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CUMULATIVE IMPACT ASSESSMENT IN THE SHARAVATHI RIVER BASIN#

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Sustainable development of a region requires a synoptic ecosystem approach that relates to the dynamics of natural variability and the effects of human interventions on key indicators of biodiversity and productivity. The concept of cumulative effects of the incremental reduction and erosion of the integrity of natural systems from the interactions of developmental activities provides a perspective to redirect impact analysis to deal with the driving causes of unsustainable development. An explicit attempt to monitor cumulative changes at catchment level due to hydroelectric projects is expected to lend itself to the establishment of notional ecological thresholds. This paper focuses on the cumulative effects that have taken place in the river ecosystem due to developmental projects over the last four decades.

BACKGROUND

Many of the developmental projects in the past have been implemented with little environmental concern in India. The assessment of the projects was based on only technical, economic and political criteria, mainly due to the fact that knowledge of environmental impacts and impact assessment technology were not fully developed at that time. As a result, a number of large-scale development projects led to adverse impacts on the environment. Environmental Impact Assessment (EIA) has gained tremendous importance in nineties and is mandatory for any major developing work in

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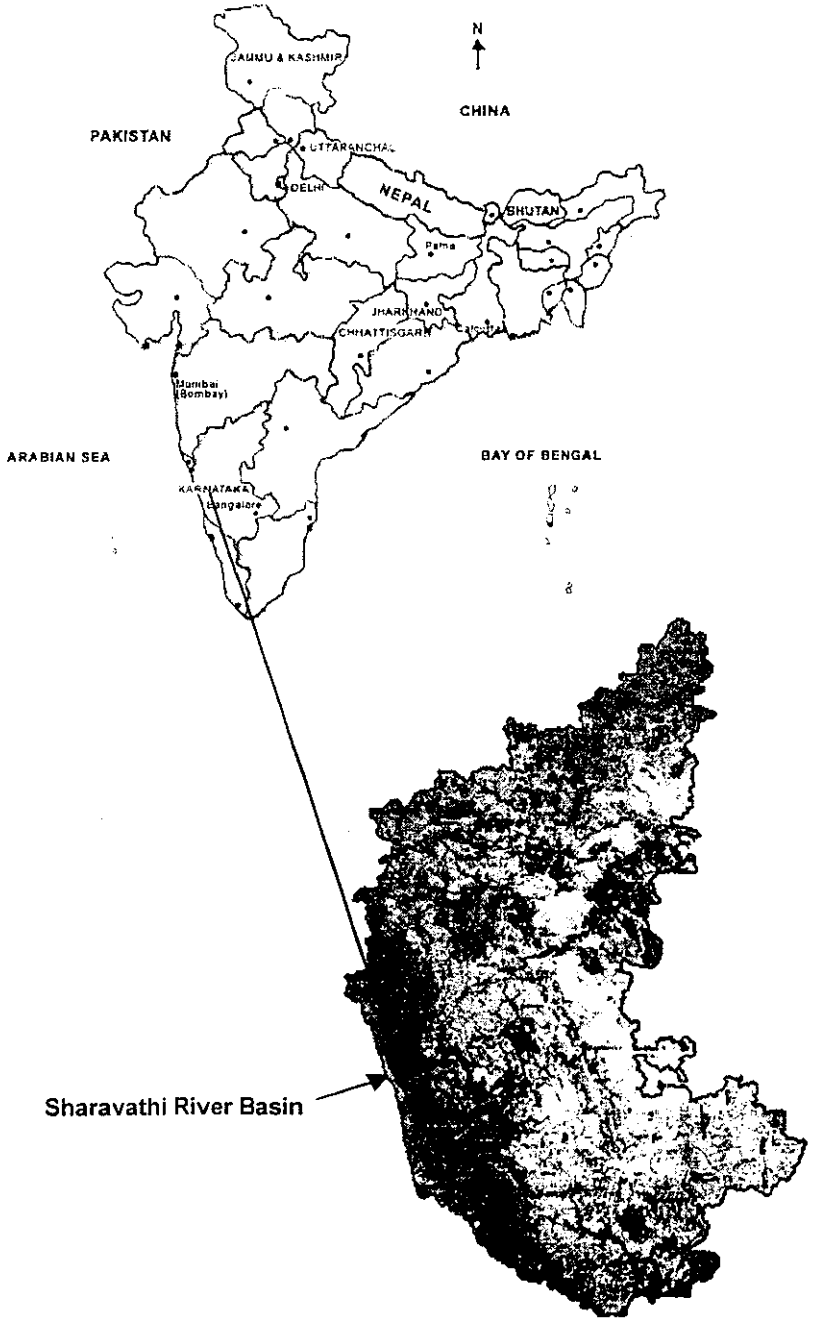
India An EIA is an effective tool in identifying and evaluating the potential impacts of the project, related to physical, chemical, biological and socio-economic components of the environment and in-turn reducing the likely adverse consequences, by proper mitigation measures, appropriate monitoring as well as auditing programmes. Normally, EIA is vastly implemented prior to project initiation. In absence of such investigations, the scope is expanded to include larger issues, such as biodiversity changes, sustainable development, economic valuation of natural resources and impacts etc., to assess the cumulative impacts. The projects that have not undertaken EIA, during the construction phase can be valued using Cumulative Impact Assessment studies. The Cumulative Impact Assessment or Cumulative Effects Assessment (CEA) considers systematically multiple impact sources, pathways between sources and impact receptors, and direct and indirect, additive and non-additive interactions

The practice of Environmental Impact Assessment (EIA) was nonexistent at the time of execution of the Linganamakki and Talakalale reservoirs. Naturally these projects had telling consequences on the fragile ecosystems of which no documentation, whatsoever, was ever made. The area affected had substantial tracts of species rich tropical forests with their varied kinds of habitats. These included climax forests, Myristica swamps, gallery forests, grasslands, and ecosystems of varied kinds. Also were lost large tracts of traditional agricultural systems, which harboured priceless heritage of domesticated biodiversity. The submersion of lands and consequent resettlements of the affected people as well as the influx of migrant population brought in for the various developmental activities in the region had tumultuous effects on the entire ecosystems. These included fragmentation of natural habitats, forest encroachments, poaching of wildlife, excessive extraction of forest biomass, disruption of wildlife corridors, diversion of streams for agriculture, over grazing, etc. After the passage of four decades, the need was felt to assess the cumulative impact of the Sharavathi river valley hydroelectric projects on the environment. In this connection, the Karnataka Power Corporation Limited approached the Centre for Ecological Sciences, Indian Institute of Science, Bangalore, which is one of the centres of excellence under the Ministry of Environment and Forests, Government of India, to undertake such a study.

STUDY AREA

The Sharavathi river originating in the central Western Ghats runs through the districts of Shimoga and Uttara Kannada (Karnataka state, India) and is depicted in Figure 1. The river has a catchment area of about 3600 sq. km (Figure 2). The river, and its tributaries and numerous streams run through the rugged terrain of the Ghats. The river, which takes birth at Ambuthirtha in Thirthahalli taluk flows northwesterly for 130 km to join the Arabian Sea at Honnavar, in Uttara Kannada district. At Jog, the river drops precipitously from a height of 253 m into a deep gorge creating, one of the most spectacular scenic places of the Western Ghats. The major tributaries of the river are, Nandiholé, Haridravathi, Sharmanavathi, Hilkunjiholé, Nagodiholé, Hurliholé, Yenneholé, Mavinaholé, Gundabalaholé, Kalkatteholé, and Kandodiholé.

Figure 1 : Location Map — Study Area



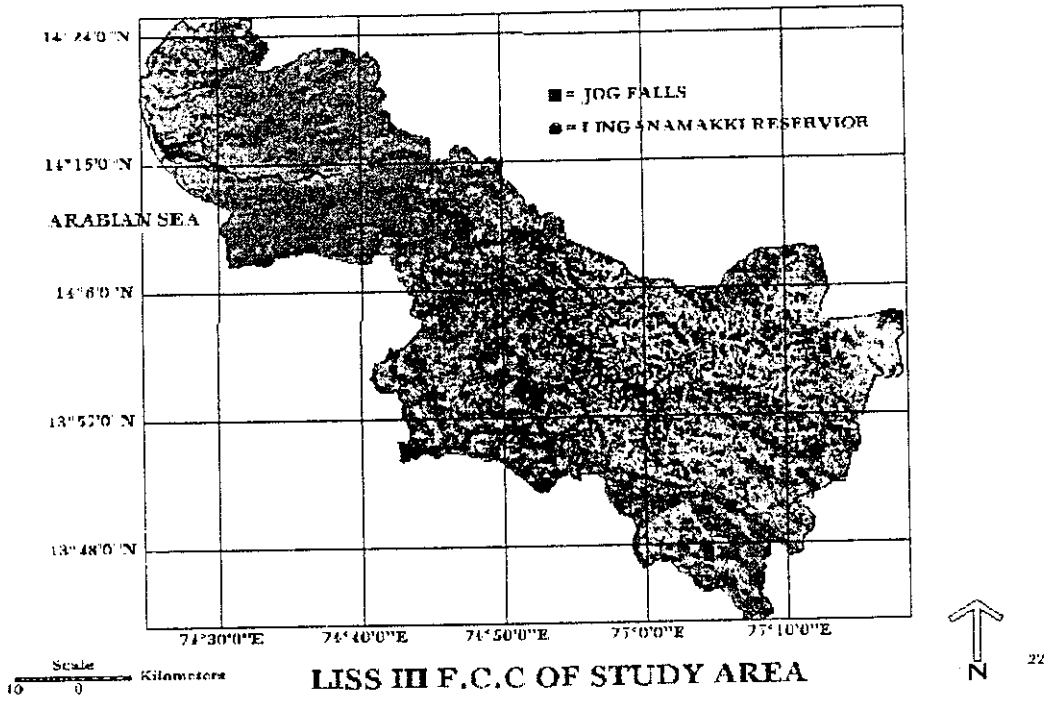
The river basin has been harnessed for hydroelectric projects to its fullest potential The Mahatma Gandhi Hydroelectric Project with present installed capacity of 120 MW was commissioned in 1948. This was followed by Sharavathi Generating Station (1035 MW) commissioned in 1964-65, the Linganamakki Dam Power House (55 MW) and the Sharavathi Tail Race Project (240 MW) at Gerusoppa in 2001. These account for about 45 % of the total installed capacity of hydroelectric power in the state. Sharavathi river alone, in its fullest potential, accounts for an estimated electricity generation of about 6,000 million units (kWh) per annum

The river water is stored in three major reservoirs, at Linganamakki (14° 10' 24"N, 74° 50' 54" E), Talakalale (14° 11' 10"N, 74° 46' 55" E) and Gerusoppa (14° 15'N, 74° 39'E) The areas submerged for these reservoirs are 326 34, 7 77 and 5 96 sq km respectively The Linganamakki reservoir resulted in the full or partial submergence of 99 villages in the Sagar and 76 villages in the Hosanagar taluks of Shimoga district, also causing the displacement of 12000 people The Talakalale reservoir resulted in the full or partial submergence of 3 villages in the Sagar taluk. Whereas, the Gerusoppa reservoir did not affect any populated village or caused any displacement of humans, but the submergence of 5.96 sq. km of tropical evergreen to semi-evergreen forests. In addition, for the Sharavathi Tail Race project 4.72 sq km of forest and 0 08 sq. km of other lands was also acquired for the township, roads, etc.

The current study went a long way in identifying the cumulative environmental impacts of river basin projects. In this regard, the foremost necessity was gathering baseline information on the prevailing ecosystem condition. The outcome of this study, carried out by a multidisciplinary team of scientists and engineers helped in diagnosing the adverse effects of the project on the ecology. This study highlights the need for adopting higher standards in environmental management, which should include conservation, restoration and management strategies for natural ecosystems, like the restitution of corridors of animal migration and improving the quality of aquatic ecosystems and terrestrial ecosystems surrounding the reservoir. The outcome of the study is also a substantial addition to the current benchmark database on existing biodiversity and ecology of the Sharavathi River Valley. The recommendations if implemented properly would certainly help in restoring and conserving the ecosystem in Sharavathi river basin.

The Linganamakki reservoir has a catchment area of nearly 1991 sq.km. It receives water mainly from rainfall and also from the Chakra and Savahaklu reservoirs, which are linked to Linganamakki through a canal The water from Linganamakki dam flows to Talakalale Balancing Reservoir through a trapezoidal canal with a discharge capacity of 175.56 cumecs. The length of this channel is about 4318.40 m with a submersion of 7.77 sq km It has a catchment area of about 46.60 sq.km. The gross capacity of the reservoir is 129.60 m cu m.

Figure 2: Sharavathi River Basin Western Ghats



Due to the hilly terrain, the submergence and consequent increase in water spread area has resulted in creation of several islands distributed throughout the reservoir There are about around 125 islands with sizes ranging from 2-3 hectares to less than 25 sq. km In most of the submerged areas the highlands and hilltops protrude out of the water-filled surroundings as islands During monsoon the water level reaches its peak leaving the top of the hills and hillocks on which the vegetation thrives. However, summer season interconnects the Islands as the water level recedes The remnants of once inhabited villages that got submerged during construction of the dam can be seen in this region as water level goes down The entire submersion area is rich in relics of varied kinds, which speak of its human habitation once. These relics include temples and idols, asphalted roads , pots and other earthenwares, stone inscriptions etc., lie randomly reminding us of the bygone history and culture Rows of dead stems of arecanut palms and remains of irrigation channels also surface when the water level goes down, in addition to the diversity of a trunks of dead trees

LAND COVER AND LAND USE ANALYSES

Land cover and land use analyses was done using remote sensing data as well as collateral data Geographic Information System (GIS) has been used for integrating remote sensing data with collateral data Supervised classification approach using Gaussian maximum likelihood classifier is used for classification of remote sensing data. This is done by collecting a training data (GCP) from the study area and GCP's were uniformly distributed all over the study area *Normalized Difference Vegetation Index (NDVI)* is the most commonly used Vegetation Index (VI) for land cover analyses. The results show that area not under vegetation ranges from 39 % - 46 % while area under vegetation ranges from 54 % - 61 % in the Sharavathi basin

Land-use change is significant to a range of themes and issues central to the study of cumulative impact assessment The alterations it effects in the surface of the earth hold major implications for sustainable development and livelihood systems. Land-use change analyses help to understand (i) the driving forces (exogenous variables) of land use as they operate through the land manager; (ii) the land-cover implications of land use; (iii) the spatial and temporal variability in land-use/cover dynamics; and (iv) impacts on biodiversity and ecosystem functioning Land use analyses of the upper river basin show that 25% of the area is under moist deciduous, followed by category II (21%, consisting of grass land, scrub, cultivable waste) , evergreen to semi-evergreen (16%), plantations (9 7%), agriculture (8 5%), water body (7.1%), class I (7.14%, habitation, roads, rocky area, etc) and dry reservoir bed (5 4%)

Human interventions in the ecosystem have resulted in erosion of biodiversity in the recent past in the river basin The loss in biodiversity has been attributed to habitat loss and fragmentation of the natural landscapes The analyses revealed extensive fragmentation in the river basin as a consequence of damming the river, conversion of forestlands to agricultural lands, and encroachment etc. Fragmentation has resulted in the remnant areas of native vegetation surrounded by a matrix of agricultural, horticultural and other human impacted lands. These in turn have important influences on the biota within the remnant patches, especially along the edges of the remnant patches as well as in the surrounding matrix. The fragmentation is fuelled by anthropogenic activities, which are degrading the forest habitat of the critical watershed areas Such human pressures have caused fragmentation of large, unbroken tracts of forests into, smaller isolated patches This process has lessened the value of the forest as a habitat for many of the plant and animal species native to the Sharavathi river basin, from where, it is feared that many are lost forever These consequences vary with the distance from the patches and connectivity with the other patches The physical distances and influences modify the size, shape and the position in the patch and its constituents The characteristics of the patch along with the spatial and temporal changes in the landscape were done to quantify the extent of damages The remote sensing data in conjunction with GIS and GPS helped in landscape characterization

Land use changes, Landscape dynamics and Landscape characterization have been analyzed from patch to river basin level to understand the temporal changes due to developmental activities in the river basin. Landscape analysis showed that the indices of shape, richness and diversity provided an additional evaluation of land cover spatial distribution within the complex mountain landscape. The landscape analysis has provided an outline of the degree of propagation of the disturbance from the non-biotic sources and fragmentation. It is revealed that fragmentation has caused loss of connectivity, ecotones, corridors and the meta-population structure.

As a result of the development programme based on ad-hoc decisions, considerable changes in the structure and composition of the land use and land cover in the region have been very obvious during the last four decades. Pressure on land for agriculture, vulnerability of degraded ecosystems to the vagaries of high intensity of rainfall and high occurrence of steep erosion and landslide-prone areas, lack of integrated and coordinated land use planning are some of the reasons for rapid depletion of the natural resource base. These changes have adversely affected the hydrological regime of river basins resulting in diminished river / stream flows. Frequent landslides damage the infrastructure and threaten human lives. In this situation, in order to resolve present problems and to avoid a future crisis, a comprehensive assessment of land use changes, its spatial distribution and its impact on hydrological regime is required and accordingly, appropriate remedial methods should be employed for the sustainable utilization of the land and water resources of the catchment.

BIODIVERSITY

Flora

The vegetation was studied using transect based quadrat sampling methodology in 140 localities of the Sharavathi upper catchment area and in 26 localities in the Sharavathi lower catchment area (*field investigations are in progress in the downstream region of the river basin*). The natural vegetation ranges from the climax tropical evergreen to semi-evergreen forests along the high rainfall areas of the main hill ranges of the Western Ghats to the moist deciduous forests in the undulating plains and low hills along the eastern drier tracts of the river basin. The landscape everywhere is in fact a mosaic of a variety of elements, which are caused by human impacts through historical times to current period.

The number of tree species per hectare in the evergreen to semi-evergreen forests is in the range of 35 - 60. The moist deciduous forests have 15 - 25 tree species per hectare. Basal area per hectare ranges from 35 - 60 sq. mt. in good forests. In the deciduous forests, the basal area ranges from 20 - 35 sq. mt. The evergreen forests are of high conservation value since they are great repositories of endemic species of the Western Ghats (50 - 80 % for trees). On the contrary, the deciduous forests, largely caused by human induced fires have endemism as low as 9 - 15 % for trees.

We have observed that there exists a high correlation between vegetation endemism and endemic fauna. Endangered endemic animal species such as the Lion tailed macaque, Slender loris, Jungle striped squirrel, Malabar pied hornbill, Saw scaled viper and the butterflies like Southern birdwing, Budha peacock are associated with the last relics of the climax evergreen patches. *Semecarpus kathalekanensis* an altogether new species of tree has its precarious existence in the endangered Myristica swamps of Siddapur Taluk.

The evergreens to semi-evergreen forests are the major sources of perennial water sources throughout the catchment of Sharavathi. On the other hand in the deciduous tract, the streams mostly dry up in the summer months. Therefore conservation of evergreen forests and restoration of such forests in the eastern parts of the catchment are of paramount importance.

Bulk of the water into the reservoirs comes from natural forests. Unfortunately in substantial part of the catchment area monoculture plantations have been raised causing the drying up of the streams and impoverishment of the ecosystems as a whole. Since the plantations do not yield any fodder or NTFP, the rural population is put to great hardships. Therefore such land uses are not desirable in the catchment area of this important river, which produces substantial part of hydropower for Karnataka state.

The river basin has a variety of habitats (21 listed in the report) that support rich flora of herbs, shrubs and climbers of which we have recorded about 215 species. Temporal seasonal surveys will reveal more number of herbs. Evergreen to semi-evergreen forests and grasslands of the Western Ghats have the largest congregations of endemic herbs. Some of the herbs are exclusive to specialized habitats like tree trunks and wet rocks. The increasing human impact and openings in forest canopy as well as over grazing by cattle are posing threats to many of the herbs.

The numerous streams and the banks of the river and its tributaries in the evergreen to semi-evergreen forest belt are lined with characteristic riparian vegetation of which the notable tree species are *Calophyllum apetalum, Elaeocarpus tuberculatus, Mastixia arborea, Hydnocarpus wightiana, Madhuca neerifolia, etc.* Towards the drier forests of the east the water bodies are lined with tree species such as *Pongamia pinnata, Madhuca neerifolia, Hopea wightiana, Bambusa sp,* etc. The riparian vegetation plays a crucial role in protecting the water bodies from siltation, creating shade conditions to maintain appropriate temperature regime for sustaining populations of endemic fishes, amphibians, phytoplankton, zooplankton and aquatic insects. Of late there has been numerous instances of misuse of the banks of streams and rivers in the catchment area causing severe upsets in the characteristic biota associated with them. Stream waters are often diverted to newly created horticultural farms thereby also affecting the water flow into the reservoir.

Fauna

Sharavathi River Basin is rich in animal diversity. The basin also covers part of Sharavathi Wildlife Sanctuary. The region is also adjacent to Mookambika Wildlife Sanctuary of Udupi District and Shettihalli Wildlife Sanctuary of Shimoga District. Many animals from these sanctuaries pass through the catchment area. Due to rising human pressures including creation of numerous monoculture plantations many of the migratory paths of the animals are disrupted. We have therefore proposed the creation of wildlife corridors to facilitate animal movements. These corridors are depicted in the figures 5-10

The study area harbours some of the endemic and endangered species of the Western Ghats. The major mammals found here are Gaur, Leopard, Sambar, Barking Deer, Spotted Deer, Mouse Deer, Common Langur, Wild Boar, etc. The Lion tailed macaque is an endangered endemic species found in dense evergreen forests. Tiger, Leopard, Wild Dog, Civet Cat, Sloth Bear, etc are rare animals in the study area. Some of the minor mammals are Indian Hare, Slender Loris, Flying Squirrel, Giant Squirrel. Common Indian Mongoose, Common Otter, Porcupine and Pangolin. Several species of bats, both frugivorous and insectivorous are also found.

A total of 140 species of birds has been sighted in the study area. Of the birds the order the most abundant are Passeriformes, which include the Flycatchers, songbirds, Warblers, etc. Notable endemic bird species include, Blue Winged Parakeet, Crimson Throated Barbet, Grey Headed Bulbul, Heart Spotted Woodpecker, Malabar Grey Hornbill, Malabar Pied Hornbill and Small Sunbird. The endangered Great Indian Hornbill was sighted near the Malemane village of Siddapur taluk

The wetland habitats include the reservoirs and their environs, the Sharavathi estuary and several tanks in the study area. The wetlands are dominated by both Passeriformes and the Ciconiiformes, the latter includes the Egrets, Herons, Ducks, Kites, Kingfishers, Coots, etc. While the lands are dominated by resident birds the aquatic habitats have by both resident and migratory birds.

A spate of construction activities in the lower catchment of Sharavathi river and ongoing and threatened fragmentation from the burgeoning human population are perilous to the habitats of several forest birds. There has also been considerable decline in the mangrove vegetation threatening the estuarine birds as well.

The notable reptiles are crocodiles (in the reservoir), turtles, King Cobra, Python, Saw Scaled Viper, Russel's Viper, Malabar Pit Viper, Striped Keel-back, Johnson/s Boa and the Flying Snake.

The notable amphibians and Caecilians observed in the river basin are, *Rana tigrina, Rana limnocharis, Rana curtipes, Philautus sps, Ansonia sps, Ichthyophis sps, etc.*

A total of 134 species of Butterflies were reported from the study area. Some are endangered and some are endemic species Notable among the butterflies are, Fluffy Tit, Monkey Puzzle, Southern Birdwing (the largest south Indian butterfly), Malabar Raven, , Paris Peacock, Malabar Banded Peacock, etc The diversity of butterflies is correlated to the diversity of host plants The varied kind of human impacts are posing threats to several rare plants thereby also affecting their dependent butterflies Examples are Crimson Rose, Malabar Rose, Southern Birdwing, (dependent on members of *Aristolochia* family), Blue Nawab (host plants unknown), Malabar Banded Swallow Tail (dependent on *Acronychia* and *Euodia*) Therefore while redesigning vegetation in the human impacted landscape of the catchment attention should be paid to the rehabilitation of these rare and endangered butterflies by planting their host plants.

Except for stray references no systematic study has ever been undertaken of the beetles, of which there is an amazing diversity in the Sharavathi catchment area We could record during a short period about 122 species belonging to 26 families. Many of these beetles are very specific to their microhabitats The beetles have important role in the ecosystem, as they are pollinators of several plant species including the endangered Myristica of the swamps

The diversity of common beetles such as the root grubs is high in the monoculture plantations These root grubs, of late, have become a major threat to the horticultural plantations, which contribute substantially to the economy of Uttara Kannada and Shimoga

In the absence of any previous studies on the ants of the Sharavathi catchment area, ours is a benchmark study. A total of 84 species of ants representing 31 genera under 5 subfamilies have been recorded from this study. Of the various habitats studied for ants maximum number of 64 species was found associated with deciduous forests. Some of the ants such as members of *Myrmicinae* are associated with all vegetation types.

Ants like *Polyrhachis mayri* are exclusively found inside undisturbed evergreen forest patches Some species of ants are indicators of disturbances. The islands of Sharavathi frequented by tourists are being inhabited by hot climate specialist ants suggesting disturbances (open canopy, hard soil and absence of litter cover). Such findings highlight the importance of keeping the pristineness of the fragile ecosystems of the Western Ghats from the forays of unplanned tourism.

Lichens are indicators of pristineness as well as disturbances of terrestrial ecosystems They are pioneers of vegetation and many of them can endure hostile environmental conditions. Some of the lichens have economic importance too. The catchment area is very rich in lichens. Of the 175 species reported from the Karnataka Western Ghats, the study area has 143 species.

The disturbing trend is that the *crustose lichens, with 108 species are found dominating the human impacted areas, especially exposed and fire affected places*.

On the contrary, the semi-evergreen to evergreen forests are poor in lichens because of denser shade and humid conditions. Therefore a constant monitoring of such indicator species is essential for the upkeep of the ecology of the catchment.

AQUATIC BIODIVERSITY

Phytoplanktons are the primary producers of aquatic ecosystems. They are also one of the rapid detectors of environmental changes because of their quick response to pollutants and fluctuating light and temperature conditions. Pollution stress reduces the algal species diversity but increases the number of individuals of few tolerant species. We studied seven streams as well as the reservoir waters in the upper catchment and ten streams in the lower catchment for phytoplankton. The study area has a rich diversity of 216 species belonging to 59 genera. Of these the diatoms are more common in streams and desmids in the reservoir. No algal blooms indicative of eutrophication was found during the survey. However, it should be taken with caution that all the waters of streams and the reservoir show light to moderate levels of pollution.

Zooplanktons are the secondary producers of the aquatic ecosystems. They transfer energy from primary producers to higher animals and therefore play an important role in the nutrient cycle of these ecosystems. Zooplanktons were studied in thirteen localities. The freshwater zooplankton of the river is rich and diverse. We could record 39 species. The species richness was low in lotic system compared to lentic water system. No large zooplankton was recorded mainly due to predatory pressures from fishes.

Insect groups like Mayflies, Dragonflies and Caddiesflies are important in the functioning of stream ecosystems. They are important links in the nutrient cycling in forest streams. They process wood and leaf litter and degrade them into forms absorbable by fungi and bacteria. These nutrients are absorbed by plants of the riparian zone. Aquatic insects also form food for fishes. During our study covering 12 sites and 20 sampling localities a total of 37 genera belonging to 27 families were collected. Votehalla in the lower Sharavathi catchment with 18 genera topped the streams in insect communities. In streams subjected to higher temperature due to poor canopy cover the generic diversity was low.

For the first time a monotypic genus i.e., *Phylloneura westermanni,* is recorded in the study area, which was earlier reported from only Nilgiris, Coorg and Wayanad in 1933 by Fraser, from a Myristica swamp of Kathlekan in Siddapur. The presence of Philorus in the Votehalla stream indicates its pristine nature and presence of primeval forests around. Some pollution sensitive genera have also been found in Kathlekan indicating the beginning of human disturbances.

The Western Ghats is renown in the world for the diversity of endemic fishes. A total of 51 species belonging to 32 genera and 16 families has been recorded only from the upper catchment of Sharavathi. From the lower catchment also 51 freshwater

fish species have been recorded The Sharvathi estuary has a total of 44 species of fishes. Altogether, the entire basin has a total of 112 species The prominent endemic species are *Tor khudree, Labeo fimbriatus, Puntius fasciatus, Puntius filamentosus, etc.* The investigation in the downstream has reported a new species - *Parabatasio sharavatiensis*.

The study of locality-wise species distribution revealed that, western streams and reservoir areas were dominated by native and endemic species and absence of introduced exotic species. Compared to this, on the eastern side most of the native species are gradually becoming rare due to insufficient food availability, disease and over exploitation. Epizootic Ulcerative Syndrome (EUS) affected mainly the, *Channa* spp , catfishes and minor carps. The outbreak of parasitic infection in *Mastacembelus armatus* (havu meenu) substantiates that the native fishes are continually being affected. The practice of targeting the breeding grounds (for fishing) is a threatening factor to native fish species like *Garra, Gonoproktopterus, Puntius, Labeo, Cirrhinus, Mystus, and Pseudeutropius* etc. Silt deposition in the reservoir due to poor catchment conditions has damaged the breeding areas of endangered species such as Mahseers.

AGROBIODIVERSITY

The Sharavathi river basin harbours diverse agriculture systems and the study revealed that the region has treasured 59 paddy varieties of which 29 are traditional. The genetically diverse traditional varieties well suited to the local environment are disappearing due to adoption of high yielding varieties, and greater spread of commercial and horticultural crops. The study also revealed that improper usage of modern techniques in agriculture has resulted in devastating effects on the environment Extensive use of inorganic fertilizers with the adoption of modern agricultural practices, has resulted in the conversion of self-sustained traditional system to a system depending on external interventions. This is one of the factors contributing to non-point source of pollution in the eastern region.

Soil Erosion and Siltation

Soil erosion is a natural phenomenon even in the pristine ecosystems. However, it gets accelerated due to removal of vegetation cover and disturbance to the upper soil strata The most severe soil erosion is taking place at the ecotone of upper limit of reservoir level and the adjacent terrestrial ecosystem. Soil-separates (gravel, sand, silt, clay, etc) are transported to varied distances depending on the catchment runoff and ultimately results in silting of reservoir, which reduces its storage capacity In western region, siltation is arrested by species such as *Holigarna, Madhuca neriifolia, Elaeocarus* and *Pandanus* etc. and by the multi-canopied evergreen forest itself

There are two paths of escape for surplus water - through infiltration into underground aquifers, and as surface water flows. Natural land cover has various properties that help to regulate water flows both above and below ground. Forest canopy and leaf litter, for

example, help to attenuate the impact of raindrops on the earth's surface, thereby reducing soil erosion Roots hold the soil in place, especially on steeper slopes, and also absorb water. Openings in leaf litter and soil pores permit the infiltration of water, which is carried through the soil into the ground water. Where ground cover is insufficient, sheet, rill and/or gully erosion may result. Such erosion reduces the productivity of the land and may result in sedimentation of watercourses down stream.

Streams eventually carry excess surface water to the ocean, though they may feed intermediate destinations such as lakes and wetlands. In their natural state, the network of streams in a catchment will slow down water flows so that there is a significant time lag between a period of peak precipitation and peak runoff further downstream. Riparian forests can serve as important buffers, reducing sediment loads and keeping runoff from moving too quickly into streams.

Growing vegetation allows retention of moisture and soil are able to absorb more solar energy than the previously sparsely vegetated surface. In addition moisture is available for evaporation, both at the soil surface and in the root zone. These changes affect the temperature and humidity of the lower atmosphere and make rainfall more likely. Conversely, in dry years soils tend to have higher albedos (absorbing less of the sun's energy) and there is less moisture available for evaporation, which can lead to a positive feedback in the opposite direction, yielding lower rainfall

Water Characterisation

Based on composite sampling, and physico-chemical and biological analyses the river basin is categorized into most disturbed (Sharmanavathi, Haridravathi, Keshwapura, Gazni, Sampakai, Gudankattehole), moderately disturbed (Muppanae, Talakalale Dam Reservoir, Debbe falls, Hosagadde) and least disturbed (Yennahole, Hurlihole, Nittur, Valagere, Dobbod) zones. The disturbance is due to anthropogenic activities in the catchment, mainly agriculture. Presence of coliform bacteria at Sharmanavathi, Haridravathi, Keshawapura and Nandihole indicates faecal contamination. This study also shows that salinity ingress was found to be absent at Gerusoppa and it decreases with increase in the river discharge.

Soil and Sediment Characterization

Soil samples were collected from 78 locations distributed all over the upper catchment and subjected to physico-chemical analyses Soils are rich in organic matter and low in phosphate, nitrate and sulphates concentration, while pH ranged between 5.5 - 6.8. The sediments have low sulphate (0.191 - 0.68 mg/gm), nitrate (0.0 - 0.0007 mg/gm) and phosphate (0.00024 - 0.001 mg/gm) indicating close correlation between sediment and catchment soil. The sediment samples are rich in organic carbon and the elements like Na, K, Ca, Mg are found well within the prescribed standards. Bulk density of sediments in streams of the western region indicates porous condition (0.783 - 0.983 gm/cm3) while in the eastern side they are less porous (1.23 - 1.475 gm/cm3)

ENERGY AND SOCIO-ECONOMIC STUDIES

Energy survey carried out in 447 households covering 42 villages in the catchment reveal that the majority of the population is dependent on bioresources to meet the daily energy requirements The dependence is of the order 85-92% and the per capita consumption corresponds to 1 2 tonnes per year, which is quite high compared to the per captia consumption in Karnataka state The major cooking device being used is the traditional Chula Bioresource status considering the availability and demand indicate that the villages in the eastern parts of the catchment have high levels of consumption of fuel, in the order 40-60%. Most of the households still depend on traditional stoves with efficiency less than 10%, which indicate that there is a scope for energy conservation by just switching over to the fuel efficient devices.

Among the surveyed households, landless labourers in the study area are deprived of many basic needs for their livelihoods Majority of them are unskilled and uneducated, which make them ineligible for getting any secure jobs The literacy level among the population ranges from 44% (female) to 64% (male). The annual income of each household with family size of 4.78 is Rs 9329.67.

THREATS AND MITIGATION MEASURES

- The fragmentation caused by the submersion of vast area and also due to biotic pressures (increasing settlements, agricultural fields, quarrying, fuel wood, fodder and NTFP collection, encroachment, roads in reserve forests, etc) Land use in the catchment needs to be strictly monitored for changes using satellite imageries and ground surveys. A centralized planning is necessary to maintain landscape in desirable state

- Lopping of branches for fuel wood and collection of leaves for fodder deprives animals of their food. JFM committees to be formed in the catchment area and be associated with future management of forests in respective village territories.

- Overgrazing in the region has resulted in scarcity of resources for wild animals. Village fodder farms to be created to safeguard forests and wildlife and to meet the needs of soil and water conservation as well as for other ecosystem needs.

- Conversion of forests to monoculture in vast areas for commercial purposes has affected the free movement of wild animals and deprived them of food and habitat. Monoculture plantations only serve either small mammals and agricultural pests as hiding places An action plan needs to be prepared urgently for reducing greatly area under monoculture by introducing forest species, an appropriate list of species is given in the report. Moreover conversion of plantations into natural forests is necessary for meeting other ecological requirements including enhancement of watershed value.

- Fire, within limits, has an ecological role to play in the Western Ghats But unregulated and frequent forest fires, accidental as well as intentional, have detrimental effects on the flora and fauna, and ecosystems as such necessitating appropriate management strategies such as creation of fire lines, restoration of evergreens, which provide greater fire immunity to the forests, adoption of a village centered fire management strategy etc

- Theft of forest products and poaching of animals have also affected the faunal diversity Strengthening of JFMs, creation of nature clubs in the village, and spread of awareness can go a long way in controlling hunting menace. The nature clubs may be affiliated to WWF State or NGO sponsored ecological or nature conservation/awareness movements. The village based nature clubs may be associated with animal census activities and other conservation centred activities

In this regard, there is a need for:

1 A comprehensive conservation strategy should be formulated immediately in consultation with stakeholders such as local villagers, environmentalists, and forest department personnel to conserve the unique flora and fauna of riparian ecosystem

2 Field observations show that many of the riverine swamps which harbour rare flora and fauna such as *Semicarpus kathalekanensis* and *Phylloneura westermanni are* under severe threat due to encroachment and expansion of agricultural activity. Immediate remedial measures need to be taken by forest department to stop such activities and conserve the endangered ecosystem

3 A detailed study, focusing on riparian forests is to be initiated immediately to document rare flora and fauna and evolve a conservation strategy for this unique eco-region-the Sharavathi Catchment.

RESTORATION OF HABITATS

The natural vegetation ranges from the climax tropical evergreen to semi-evergreen forests along the high rainfall area in the western side to the moist deciduous forest in the undulating plains and low hills along the eastern drier tracts of the river basin. The evergreen to semi-evergreen forests is the major sources of perennial water sources through the catchment of Sharavathi. On the other hand in the deciduous tract, the streams dry up in the summer months Therefore conservation of evergreen forests and restoration of such forests in the eastern parts of the catchment are of paramount importance.

Reforestation should not merely be a simple agglomeration of useful fast growing trees, but should stabilize ecosystem with built in dynamics of regeneration of multiplier effect. This would aid in natural balance in climate abetting rich growth of flora and fauna. Trees indigenous to the natural habitats of the region must be given due

importance. Local demands of fuel, fodder and medicine and minor forest produce like gum, fruits, spice etc should also be considered While planning, emphasis need to be laid on species that would meet fuel, fodder and biomass requirements of artisans like potters, basket makers, mat weavers, wood carvers etc.

List of plants recommended for restoration of forests especially in the drier eastern side of the catchment is given in Table 1.

Table 1: List of plants recommended for reforestation of dry areas of eastern side

Plant species	Common name	Ecosystem and human value
Acacia catechu	Khadira	NTFP, MD
Acacia concinna	Seege	NTPP
Bambusa arundinacea	Bidiru	NTFP, Fodder
Buchanania lanzan	Nurklu	EV, FR
Careya arborea	Kavalu	LM, EV, LM
Cassia fistula	Kakke mara	MD
Dillenia pentagyna	Kanagalu	EV, LM
Emblica officianlis	Nelli	NTFP, MD
Ficus benghalensis	Aala	EV
Ficus glomerata	Atti	EV, FR
Madhuca indica	Ippe	EV, NTFP, Leaf fodder
Mangifera indica	Mavu	MD, FR
Phoenix sylvestris	Ichalu	NTFP, FR
Sapindus laurifolia	Antavala	EV, NTFP, MD
Schleichera oleosa	Kindala	LM, Fuel
Semecarpus anacardium	Guddegeru	NTFP, F
Syzygium sp.	Nerlu	EV, F, MD
Zizypus jujuba	Bore	EV, FR

Note: EV:Ecosystem value, FR:Fruit; LM:Leaf Manure; MD:Medicinal; NTFP:Non Timber Forest Produce

SEMIEVERGREEN/*KAN* FORESTS

In the Linganamakki catchment especially in the eastern side there are some isolated small patches of semi-evergreen forests. These forests commonly known as *kans*, were formerly conserved by the local communities considering them as sacred.

These forests indicate the local climate to be favorable for sustaining evergreen to semi-evergreen forests. The latter type of forests has greater watershed and ecosystem value than deciduous forests. Therefore all efforts should be made to conserve the existing semi-evergreen forests and also enrich them with more evergreen species. The creation of such forests in all potential areas should be considered seriously. The species recommended for planting in the *kans* and semi-evergreens are listed in the table 2.

Table 2: Species recommended for the planting in *kans* and semi-evergreens

Plant species	Common name	Ecosystem and human value
Aporosa lindleyana	Salle	Fuel, FR
Artocarpus hirsutus	Hebbalasu	EV, T, FR
Caryota urens	Baini	NTFP, EV
Diospyros assimilis	Karimarlu/ Tumru	EV
Diospyros crumenata	Tumru	EV
Ficus nervosa	Neeruvate	EV
Flacourtia montana	Mullu sampige	EV, FR
Holigarna arnottiana	Sannele holageru	EV
Holigarna grahamii	Doddele holageru	EV
Knema attenuata	Hedaglu	EV
Mimusops elengi	Ranjalu	EV, FR
Olea dioica	Madle	EV
Syzygium cumini	Neralu	EV, FR, Fuel
Syzygium sp	Neralu	NTFP, MD, FR
Vitex altissima	Nviladi/Barnige	EV, Fuel

Table 3: Plants recommended for restoration of degraded areas in the western side

Plant species	Common name	Ecosystem and human value
Olea dioica	Madle	EV
Mimusops elengi	Ranjalu	EV, NTFP
Aporosa lindleyana	Salle	EV, FR
Dillenia pentagyna	Kanagalu	EV
Garcinia indica	Muruga	EV, FR, NTFP
Terminalia paniculata	Hunalu	EV
Flacourtia montana	Mullu sampige	EV, FR
Mangifera indica	Mavu	EV, FR, MD
Syzygium caryophyllatum	Kunnerlu	EV, FR
Syzygium cumini	Neralu	EV, FR
Artocarpus heterophylla	Halasu	EV, FR
Artocarpus gomezianus	Wote	EV, NTFP
Caryota urens	Baini	EV, NTFP
Emblica officinalis	Nelli	NTFP, MD, FR
Strychnos nux-vomica	Kasarga	MD, LM
Pterocarpus marsupium	Honne	Fodder, EV, Fuel

Table 4: List of plant for restoration of semi-evergreen forests in western region

Plant species	Common name	Ecosystem and human value
Aglaia anamallayana	Kempunola	EV
Artocarpus heterophyllus	Halasu	NTFP, F
Artocarpus hirsutus	Hebbalasu	EV, F
Canarium strictum	Kaidhupa	EV, NTFP
Dimocarpus longan	Kendal	EV
Garcinia morella	Harisina gurgi	EV, F
Holigarna arnottiana	Sannele holageru	EV
Holigarna beddomei	Doddele holageru	EV
Hopea ponga	Haiga	EV
Knema attenuata	Hedaglu	EV
Mimusops elengi	Ranjalu	EV, NTFP
Vepris bilocularis	Mangappe	EV
Polyalthia sp		EV
Mangifera indica	Mavu	EV, F
Symplocos racemosa	Chunga	EV
Caryota urens	Baini	EV, NTFP
Garcinia gummi-gutta	Uppage	NTFP
Garcinia indica	kokum	NTFP, MD, EV
Corypha umbraculifera	Talemara	NTFP, EV
Syzygium cumini	Nerlu	Fruit, MD

Table 5: List of plants recommended for restoration of evergreen forests in the Western region

Plant species	Common name	Ecosystem and Human value
Poeciloneuron indicum	Balgi	EV
Knema attenuata	Hedaglu	EV, F
Myristica malabarica	Rampatre	EV, NTFP
Myristica dactyloides	Patre	EV, NTFP
Persea macarantha	Gulmavu	EV
Calophyllum tomentosum	Surhonne	EV
Dipterocarpus indicus	Dhuma	EV
Palaquium ellipticum	Hadasale	EV
Ficus nervosa		EV
Mastixia arborea	Niratte	EV
Vateria indica	Saidhupa	EV, NTFP
Elaeocarpus tuberculatus		EV
Mangifera indica	Mavu	EV, F
Chrysophyllum roxburghii		EV
Canarium strictum	Kaidhupa	EV
Calamus sp.	Betha	NTFP
Syzygium gardneri	Nerlu	EV, FR

- Compensatory Forest in Non-forest Area: Compensatory forest raised by KPCL to make up for the loss of forest submerged (700 ha) in Sharavathi Tail Race project is undertaken in the non-forest area of 700 ha in Thirthahalli taluk of Shimoga district at an estimated cost of Rs. 77 lakhs. Subsequently these lands have been transferred to the Forest Department.
- Afforestation in Wastelands and Degraded Area: The suitable species for such areas within the different forest types are given in the tables.
- Restitution of corridors of animal migration as depicted with maps.
- Restoration of Disturbed Patches by Planting Native Species -Details on the species to be planted in such patches falling within various vegetational regimes are given in the tables referred to
- Degraded and vulnerable areas to be considered as priority areas for afforestation and soil conservation program
- Environmental Safeguards related to Dam Safety and any possible usage of Hazardous or Toxic materials in any activity in the region

WASTELAND REHABILITATION AND MANAGEMENT

The characteristics and descriptions of land use (agricultural, wastelands etc.) in the eight sub-basins of the Sharavathi upper catchment were given in the *previous sections*.

The main objective of proposed wasteland management is to meet:

1. The domestic requirements of fuelwood, fodder, timber forest produces in rural areas
2. NTFP (non-timber forest produce) for rural population.
3. Soil conservation, to create shelter belts or wind breaks and to reclaim ravine and gullies
4. Maintenance of ecological balance, biodiversity, ground water recharge and a healthy food web.

These purposes can be met by the selection of appropriate species in the sub-basin based on the land use, soil class or soil capability class, agro-climatic zone, temperature etc.

The factors for species selection includes:

- Silvicultural characteristics.
- Utilization potential

- Weightage for site-specific native species.
- Avoiding exotic species as far as possible and only considered when the indigenous species are unable to thrive in degraded ecosystem
- Afforestation should involve a multi-species approach. This would be more resistant to pest and diseases, and equally efficient in utilizing environmental resources. This can also act as a soil cover and serve in regeneration of soil
- To generate rural employment and also to involve the local population in afforestation, farmer's nursery movement needs to be promoted.
- Wastelands under high-tension line need to be used for productive purposes. Village fodder farms and medicinal plant gardens may be started under the management of village Self Help Groups (SHGs). By bringing such lands under the local community management fire hazards can be prevented. Planting of moisture retaining plants would also assist in reducing fire hazards.
- The plant species suggested for reforestation of open, fallow and degraded lands of low rainfall zones in the eastern part of the catchment are *Acacia catechu, Acacia concinna, Butea monosperma, Pongamia pinnata, Schleichera oleasa, Madhuca indica, Emblica officinalis, Cassia fistula, Strychnos nux-vomica, Odina wodier, Dillenia pentagyna, Xylia xylocarpa, Buchanania lanzan, Careya arborea, Terminalia chebula, Pterocarpus marsupium, Phoenix sylvestris Mangifera indica, Dendrocalamus strictus, Bambusa arundinacea, Azadirachta indica. Cordia myxa, Aegle marmelos, Sapindus laurifolius* and *Spondias mangifera*

SOIL EROSION AND SILTATION

Solutions to this part of soil erosion problem may come from searching for suitable plants that could grow well at aforesaid ecotone. In estuarine wetlands this problem is even more severe than inland reservoirs because of stronger wave action. However, nature has a solution in the form of mangrove vegetation. Experiments with available and speculated-to-be suitable plant species can be tried.

Species like *Ipomoea carnea, Ipomoea biloba, Ipomoea aquatica, Saccharum sps, Terminalia arjuna, many other aquatic and semi-aquatic plants (creepers-cum-floaters), Cyperus species etc can also be tried. The riverbeds of fluctuating water levels could be looked for suitable plant species. Even mangrove plants like Clerodendron inerme, Ipomoea biloba, Derris sp., etc.* could be tried. The difference between estuarine wetlands and the reservoirs is that mangrove plants have a very long evolutionary history compared to the plants interacting with inland reservoirs. This is because the dams and reservoir (wetlands with highly fluctuating water level) are of recent origin from the point of view of evolutionary time scale. Flood-tolerant species like *Holigarna, Madhuca neriifolia, Elaeocarus* and *Pandanus* etc can be tried. Among the colonizers

on the exposed area below the Full Reservoir Level, three species were noticed besides other plants; these were *Cynodon, Eupatorium* and *Cleome* Even if some species from these plants start growing well in this exposed area, the erosion will reduce. This ecotone zone should be searched whether suitable plants have evolved. Plants suitable for such erosion prone areas may be propagated. *Cynodon* is good for cattle but here it should not be allowed to be grazed. *Eupatorium* is a difficult exotic weed and not good except for its low quality biomass. *Cleome* is a weed as well as a crop. (Please note that no plants can grow in submerged state, except hydrophytes). The others grow seasonally, only when the water level goes down. Grasses are the best option, because of their spreading nature)

ENERGY MANAGEMENT

Lack of employment opportunities throughout the region is one of the main reasons for poverty. Employment programs are important elements for economically sustainable development. These programs should aim at enhancing the employment opportunities by utilizing the technology and thereby increasing the labour productivity. Training camps can be started to train these unemployed and under-employed persons in various non-farm activities This will diversify the employment opportunities thereby increasing their income. Establishment of self-help groups can be another possibility. Self-employment of rural women can improve their financial situation.

Shifting to improved cook stoves and other energy sources can conserve about 40 % of fuel wood consumption. Low cost and compact designs should be developed in case of biogas plants, by which the technology can reach the poor people, who really deserve it. These alternatives once again decrease the efforts of rural women in fuel wood collection Reducing the burden of fetching fuel, fodder and water can certainly help the women to engage in productive and income generating activities. Primary education comprising health, nutrition, family planning, water and sanitation is highly essential for women. Providing basic amenities such as basic education, primary health care, low cost water and sanitary facilities is one of the effective methods to improve the quality of life to a large extent. Investing on road networks can be one of the effective methods to improve the poor links between all parts of the catchment. Establishing some of the satellite places to main head quarters, where people can get the basic facilities easily can minimize the transportation problems to certain extent. Providing protection to the degraded forest patches can regenerate them to the original condition and emphasis on appropriate methods of fuelwood collection can drastically reduce the stress on forests Further, afforestation programmes with preference to native species need to practiced to meet the energy requirements of the region.

Even though the Linganamakki Dam has been constructed with solely power generation purpose, several villages in the catchment (mention some) still lack the power supply. Electricity is the prime amenity required and facilities should be made to reach it to rural areas as well.

ECOSYSTEM MANAGEMENT

Anthropogenic activities due to these developmental projects have caused considerable fragmentation of natural habitats. Encroachments and conversion of forest lands for human habitation and agriculture, etc. have aggravated the fragmentation of otherwise contiguous habitats. Submersion and fragmentation of forests have seriously affected wildlife habitats and wildlife movements considerably. In recent times, it is reported that smuggling, poaching and hunting of rare species of fauna in the catchment No effort was made to prevent the causal factors of fragmentation. It is noticed during fieldwork encroachments, poaching and smuggling is unabated and sometime it is done at authorities connivance In addition to this extraction of industrial timber and clear felling of virgin forests to raise teak and eucalyptus plantations are persistent This has hampered, ecosystem productivity, which is evident from conversion of perennial streams to seasonal streams, reduced biomass productivity and disruption of wildlife movement and migration corridors.

Prior to the Sharavathi River Valley projects, elephants used to move freely to the northern parts of Uttar Kannada. With the commissioning of various projects very little attention was paid to the animal migration corridors, so much so that, one small herd of elephants was trapped in the Gerusoppa and has disappeared now. Similar situation is observed in Kali river catchment small herds still live confined to Dandeli forest patch. In the absence of effective regulatory stipulations on environmental safeguards, and lack of understanding of niche requirement of fauna and flora he Sharavathi River Valley ecosystems have eroded considerably during the late twentieth century

Some of the families returned to Sharavathi catchment due to lack of proper infrastructure at rehabilitated localities. This along with arrival of migrant workers and traders from neighboring states has led to large-scale encroachments Other factors that has contributed to devastation of environment are quarrying, unplanned agriculture development and plantation activities. This has caused severe impact on the flora and fauna and their habitats as well as influenced silt movement ending up as depositions in the streams and ultimately in the reservoir

Establishment of Monitoring team to plan, coordinate, implement and evaluate all the associated aspects as indicated in the recommendations.

Implementation of the Soil Conservation / Afforestation Program.

— Identification of waste, degraded lands and potentially disturbed patches as indicated by the current study.

— Implementation of the afforestation progarmme by the Forest Department and Agriculture Department by planting the species as indicated by the study.

— Bund construction and small check dams to be constructed by the KPCL at places in the reservoir potentially identified for soil erosion and siltation due to landslides.

— Agriculturists and native residents/villagers to be encouraged to venture plantation of leguminous plants and suggested species in patches of wastelands/ non-arable lands (to restore these lands)

— Peoples' participation to be extensively advocated in the implementation of afforestation and other conservation programs