodiversity and controls the hydrological regime. Mothronwala swamp possesses peculiar vegetation due to topographic and edaphic variations. It has diverse and dense vegetation ranging from climbers and small herbs to tall trees. The benefits derived from the wetland include flood control, pollution reduction and water supply.

Ecological Change
Disturbances and Threats

Indiscriminate human interference has led to the degradation of the swamp forest to a great extent leading a very small green cover. The original forest vegetation had dwindled to a larger extent.

With regard to water quality and quantity, marked temporal variations have been reported. The exploitation of groundwater resources is causing a reduction in the water flow and the discharge of sewage is causing water pollution, which will ultimately affect the condition of the wetland. It is also threatened dueto profuse growth of water hyacinth, pollution and reduction in water inflow.

The unsustainable use of wetland resources is prevalent throughout; reclamation for industrial use or housing in urban areas, encroachment, cutting and filling, etc.

Vulnerabilities to Climate Change

Climate change threatens the wetlands through the joint effects of either higher or lower precipitation, temperature, and evapotranspiration. It will alter the amount of available water for wetlands by magnifying the differences between the rainy and droughty periods and drastically declining groundwater recharge.

Climate Change Risk Management

There is no single solution to these threats. The solutions involve much more than addressing individual sites or specific ecosystems.

To minimize the negative effects of climate change wetland restoration is required. Adaptive responses to climate change; conservation and development will add to risk management. Improved water harvesting and storage and rehabilitation of vegetation cover and grasslands, in particular, require urgent attention if this excellent condition is to be maintained.

Case study -3 Teenpani, Laltappar Wetland

Geo-Environmental Appraisal

Teenpani, Laltappar wetland is one of the largest freshwater wetlands located near Rajaji National Park. It forms a wetland together with Marsh covers. Periodically flooded forests can be found on low, poorly drained lands adjacent to watercourses or swamps. A permanent, shallow, freshwater lake and associated marshes with some adjacent riparian forests are found in this area. Lake and the associated marshes get flood during the summer monsoon and generally retain water throughout the winter and into early spring. It is prone to drying out in the dry season.

It is rich in biodiversity. The wetland is dominated by trees or shrubs. A wide range of vegetation types from grasses, herbs, shrubs and trees. They are often forested.

Ecological Change
Disturbances and Threats

The pressures facing the wetland are growing population pressure. Major threats are residential, agricultural and industrial developments; over-harvesting of wetland species; and pollution from industrial and domestic wastes. As a result, the wetland has been seriously degraded. Other threats include hunting of wildlife, the gathering of fodder and fuel, and the harvesting of certain aquatic plants for human consumption.

The wetland of Teenpani constitutes a highly productive ecosystem capable of supporting large sustainable harvests of fish, edible plants, firewood, and fodder. However, unless the conversion of these wetlands into agricultural land is stopped and

the present high levels of exploitation are reduced, the great economic value of the system will be lost.

Vulnerabilities to Climate Change

Climate change- water shortages are expected to become severe with the challenge of declining quality and overall loss of area of wetland ecosystems. Climate change and warmer temperatures are likely to increase evaporation and evapotranspiration which could lead to major changes for sensitive ecosystems. This may cause more extensive destruction of wetland habitats in the future as climate change will make conditions worse in some regions, particularly in the areas of swamps and marshes.

Climate Change Risk Management

Climate change is really a big challenge for fresh water and wetland ecosystem. There is a 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.

There is also a need for conservation of water through locally relevant measures of improved water harvesting and storage, wetland restoration, conservation and development. There is also need for rehabilitation of vegetation cover and grasslands.

Case study -4 Bhimgoda Wetland

Geo-Environmental Appraisal

This is the Man-made, riverine, lacustrine wetland formed due to the construction of a barrage located in Haridwar. Riverine wetland means 'of the river' with flowing fresh water. Floodplains also belong to the riverine system. It has ecologically-sensitive habitats.

It is described as an excellent permanent jheel, important for migratory and resident waterfowl. The area is important for numerous species of breeding, wintering and staging water birds and supports several notable plant species.

Ecological Change Disturbances and Threats

The wetlands are under threat. Wetland habitats are among the most heavily impacted and degraded of all ecological systems. What perhaps even more important is the fact that the only factor to which this degradation can be attributed, to the human interference and mismanagement of what is, essentially, one of the most important elements for life.

The principal threats to the wetlands are drainage for cultivation, conversion to agricultural land and general over exploitation of all the wetland resources. Human activities cause a considerable amount of disturbance.

Vulnerabilities to Climate Change

Climate change will lead to extreme weather conditions such as; longer spells of dry heat and more droughts. Longer spells of dry heat will cause water scarcity in the long run. The intensity of extreme events might increase, leading to the over-use of freshwater resources and projected future increases. It poses serious threats – not only to the continued maintenance and functioning of wetland ecosystems and their biological diversity but to their well-being. Species' habitats will decrease, thus the chances for various ecosystems to adapt naturally will diminish.

Climate Change Risk Management

To save wetlands for future generations and life, there is a 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. Wetlands and freshwater resources require risk management and adaptive responses to climate change.

The solution is not to be found in a single response. It requires a concerted, multifaceted approach to manage the natural freshwater ecosystem and its resources.

Case study -5 Assan Wetland

Geo-Environmental Appraisal
Assan wetland is a freshwater wetland with riparian habitat adjacent to the Yamuna, in Doon valley. It is a man-made wetland that came into being due to the construction of the Assan barrage at the confluence of the Assan River. The wetland has extensive submerged plain land. One of the most productive ecosystems influenced by free water accumulation, performs a major ecological role in the biosphere. It is a "Hot Spot" of biodiversity. Assan wetland has diverse habitats for many plant species, fishes, birds, insects, and other animals. It is in the fly way of migratory birds.
Ecological Change Disturbances and Threats
Conversion of swamps, marshes, lakes and floodplains for agriculture, housing and other uses has led to dramatic alterations in landscapes and ecosystem functioning. It is not surprising that as an impact of this, the Assan wetland is shrinking very fast. What is alarming, however, is that the consequences of this action are still unclear, as well as the rate at which this process is advancing. 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.

Vulnerabilities to Climate Change :

Warmer temperatures as a result of climate change will likely to reduce river runoff. It is likely to have a negative impact on the sensitive ecosystem of this area. The unique ecosystem that contains freshwater species will be affected. Even minor changes in water level may have a major impact on these sensitive ecosystems because very delicate and need to be maintained that way.

Habitat loss may aggravate the situation which could upset the entire ecosystem as it will break the delicate balance of these sensitive ecosystems. A sudden collapse of biological and ecological systems may occur and it will aggravate the environmental crisis. A vicious cycle whereby each problem will exacerbate other problems which will feedback on each other.

Climate Change Risk Management :

Involving local communities in wetland management is proving to be an effective means of meeting local needs in terms of subsistence with conservation goals. Sustainable approaches such as these are slowly gaining recognition but, in the long-term, it is likely that these will have the most to offer – as long as there are still enough wetlands to go around.

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, a rise in temperature, and increased evapotranspiration. It will alter the amount of available water by magnifying the differences between the rainy and droughty periods, and drastically decline the groundwater 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 of life, will be most heavily impacted and degraded. The intensity of extreme events might increase, leading to the over-use of freshwater resources and projected future increases. The water resources in any form and at any location will be affected.

Climate change - water shortages - warmer temperatures are likely to increase. A 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. This may cause more extensive damage in the future as climate change will make the 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 lead to dramatic alterations in 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.

As temperatures rise, it would lead to major changes for sensitive ecosystems, thus the living condition will be affected. The unique ecosystem that contains freshwater species will be affected. The disturbances and threats can be broadly categorized as habitat destruction and degradation, loss of ecosystem integrity and depletion of species abundance and diversity. Even minor changes in water level may have a 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 the 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 their well-being.

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 a 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.

Water resources require risk management and adaptive responses to climate change. There is a 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,

Appendices 1 : Fresh Water Swamps and wetlands of Siwaliks

Types of Wetlands	Characteristics	Location
Riverine	Riverine means 'of the river'- Flowing fresh water. Usually with low vegetation cover. Floodplains also belong to the riverine system.	Assan
Swamps	Wetlands dominated by trees or shrubs. A wide range of vegetation types from grasses, herbs, shrubs, trees. They are often forested.	Mothrawala
Swamps and Marshes	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.	Maru Siddh, Lacchiwala
Marshes	Wetlands with predominantly grassy vegetation. A frequently or continually inundated wetland characterized by emergent herbaceous vegetation adapted to saturated soil conditions.	Golatappar
Floodplains	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.	Nakronda
Flooded Grasslands	Periodically flooded grasslands, herbaceous formations growing on soil that is completely submerged during flooding.	Raiwala
Flooded Forests	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.	Teenpani, Laltappar
Lakes	Developed through several processes, stream action forms oxbow lakes; manmade lakes.	Dakpathar

multifaceted approach to manage natural freshwater ecosystem and its resources.

To minimize the 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 a need to give priority to raising public awareness on environmental issues, mitigate the adverse effects of loss of all forms and all sources of water on the environment (ecology, economy and society), control unsustainable use and the conservation of water.

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