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About Guest Editor

Dr. Aparna Watve teaches as Assistant Professor (Environment) at the Tata Institute of Social Sciences, Tuljapur campus. She has been studying the ecology of Rock Outcrops for the past 15 years and has published her work in several international journals of repute. She coordinates a network of individuals and organizations working towards conservation of Rock Outcrops in India. She is also involved in many research projects and field action programmes which link environmental conservation with well-being of local communities.

Reviewers

The papers titled 'Research' in this journal have gone through a double-blind peer review process from eminent researchers in the respective field. All other contributions have also undergone peer review from experienced reviewers.

About the Journal

- The Journal of Ecological Society is published annually.
- The opinions expressed in the papers here are not necessarily those of the Ecological Society.
- The Journal is available digitally at our website at no charge.

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Contents

Foreword

We are pleased to present the 28th issue of the Journal of Ecological Society. As in the past, this issue of the journal publishes papers and articles which integrate various scientific disciplines through a socio-economic approach. Since its inception, the journal has catered to diverse readers including nature lovers, students, researchers, environmentalists and scientists. Considering the different expectations that such an audience imposes, the journal encourages scientific research papers, field reports and opinion articles.

This issue presents two special sections – one on Rocky plateaus and another on Ecological Society's field work in the Panshet catchment. Both the sections have detailed field reports while the Rocky Plateau section also has scientific research papers. The research papers are multi-disciplinary scientific studies which have undergone a double-blind peer review process. The reports are descriptive articles which would normally not be published as research. Reports and miscellaneous articles undergo reviews by the editorial team and relevant subject experts.

We are privileged to have Dr. Aparna Watve as the guest editor for the current issue. Dr. Watve is a senior researcher who has spent several years studying rocky plateaus in the Sahyadris. She has many international publications to her credit and is a faculty at Tata Institute of Social Sciences, Tuljapur. The section on Rocky Plateaus deals with research being done on these ecosystems in the Northern Western Ghats. The last few decades have seen increasing efforts in nature conservation in India. However most efforts are directed to ecosystems which have an observable or tangible benefit to man. Unfortunately the Rocky Plateaus have largely been overlooked by policy makers and conservationists alike. These plateaus have almost no soil cover and do not support farming. This is perhaps the reason why they have been mistakenly labeled as wastelands. Located in the Northern Western Ghats, the source region for many large peninsular rivers, these rocky plateaus are veritable regions which recharge underground sources with fresh surface water. Considering the vagaries of monsoon in India, this turns out to be a critical ecological service for mankind. However, with utter disregard, many of the large rocky plateaus have been used for windmills, rock and mineral mining and building and construction activities. The report on the Chalkewadi windmill farm takes an interesting approach and examines the habitat destruction and alterations in water flows due to planned and unplanned roads on this rocky plateau.

We are fortunate to have a group of scientists and researchers who have focused their efforts on understanding these ecosystems and their role in the environment. Although some of them are ongoing longitudinal studies, considering the increasing rate and scale of assault on these ecosystems, the Journal of Ecological Society considers it critically important to publish these studies for a wide audience. We are hopeful that our erudite readers will help in spreading awareness of conservation efforts on these rocky plateaus.

The Panshet section presents a comparative report on the socio-economic conditions of the Panshet catchment region. This is based on a field study conducted by the Ecological Society in which a comparison is made with the detailed Panshet study undertaken by Prakash Gole and his team in 1985. Some of the findings in the report are disturbing. The region is highly attractive for urban buyers wanting second homes away from cities. Large tracts are being used up for farm house plots. If human interference continues at this scale in the watershed region, we are likely to lose the last remaining pristine forest patches in this belt.

One of the objectives of this journal is to initiate dialogues between our readers and the authors. We invite your comments and look forward to interactions on the topics in this issue.

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Foreword to the Special Section on Rocky Plateaus

This Issue of the Journal of Ecological Society includes a research section with peer-reviewed research on rocky plateaus of Northern Western Ghats. The idea was conceived while discussing with various groups conducting research and conservation action in the region, with special emphasis on rocky plateaus.

Research on rocky plateaus at present spans a range of subjects from taxonomy, ecology, community use to conservation action and advocacy. However, only a small fraction of it, one related to taxonomy and ecology, finds a place in scientific journals. The readership of such journals is limited to scientists, and they are rarely accessed by citizens from other disciplines and conservation practitioners. Considering the diverse subjects being researched, any publication arising from them will be placed in separate disciplines, effectively diffusing the focus from "rocky plateaus", a sensitive, highly fragile habitat and its multiple dimensions, which should find a place in regional conservation planning.

The solution to this problem was suggested by the Editorial team for The Journal of Ecological Society. It was planned that for one issue, the research section of the journal will accept research papers and articles on the special habitat of Rocky Plateau. The papers can now be read and reflected upon collectively by the wide diversity of readers of the journal. At the same time, the research finds a perfect niche for interdisciplinary research, not offered by other journals. This has become possible only due to the far- reaching vision of Prakash Gole, founder of Ecological Society, and the team working for more than two decades to establish the journal and to create a conducive atmosphere for interdisciplinary research and action at grassroots level.

This issue includes two research papers and an article, each, in its own way, documenting the impact of human activities on the ecological processes in rocky plateau ecosystems.

Very less has been published on the hydrogeology of springs arising from Western Ghats hill tops. It is one of the most critical issues for human well-being in the region, and has been severely neglected by water managers of the region. The paper on the spring sheds in the Mahabaleshwar-Panchgani region documents effect of human activities on springs, and ecological processes that lead to flowing of springs. It identifies critical issues in spring research and conservation which should form part of water conservation and management initiatives in future.

A review of bauxite mining on rocky plateaus and restoration efforts identifies challenges for technical restoration of the rocky plateau's complex ecosystem. This review will certainly prove useful for area managers involved in regulating mining activities in and near Western Ghats, which is a biodiversity hotspot.

Wind farm development has been one of the major activities on rocky plateaus in the last decade. Although identified as renewable and clean energy, the allied infrastructure development has high landscape level impacts on biodiversity and ecology. Study on a high density wind farm in Satara identifies landscape level changes and their impact on microhabitats and associated biodiversity on the plateaus. It makes innovative use of landscape imaging tools, and creates a set of methods for analysing landscapes level changes. I hope that in coming years, these tools and methods will contribute significantly to the landscape research in Western Ghats.

Each of these papers will be read and appreciated for their unique findings, but we hope the readers will also see the linkages amongst them as they all address the issue of human activities and their impact on a sensitive ecosystem.

I cannot thank enough the entire editorial team of The Journal of Ecological Society. It has been a great learning process for me to discuss and analyse research, together with a team of highly experienced editors, a truly multidisciplinary team. Interactions with them brought out several key points in each contribution, making them stronger and more focused. The research on rocky outcrops is yet in its exploratory phase. It has great potential for future studies, which need to be taken up by keen researchers with an open mindset necessary for interdisciplinary science. I am sure these contributions will set the trend for future research.

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Special Section : Rocky Plateaus

Research Paper

Ecohydrologic Description of Springs in the North Western Ghats, Maharashtra

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Dr. Jared Buono is a consulting ecohydrologist based in Bengaluru. He has worked on community-based water security across India and in twelve other countries. He currently leads the Springs Initiative, an association of NGOs and government departments working toward better awareness and policy on springs.

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Renie Thomas is a geologist whose research focusses on Deccan basaltic lava flow architecture, groundwater and ecosystem health. He possesses a masters degree in Geology and a diploma in Natural Resource Management and nature conservation.

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Ketaki Kulkarni is Project Assistant at oikos for ecological services and worked on various projects for eco-education, eco-assessment, habitat analysis and mapping. She has been a Spark fellow at BAIF and worked on restoration of Sacred groves with community participation.

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Dhananjay Ambrale is a Field Administrator at Grampari, an NGO operating in Satara District, Maharashtra. His focus is on supporting watershed and spring protection programmes.

Ashok More is a farmer and Field Assistant at Grampari, an NGO operating in Satara District Maharashtra. His focus is mainly on mapping hydrogeology and community mobilization around spring protection in the North Western Ghats.

Abstract

Springs are essential components of the freshwater resources in the North Western Ghats yet they are not well studied and are under threat from ecological degradation. This study surveyed ecology and hydrogeology of five springs. Observations included geology, flora, fauna and impact of human pressures. The goal was to describe the range of ecological conditions to improve baseline understanding. Results show that spring recharge and discharge areas were found to hydrologically connect separate parts of the landscape, sometimes spanning different watersheds. While spring discharge is likely controlled in large part by catchment size and aquifer characteristics, impacts from human pressures may reduce spring discharge or water quality. Reduction in spring discharge may reduce biodiversity, particularly at the spring outlet where natural ponds or wetlands may dry up and destroy freshwater habitat. Grazing, fire, construction, pumping and fuel wood collection were common human pressures effecting nearly all springs. Discussed are refined definitions of a spring shed and recommendations for future assessment, conservation and management efforts.

Keywords : *aquifer, biodiversity, ecosystem, hydrogeology, spring shed, groundwater*

Introduction

The Western Ghats mountain range represents one of the world's biodiversity hotspots and spanning much of India's west coast, supports over 400 million people with water, food and other ecosystem goods and services (Walker and Meyers 2004). The provision of these services, however, is threatened by widespread environmental degradation. It is estimated that as little as 6% of the historic vegetation cover now remains intact due to high population density and intensive land use (Aravind et. al. 2011), with many remaining endemic species threatened (Watve 2006; Watve 2013). This loss of biodiversity is likely to have significant economic, social and environmental consequences for millions of people, but the precise impacts are not yet known and require additional study.

The freshwater systems are of particular interest as India faces a deepening water crisis. The Western Ghats constitute the headwaters for almost all rivers basins in central and south India. The rivers, lakes, wetlands, springs and aquifers are used for drinking water, household use, irrigation, power generation, industry, and tourism across eight states. They also provide unique habitats on which millions of people depend for livelihoods and food sources. (Aravind et. al. 2011). These water bodies, although a small fraction of the total land area, can support entire ecosystems, and areas such as wetlands are responsible for up to one fifth of local biodiversity (Space Applications Centre 2011).

Freshwater systems are also some of the most sensitive and threatened ecosystems (Bassi et. al. 2014), the main threats in the Western Ghats being

Figure 1 : The typical landscape of the North Western Ghats showing the plateau and valley formations and characteristic horizontal banding due to geology and its influence on vegetation (gallery forests). Anthropogenic impacts can also be seen including a loss of tree cover on the southern aspects (right-hand foreground) due to pressures of annual burning, intensive grazing, wood collection and farming.

construction, agriculture, pollution, groundwater exploitation, invasive species and deforestation (see Figure 1). Many freshwater plants and animals are routinely harvested for food and livelihood activities. These systems face such intensive anthropogenic pressure, that at least 18% of freshwater taxa are threatened with extinction (Aravind et. al. 2011).

One of the lesser studied components of the Western Ghats is the natural springs which occur when groundwater intersects the landscape and flows onto to the surface. Although the number and extent of springs is not known, they appear ubiquitous across the mountain range and may be integral to the entire freshwater resource. For example, many if not most of the rivers, lakes and wetlands in the mountain range are spring derived. For the people of the mountains, springs have been used for generations as a source of safe, perennial drinking water, small-scale irrigation and distributed water points for domestic animals (Naik et. al. 2002). Springs also provide cultural and religious value as many temples are built on and around springs, such as the Old Mahabaleshwar Temple at the source of the Krishna River in Maharashtra.

But there are signs that springs are under threat and there is increasing concern about declining spring discharge and water quality. Temple springs are going dry, spring-fed village water tanks no longer provide adequate household supply, and community drinking water springs are being abandoned due to contamination. Most of these occurrences appear to be related to increasing human impacts such as groundwater exploitation, deforestation of recharge areas, and improper sanitation. However, few of these anecdotal examples have been documented and there is little baseline information on springs in general.

The present study was conducted to expand our understanding of the role and current status of springs in the North-Western Ghats. In particular, the objective was to advance a general description of springs in the Western Ghats to develop a baseline for future monitoring and management.

The Geology of Western Ghats

This study focused on the North-Western Ghats which is hydrologically distinct from the southern part of the range. The section extending from the Karnataka border towards north up to Gujarat is dominated by the Deccan Volcanic Province, volcanic rocks formed by outpouring of basaltic lava flows (approx. 65 my) with near horizontal layers called flood basalts, which occur in simple and compound pahoehoe type flows (Deolankar 1980, Deshmukh 1988) (Figure 2.a). This is what creates the characteristic landscape of flat-topped plateaus and horizontal banding of the mountains (Figure 1).

The typical geologic cross section in this area consists of alternating units of relatively dense, compact basalt interspersed with layers of relatively porous, or vesicular sections – the result of lava morphology that also affects the nature of weathering, joints and fractures between the two formations (Kulkarni and Deolankar 1995; Kale and Kulkarni 1992). Hydraulic conductivity in the vesicular basalts is greater than that in the compact basalts because, in addition to vesicular pore space, the former tends to be more heterogeneous and more prone to weathering while the compact basalt tends to be more homogenous, have less jointing and be more resistant to weathering (Deolankar and Kulkarni 1987). Therefore, the vesicular basalt tends to store and transmit groundwater while the compact basalt tends to limit groundwater. Springs are formed when groundwater in the vesicular basalt percolates down to a compact basalt layer and moves laterally to emerge on the surface (Naik et. al. 2002). Springs such as this, formed when groundwater flow is impeded by an impervious material, are called fracture springs (Bryan 1919).

Important water bearing rock formation in the area is laterite. This is highly weathered basalt that caps many of the plateaus (see Figure 2.b) and has a high porosity and specific yield relative to other basalt formations (Widdowson 1997; Widdowson and Cox 1996, Widdowson and Gunnell 1999). Many springs are associated with the contact between laterite and compact basalt or other impervious layers (Naik et. al. 2002).

Finally, there are a series of fracture zones, or lineaments that cross the landscape. The superimposition of post volcanic tectonics, these N-S trending fractures increase hydraulic conductivity and often connect vertically separated water bearing formations contributing to movement of groundwater at the landscape scale (Kulkarni and Deolankar 1997; Duraiswami et. al. 2012, Duraiswami 2013). Some springs emerge directly from these fractures; these are defined as fracture springs (Bryan 1919).

Study Area

The location of the study area is in the subcatchment of river Krishna. The springs surveyed were centered on the town of Panchgani, a hill station in Satara District, Maharashtra (Figure 2.b). Rainfall in this area is highly variable but averages 2000mm

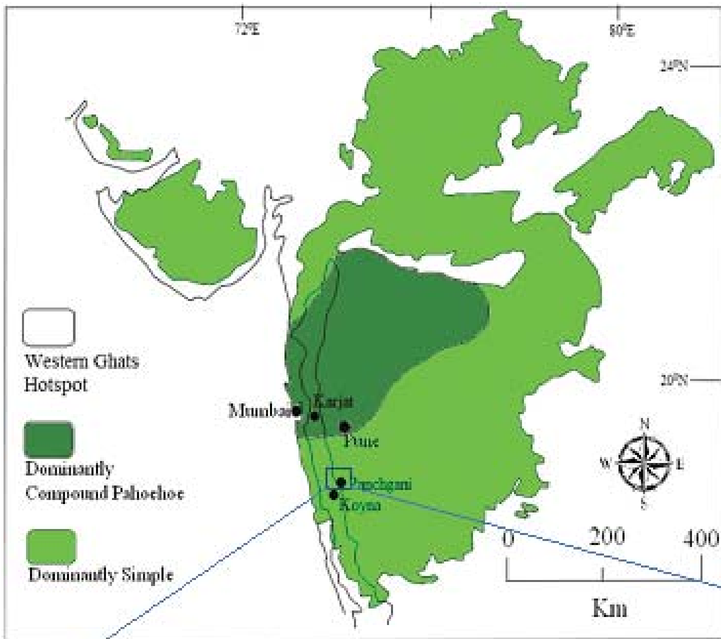

Fig.2.a : The Deccan Province, and the two dominant types of basalt formation, as well as the North-Western Ghats boundary (modified after Deshmukh 1988; Aravind et. al. 2011).

Fig. 2.b : A satellite image with spring study locations in yellow and laterite-capped plateaus in brown. (modified after Widdowson et. al. 1996).

annually at Panchgani. The terrain is characterized by broad flat plateau top mountains and deep valleys with a range of dense forest types and grasslands. Settlements include semi-urban hill stations and rural farm communities.

Methods

Approach

The focus was on observations of hydrogeology, and ecology including plants, animals and human pressures and impacts. A small number of springs were examined in detail, with locations chosen to represent the range of conditions - from springs in remote locations that were relatively untouched, to heavily impacted, urbanized springs. The goal was to describe the historic, native ecological conditions of a typical spring, as well as the range of conditions that occur under various levels of human impact. Five springs were selected from project sites of a local NGO, Grampari, who has been for several years' actively managing springs with local communities for their drinking water needs. The rapport with the community was useful for determining spring water use and history. Other criteria for choosing these springs included accessibility, observed human impact and land use. See Figure 2.b for spring locations.

Hydrogeology Methods

Geology was mapped in the area of each spring taking transects from ridge to valley. Locations of geologic features and structures were recorded on GPS including rock type, contacts between rock formations, joints and fractures. Satellite imagery from Google Earth was also used to identify larger structures such as landscape-scale fracture systems. For each study site a geologic cross section was developed. The cross-section enabled a determination of the type of spring and provided an estimate of the extent of the potential aquifer and the likely recharge areas. These areas were visited and, based on topography or other relevant geologic features; the catchment area of the spring was delineated. These were used to inform the ecological observations of the larger 'spring shed', not just the spring outlet.

Spring discharge was measured at the spring outlet by timed volumetric samples. Discharge was measured in the hot season (between March and May) to determine the lower bounds of water flow and to identify whether the spring was perennial or seasonal.

Ecology Methods

Field surveys were conducted quarterly at each study site over a one-year period between March 2014 and March 2015. Observation teams included fauna and flora experts as well as a geologist and local community members. Transect walks were conducted within the spring shed – including the spring outlet and catchment area. Surveys included inventory of flora and fauna species, identification of human pressures, impact, and land classification.

Flora and Fauna Inventory : Observations of trees, shrubs, birds, reptiles, mammals and amphibians were conducted by the team of experts at each site. All individual species were recorded whenever possible; otherwise a large representative list was created. Special attention was given to invasive and non-native vegetation species and faunal observations at the spring outlet where biodiversity appeared high.

Human Use, Impact and Land Classification : Human pressures were recorded under direct observation and with interviews with community members. Drivers of human pressures include type and intensity of grazing, annual burning, extent and intensity of harvesting of wood, wild food or other forest/land product, extent of agriculture, construction, and groundwater pumping. Particular attention was given to the spring outlet which tended to have intensive use by domestic animals or the community in terms of infrastructure to harvest spring water. Human impacts as a result of these pressures was similarly observed: the number of domestic animals or signs of grazing, density of footpaths, extent of cut trees, signs of accelerated erosion, etc.

Land use was also classified for each spring catchment using satellite imagery and field verification. Cover classes were developed after initial observations with the following definitions :

Dense Canopy – where tree spacing is less than 3m to 4m, with closed canopy and touching crowns, and multistory vegetation showing a mixed age class of trees, shrubs, herbs and climbers. This class represents the minimum human interference.

Plateau – areas with relatively flat surfaces surrounded by steep slopes. These are the characteristic plateaus of the area.

Rocky Area – areas with exposed outcrops and little soil or vegetation due to either erosion or natural means.

Shrubbery – areas dominated by shrubs or small trees up to 3m height. This class could vary depending on whether the shrubs were sparse or dense.

Fields – dominated by areas under cropping or other intensive agricultural practices.

Settlement – areas showing significant human activity such as any kind of infrastructure, construction, roads, houses, etc.

Grassy Patches – open areas dominated by herbaceous vegetation.

Regenerating Forest – areas showing secondary growth, with smaller trees, dense undergrowth, and higher proportion of invasive species in some cases.

Results

Spring discharge ranged from 31 to 0 litres per minute in the hot season when flow is lowest. Elevations of spring outlets ranged from 1170 to 1240 meters and the size of spring catchments ranged from 6.1 to 15.8 hectares. All but one spring was determined to be a contact-type spring – meaning the spring is created when groundwater contacts a relatively impervious layer and emerges on the surface. The aquifers were generally associated with laterite rock and soils while the impervious zones were either compact basalt or lithomarge.

Catchments ranged from dense, mature forests to urbanized areas, while spring outlets ranged from completely covered by springbox infrastructure to natural, open pools with diverse animal and plant life. Human pressures included annual burning, grazing, tree cutting and fuel collection, construction, and groundwater pumping. Trampling and soil compaction were also observed at many spring outlets.

Specific results for each spring study location are given below, with summary information and coordinates of spring catchment centroids given in Table 1.

1. Akhegani Spring

This spring is located within the village of Akhegani in Jaoli Block, Satara District. The spring outlet and catchment area are several kilometers away from habitations, with the water being gravity-fed to the community via pipes (see Figure 3). The geological survey suggested that groundwater is being recharged through fractures on the plateau above, and through the deep lateritic soil and talus of the adjacent slopes. Percolation occurs through the soil-talus complex until an impervious lithomarge is reached. The spring outlet emerges along roughly 10 meters of the horizontal contact of the lithomarge making this a contact spring. However, other springs in the area occur not along the contour of the lithomarge but along the slope-line of *nallas* indicating fracture springs. Spring discharge was measured as 15 liters per minute on April 14, 2014.

Land cover classes were observed as :

Land Cover Class	Area (hectares)	Area (%)
Regenerating Forest	5.7	92
Settlement	0.4	6
Grassy Patch	0.1	2
Total	**6.2**	**100**

Figure 3: Akhegani Spring and surrounding area. The village sits to the west of the image.

The area of both the spring outlet and catchment were similar - forested with a closed deciduous canopy of moderate density and a stratified structure showing some shrubs, climbers and the presence of regenerating species. The dominant tree species included Tambat (*Flacourtia indica*), Jambhul (*Syzygium cuminii*), and Pisa (*Actinodaphne hookeri*). The dominant shrubs found were Phapat (*Pavetta crassicaulis*), Toran (*Ziziphus rugosa*), Alu (*Meyna laxiflora*) and climbers like Ambulki (*Elaegnus latifolia*). In terms of fauna, birds like Red vented Bulbul, Red whiskered Bulbul, Common Iora, Grey Jungle Fowl, Coppersmith Barbet, White cheeked Barbet were heard and seen. Amphibians like *Indirana* spp. were observed inside the spring box. It should be noted that all springs in the area were modified with a springbox. These are generally plastered brick boxes built at the spring outlet to collect water for community use – see Figure 6 for an example.

Human pressures in the area include moderate encroachment on the forest in the springshed, particularly from clearing for construction and wells. Grazing, fire and tree cutting are present but limited as much of the springshed is on Forest Department land. In the more pressured areas, where the canopy has been opened from tree loss, the Forest Department has undertaken restoration and recharge practices such as infiltration basins, tree plantings and farm ponds.

2. Godavalli Spring

The Godavalli village is located on the south slope of Panchgani Tableland. Panchgani town, a popular tourist destination, borders the village. Therefore, recent growth has been rapid and the village's character is changing from a rural farming community to a more urban centre with hotels, schools and weekend homes.

The geological survey indicated that recharge of groundwater occurs on the laterite plateau and the adjoining slopes which are comprised of vesicular basalt. The spring emerges at the lowest point in the village, along the contact with compact basalt. A fracture zone runs approximately NW-SE through the village that appears to help carry water from the plateau to the spring (see Figure 4). According to community members, the temple in the village was built around the spring generations ago. However, over the last few years, the spring is no longer perennial and goes dry by March. The spring was not flowing during our spring survey; thus no discharge was recorded.

Land cover classes were :

Land Cover Class	Area (hectares)	Area (%)
Dense Canopy	1.4	9
Plateau	0.8	5
Fields	2.1	14
Settlement	4.6	30
Grassy Patches	6.5	42
Total	**15.4**	**100**

Figure 4: Godavalli Villages showing the location of the spring outlet, catchment and geologic features.

The village shows presence of large, old trees. The dominant species found were Mango (*Mangifera indica*) and Jackfruit (*Artrocarpus heterophyllus*). However, little of the historic vegetation remains as most of the trees were planted domestically. Several invasive and non-native species were observed. Birds observed were Common Kestrel, Golden Oriole, Red vented Bulbul, Common Myna, Jungle Crow, House Sparrow, Red whiskered Bulbul, Coppersmith Barbet. Overall, however, biodiversity was low due to the proximity of urbanized area. There is intensive and continual pressure from grazing, agriculture, fuel wood collection, construction, groundwater pumping, tourism and annual burning.

3. Kirunde Spring

Located near the village of Kirunde, the spring is in a sparsely populated area. The catchment is on a high elevation lateritic plateau with deep soils and dense forest. The geological survey indicated that ground-water recharge occurs in the deep soils on top of the plateau and passes through laterite and vesicular basalt via a fracture system. The spring emerges just above the contact with the compact basalt. Discharge is very high (31 liters per minute in the dry season) and the flow is perennial. The catchment area on the plateau is dominated by dense forest canopy with stratified layers. Species included mature Jambhul (*Syzygium cuminii*) trees and a few specialized trees like Narkya (*Nothapodytes nimmoniana*) and *Garcinia* spp were also observed. The shrubs principally included Alu (*Meyna laxiflora*) and Karwand (*Carissa congesta*). Numerous animals were observed such as langur, wild pig, barking deer, and reptiles such as Brook's gecko, Pit Vipers, Rat snake, and Keelback. Leopard tracks were observed during one survey and sightings by community members confirmed their presence.

Land cover classes were observed as :

Land Cover Class	Area (hectares)	Area (%)
Dense Canopy	11.2	71
Regenerating Forest	1.4	9
Settlement	0.05	0.1
Rocky	0.3	2
Fields	1.1	7
Grassy Patch	1.7	11
Total	**15.7**	**100**

Human pressures are limited. There is only one family regularly utilizing the catchment for grazing, fuel wood and agriculture – the house and agricultural fields are clearly visible at the north end of the catchment in Figure 5. The spring outlet is also in a

Figure 5: Spring at Kirunde and geologic features. The one habitation can be seen on the north side of the catchment.

relatively native state. It sits over a kilometer from the village and has not been altered with a springbox or House Sparrow. A few raptors like Common Kestrel and Black Kite were observed.

(a)

(b)

Figure 6 : Springs in a relatively natural state (a) oozing out at the contact of lateritic talus deposits and basalt unit at Kirunde Spring, and a springbox built on a spring outlet to capture water (b) near Akhegani Spring.

other infrastructure. The only impact seems to be some trampling by domestic animals that use it as a water source (Figure 6).

4. Taighat Spring

The Taighat Spring sits above Taighat village bordering the hill station of Panchgani. The geological survey found that the spring emerges from a fracture in the lower section of the laterite rock and talus complex at 1195 meters in elevation. There are several similar fractures in the area. All are vertically oriented and trend north-south as can be seen in Figure 7. Many of these fractures are associated with springs. The springs would therefore be defined as fracture springs, but occur near the contact with the compact basalt. Spring discharge was very low and seasonal, going dry in April or May. Therefore, no discharge was measured in the hot season. The spring catchments were sparsely vegetated with some stands of Gulmohor and Nilgiri trees with a much smaller number of indigenous species like Mango (*Mangifera indica*), Bakul (*Mimusops elengi*) and Sonchapha (*Magnolia champaca*). Vegetation at the springs outlets consisted of open, sparse grasses and shrubs with occasional trees such as *Bombax ceiba* (*Kate Sawar*). The faunal activity observed was mainly of common city based bird species like Common Myna, Red vented Bulbul and

Land cover class was observed as :

Land Cover Class	Area (hectares)	Area (%)
Dense Canopy	2.5	39
Settlement	0.6	9
Grassy Patches	3.3	52
Total	**6.4**	**100**

Human pressure was high with intensive land use including roads, construction, residential and commercial (tourism) structures, wells and a number of latrines just upslope from the spring outlets. According to community members, the latrines, placed roughly 30 meters upslope of the spring outlet, have contaminated the water. This spring, as well as all of the others in the area, are no longer used for drinking and are now solely for domestic livestock, small-scale irrigation of tree plantations and car washing. There are a series of spring boxes built to harvest water, including a separate small tank below the outlet for domestic animal use (Figure 8).

5. Umbri Spring

Located in Umbri Village, the geological survey for this spring suggests that groundwater is recharged via a rocky laterite plateau and the slopes above the spring (Figure 9). The spring outlet occurs near the contour of

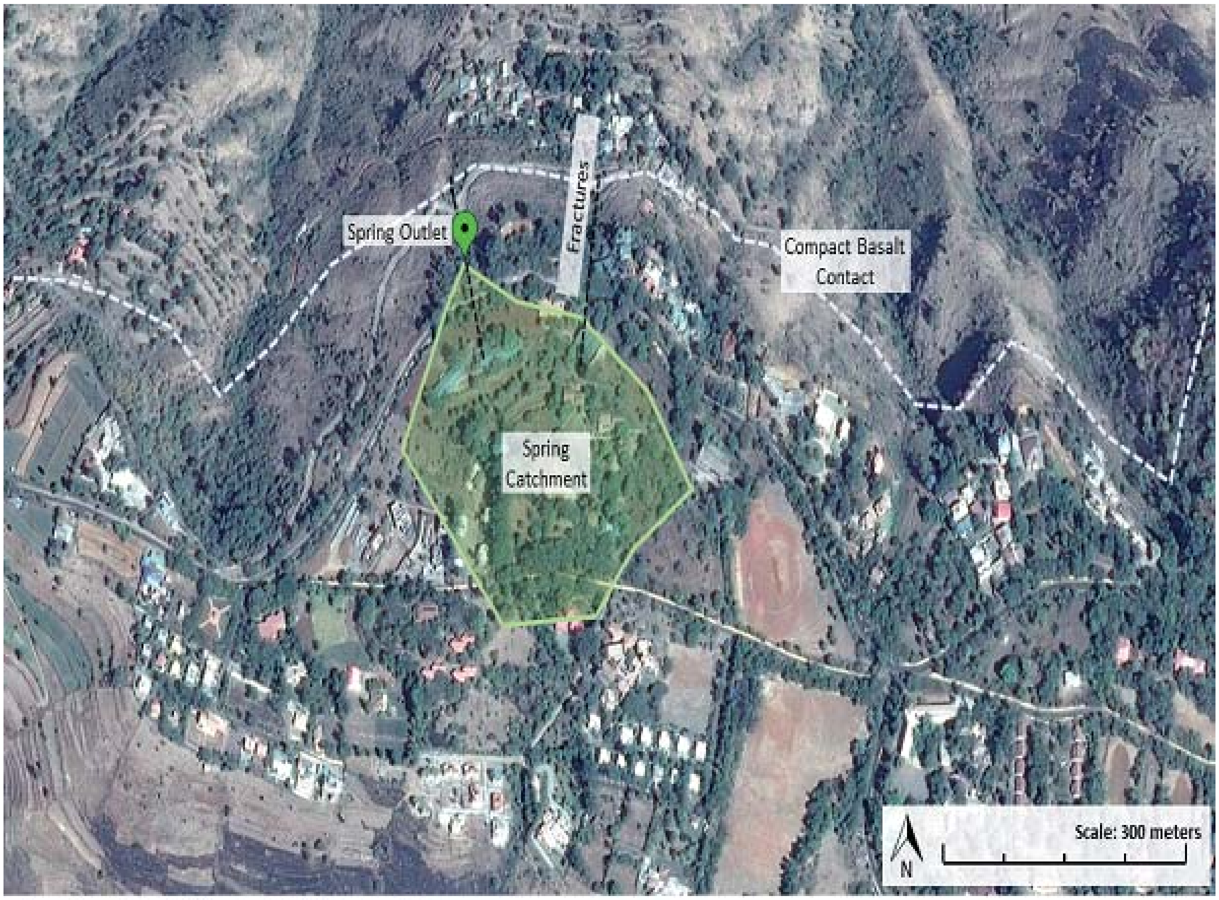

Image Source: Google Earth Image Date: December 2015

Figure 7 : Taighat Spring catchment, outlet and geological features.

Figure 8: A tank situated at distance from a spring outlet, called a 'guzzler', used for watering domestic animals or wildlife while protecting the habitat at the natural spring outlet.

the contact between the laterite and the compact basalt, indicating a contact spring. Discharge was measured as 5.5 liters per minute in April 2014.

The catchment is a mixture of grasslands, rocky outcrops and small patches of moderately dense shrubs. In grassland patches the catchment shows dominance of *Themeda* spp. with few herbs like Sonaki (*Senecio bombayensis*), *Leucas aspera* and *Pogostemon decccanensis*. The dense patches included presence of Pisa (*Actinodaphne hookeri*), Jambhul (*Syzygium cuminii*), Hirda (*Terminalia chebula*). The area surrounding the spring outlet is open with occasional tall trees and shrubs including Walunj (*Salix tetrasperma*), Karwanda (*Carissa congesta*), Toran (*Ziziphus rugosa*) and Phapat (*Pavetta crassicaulis*). The bird species mainly included Red vented Bulbul and Common Iora. Little other fauna was observed.

Land cover classes were observed as :

Land Cover Class	Area (hectares)	Area (%)
Regenerating Forest	1.0	7
Rocky Area	0.2	1
Grassy Patches	9.8	69
Shrubbery	2.3	16
Plateau	1.0	7
Total	**14.3**	**100**

Human pressure included intensive grazing, annual fires and fuel wood collection in the catchment, as well as intensive domestic animal presence at the spring outlet. The spring outlet sits above the village and is used to gravity-feed drinking water to the community centre. A springbox is built on the spring outlet, and connected nearby is an open tank for domestic animals to drink.

Discussion

Hydrogeology

Spring discharge across the springs studied averaged 10.3 liters per minute in the hot season. The aquifers were mainly composed of laterite with some vesicular basalt. All were considered contact-type springs that emerged at the lithomarge at the base of the laterite or at the contact with the compact basalt, except for the fracture-type spring at Taighat. Elevations were generally around the 1200-meter mark which marks the lower margin of the laterite plateaus in the area. Although only a small number of springs were selected for this study, these characteristics are consistent with the only detailed spring survey conducted in the area, by Naik et. al. (2002).

The only difference we observed was the presence and impact of fracture zones. Naik et. al. (2002) found

Figure 9: Umbri Spring showing spring catchment, outlet and geological features.

Name	Coordinates and Elevation	Hydrogeology	Human Pressures	Ecological Observations
Akhegani Spring	17.867970ºN 73.786247ºE 1170 m	15 acre catchment of basalt plateau with lateritic soil and talus slopes, with contact spring along contact with lithomarge. Hot season discharge of 15 litres per minute in 2014.	Light pressure from grazing and tree cutting. Some boundary encroachment of construction, pumping and fire. Limited pressure at outlet, but large springbox present.	Dominated by closed-canopy, regenerating forest with diverse, native plant and animal species. Some amphibians observed at the outlet, but spring entirely covered by a large springbox used to harvest village drinking water
Godavalli Spring	17.925608ºN 73.814197ºE 1219 m	38 acre catchment of laterite plateau and talus slope with contact spring just above compact basalt contact. No hot season discharge in last few years.	Very high human pressure, urbanized spring with intensive construction, grazing, fire, agriculture and pumping from dozens of wells.	An urbanized catchment dominated by disturbed land cover classes such as *Settlements* and *Fields*. Overall biodiversity and vegetation cover was very low.
Kirunde Spring	18.011744ºN 73.690806ºE 1222 m	39 acre catchment of laterite plateau with deep soils and dense forest, contact spring fed by fractures emerging above contact with compact basalt. Hot season discharge was 31 liters per minute in 2014.	Very light human pressure due to only one habitation in the catchment. Limited tree cutting and grazing. Light domestic animal use at outlet.	Catchment dominated by mature, native, multi-story forest. Varied wildlife including large mammals, leopards. Spring outlet in natural condition, with no springbox.
Taighat Spring	17.924328ºN 73.782914ºE 1196 m	16 acre catchment in laterite, fed by fractures and emerging at an exposed fracture – a fracture spring with seasonal discharge, goes dry by March or April every year.	High human pressure, urbanized spring. Intense grazing, construction and annual burning; latrines in the catchment led to disuse as drinking water source.	Catchment dominated by cleared land classes such as *Settlement* and *Grassy Patches*. Spring outlet is lightly protected with separate area for domestic animals to drink. A high proportion of non-native trees and invasive species present.
Umbari Spring	17.892683ºN 73.774056ºE 1249 m	36 acre catchment in talus slopes with small portion of laterite plateau. Spring emerges at contact with compact basalt. Hot season discharge of 5.5 liters per minute	Moderate pressure due to annual burning, intense grazing, fuelwood collection, and trampling by domestic animals at outlet.	Mixed grass and shrub cover in the catchment, moderate biodiversity with grazing, fuel wood and burning pressures.

Table 1. Summary of Results by Spring Study Site

only 12% of springs could be classified as fracture springs, and attributed little effect to fractures on the springs. This study, however, found that the majority of springs investigated were associated with fractures, even if they could not be specifically defined as fracture-type springs. Fracture zones have been proven to serve as conduits for groundwater infiltration and transmission in the Northern Western Ghats (Krishnamurthy et. al. 2004; Lie and Gudmundsson 2002; Peshwa et. al. 1987). They are therefore very likely to play a significant role in spring formation.

Fractures were also found to connect different parts of the landscape with outlets and catchment areas often geographically distant. The fractures tend to be vertically oriented and can extend from the surface down through mountains passing through all rock types, essentially connecting porous rock formations and allowing water to percolate through impervious formations. Therefore, a spring in a valley bottom may be recharged from a catchment on a mountaintop hundreds of meters above (Deolankar et. al. 1980; Kale and Kulkarni 1992; Kulkarni et. al. 1995; Peshwa and Deolankar 1990).

Fracture zones were evident at Taighat, Kirunde and Godavalli. Although not part of this study, adjacent spring sites at Kirunde were also fracture-type. These fractures tended to span rock formations including the laterite plateaus at the top of the watersheds. In the case of Kirunde and Taighat, they possibly spanned the ridgeline which would extend the catchment across the watershed boundary.

Figure 10 illustrates the typical groundwater flow paths including contact springs emerging at the base of the laterite along the contact with the compact basalt, as well as along fractures crossing numerous rock formations.

Ecology

Vegetation and animal surveys showed a large variation between springs. The Kirunde spring catchment was dominated by dense-canopy, mature forest and exhibited diversity of native plants and animals. The spring outlet was in a natural state and provided habitat to numerous species including an area leopard. In contrast, Godavalli catchment was dominated by human oriented land use such as

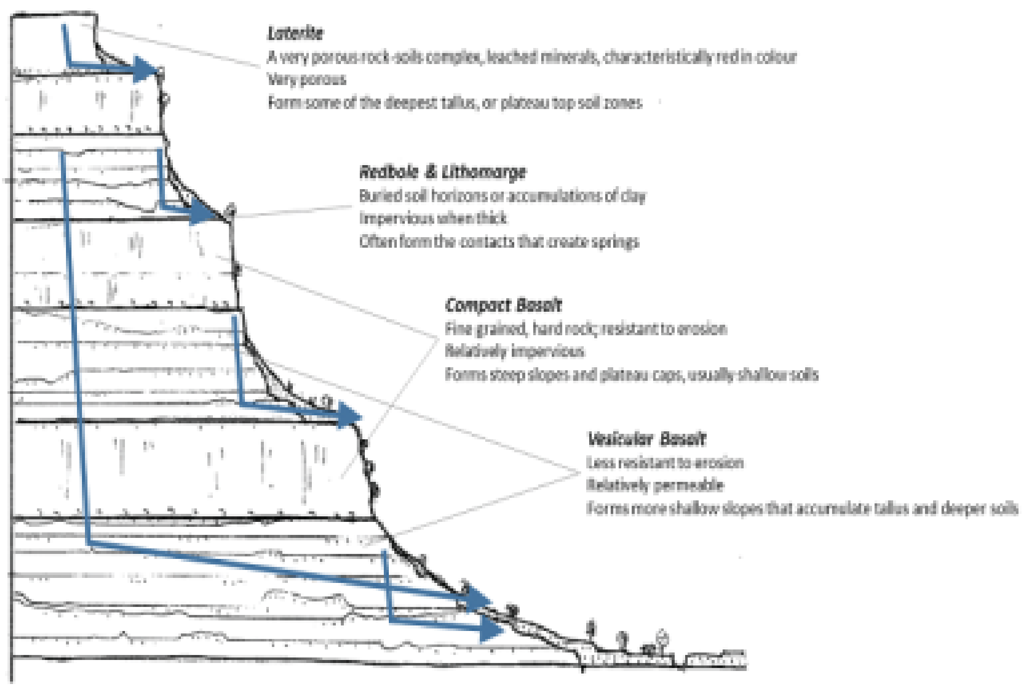

Figure 10 : Typical framework of hydrogeological units with generalized groundwater flow paths. Contact springs form when groundwater encounters an impervious material to emerge on the surface; fracture springs emerge directly from fractures. While contact springs tend to be local, associated with a porous unit overlying an impervious one, fracture springs may traverse multiple units across the landscape. Many springs observed here appeared to be hybrid systems with contact springs fed by fracture zones.

buildings and agricultural fields, and the outlet was the site of a temple and no longer exhibits seasonal discharge. The plants and animals that were observed were mainly domestic or non-native.

Human pressures included grazing, tree cutting and fuel collection, agriculture, groundwater pumping, construction, tourism and annual burning. The impacts were reduced vegetation cover, soil loss, decreased water tables and loss of habitat and biodiversity. Spring outlets experienced similar pressures and impacts but were subject to specific issues such as intensive grazing and trampling by domestic animals leading to vegetation loss and soil compaction. The construction of infrastructure for harvesting water, such as springboxes and tanks, also led to loss of habitat.

Components of a Spring Ecosystem

It became apparent that, in this context, the definition of a spring required refinement. It was observed that springs have three distinct eco-hydrologic components based on where groundwater is either recharged (the catchment), stored/transmitted (the aquifer), or ultimately discharged (the spring outlet area). See Figure 11. These components were often geographically distant and ecologically distinct with significant variation in their ecological potential in terms of native plants and animal communities, human pressures and land use.

The catchment area of a spring is where groundwater recharge occurs. This has been defined as the springshed and is conceptually similar to a watershed (Negi and Joshi 1999). It often requires a geologic survey to identify as it can be geographically separate from where the spring discharges, even occurring in a separate watershed. Catchments are spatially extensive. In this study, they averaged 11.7 hectares in size and tended to occupy plateau tops and adjacent slopes. These were often the same areas populated or used by local communities so land use could be very intensive. Degradation of the forests and soils in this area has been shown to reduce infiltration and recharge (Mehta et. al. 2008; Bonell et. al. 2010), therefore any changes in the catchment are likely to reduce spring discharge.

Spring outlets are the most visible component. This is where groundwater emerges on to the surface, generally as a point source, but sometimes as a more linear feature along a contact or fracture many meters in length, or as seep or wetland. Outlets are the points of use for humans, domestic animals and the many endemic plants and animals. High use in such a small area can lead to intensive pressure and severe impacts. Most springs near human settlements have spring boxes or tanks to harvest water. Herds of domestic animals are driven to outlets for drinking water so deforestation and erosion can be significant. Few natural pools native to spring formation remain intact therefore biodiversity may be reduced.

The aquifer is the pores in the rock that store and transmit groundwater, the component that connects the catchment to the outlet. It is harder to characterize without detailed hydrogeologic investigation. The concept of assessing or managing 'aquifer health' is not well defined (Korbel and Hose 2011). In this study, it was seen that exploitation of groundwater through pumping of wells has resulted in decreased water tables at the Godavalli where the once perennial spring

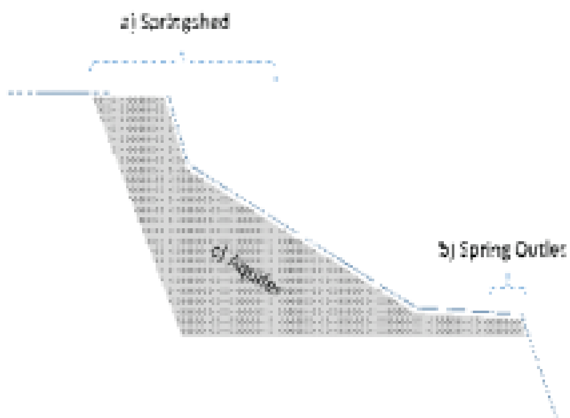

Figure 11 : Conceptual model of the components of a spring ecosystem, or springshed including the catchment or springshed (a), the outlet (b) and aquifer (c).

is now seasonal. Improper sanitation (latrines above the spring) has led to disuse of drinking water at Taighat.

Considering these three components, it is suggested that a springshed be defined as the catchment area, the aquifer and the outlet area. This will help with recognition and acknowledgement that the source of water (outlet) is supported by an often distant recharge area (catchment) and the two are hydrologically connected by an aquifer where degradation in any component may have downstream impacts.

Springshed Management Recommendations

Spring catchment areas need to be identified and protected. While the impact of human pressures on spring discharge was not possible to define in this study, and overall discharge is likely governed by catchment size and aquifer characteristics, it is apparent at Godavalli that rapid urbanization and intensive land use have degraded ecological conditions and depleted groundwater. Construction covering almost 30% of the catchment has likely reduced infiltration. Groundwater pumping has also greatly increased in the catchment above the spring - the villages now have 12 bore wells and as many open wells. This is likely why the spring has become seasonal after many generations of perennial flow. If spring water is to be managed as a drinking water source, these types of pressures will need to be managed for the common groundwater resource.

The approach used in this study, of employing hydrogeologic field methods to identify spring recharge areas, represents a potential for targeted interventions for water security. The average catchment in this study was 11.7 hectares in size. While this is only a rough estimate, and a more rigorous delineation of the catchment may be possible using tracers or other methods, it provides a baseline for costing of spring management programmes. Restoring and protecting 11.7 hectares may be all that is needed to maintain a village drinking water source.

As much as possible the spring outlet should be protected and left in a natural state to promote biodiversity. Human pressures at spring outlets appear to reduce habitat, so spring boxes used to harvest water for communities should include a provision for a separate tank for use by domestic and wild animals.

The interconnected nature of the landscape, in terms of water resources, needs to be recognized given that spring outlets and catchments are often distant. Springs in a valley bottom may be recharged by ridge top catchments. This holds for groundwater feeding nallas in the valley bottoms – rivers and streams may be dependent on protecting plateaus. Due to plateaus being flat, spatially extensive and layered with deep weathering, and often deep soils and rich vegetation, virtually all-percolating water moves through these formations before emerging as springs or entering fracture systems feeding regional groundwater (Deolankar et al. 1980; Duraiswami et. al. 2012; Larsen and Gudmundsson 2010). This gives additional impetus to protect plateaus in the North Western Ghats, and also makes landscape lineaments and fracture zones potential candidates for protection to improve groundwater recharge.

Methods to assess and monitor the ecological condition of springs need to be developed for improved management. Based on this study, a relative assessment could be made based on several factors including the extent and intensity of observed human impacts, the proportion of land cover classes in a natural state – for example, how much of the spring was under *Dense Canopy* versus *Settlement*, and the amount of habitat that appeared intact during field observation including the degree to which the spring outlet had been altered with tanks, pipes and other infrastructure. If it is assumed that these study locations represent the full spectrum of ecological conditions, with 'High' condition represented by Kirunde and its historic, native conditions, and the other end of the spectrum being Godavalli, an urbanized spring heavily impacted by all manner of observed human activity and thus considered 'Low' condition, then all other study sites could be similarly ranked.

Conclusions

Spring discharge appears largely governed by geology and aquifer characteristics, but may be reduced under intensive land use such as the pressures of urbanization and over pumping of ground water. Further any reduction in discharge may negatively impact biodiversity if spring outlets become seasonal. Grazing, fire, construction, pumping and fuelwood collection were common human pressures effecting nearly all springs.

Spring systems have three distinct components, a catchment, an outlet and an aquifer. These components hydrologically connect separate parts of the landscape from mountaintops to valley bottoms. This has potential ecological implications for land use and water management – for example, construction and mining on plateau tops may reduce spring discharge and base flows in rivers.

Springs are essential components of the freshwater resources in the North Western Ghats. Yet, despite the importance of springs to people and the environment, there is little awareness, public investment, and research.

References

Aravind, N.A., N.A. Madhyastha, G.M. Rajendra, A. Dey (2011) : The Status and Distribution of Freshwater Molluscs of the Western Ghats. In: The Status and Distribution of Freshwater Biodiversity in the Western Ghats, India, Molur, S., K.G. Smith, B.A. Daniel and W.R.T. Darwall (Compilers). Cambridge, UK and Gland, Switzerland : IUCN, and Coimbatore, India : Zoo Outreach Organisation, pp. 59 - 72.

Bassi, N., M.D. Kumar, A. Sharma, P. Pardha-Saradhi (2014) : Status of Wetlands in India : A Review of Extent, Ecosystem Benefits, Threats and Management Strategies, Journal of Hydrology : Regional Studies, *2*, pp. 1-19.

Bonell, M., B.K. Purandara, B. Venkatesh, J. Krishnaswamy, H.A.K. Acharya, U.V. Singh, R. Jayakumar, N. Chappell, N. (2010) : The Impact of Forest Use and Reforestation on Soil Hydraulic Conductivity in the Western Ghats of India : Implications for the Surface and Sub-Surface Hydrology, Journal of Hydrology, Vol. 391, pp 47-62.

Bryan, K. (1919) : Classification of Springs. The Journal of Geology, Vol. 27, No. 7 (Oct. - Nov., 1919), pp. 522-561.

Deolankar, S.B. (1980) : The Deccan Basalts of Maharashtra, India – Their potential as Aquifers. Groundwater, Vol. 18, No. 5, pp. 434-437.

Deolankar, S.B., J.G. Mulay, V.V. Peshwa (1980) : Correlation between photolineaments and the movement of groundwater in the Lonavala area, Pune District, Maharashtra, India. Journal of Indian Society of Remote Sensing. Photonirvachak, v. 8, pp. 49-52.

Deolankar, S.B., H. Kulkarni (1987) : Evaluation of transmissivity of Deccan basalts of Maharastra, India, using aquifer response from large-diameter dugwells. Mem XVIII IAH – Hydrogeology of Rocks of Low Permeability, Tucson, Arizona, pp. 622-630.

Deshmukh, S.S. (1988) : Petrographic Variations in Compound Flows in Deccan Traps and Their Significance. In: K.V. Subbarao (ed.), Deccan Flood Basalts. Mem. Geol. Soc. India, no.10, pp. 305-319.

Duraiswami, R. A., Das, S. and Shaikh, T. N. (2012) : Hydrogeological Framework of Aquifers in the Deccan Traps, India: Some Insights, Memoir 80, Geological Society of India, pp. 1-15

Duraiswami, R. A. (2013) : Pahoehoe–aa Transitions in the Lava Flow Fields of the Western Deccan Traps, India - Implications for Emplacement Dynamics, Flood Basalt Architecture and Volcanic Stratigraphy, Journal of Asian Earth Sciences, Vol. 84, pp. 146-166.

Kale, V.S., H. Kulkarni (1992) : IRS-1A and Landsat Data in Mapping Deccan Trap Flows around Pune, India: Implications for Hydrogeological Modeling. Archives, International Society of Photogrammetric and Remote Sensing, v. 29 (B7), pp. 429-435.

Korbel, K. L., G.C. Hose (2011) : A Tiered Framework for Assessing Groundwater Ecosystem Health. Hydrobiologia, Volume 661, Number 1, pp. 329-349.

Krishnamurthy, V., R.A. Duraiswami, V.B. Joshi (2004) : Application of Remote Sensing Tools in the Delineation of Saline Groundwater Zones in Hard Rock Areas : A Case Study From Pune District. Global Spatial Data Infrastructure 7th Conference, February 2-6, Bangalore.

Kulkarni, H.C., S.B. Deolankar (1995) : Hydrogeological Mapping in the Deccan Basalts : An Appraisal. Journal, Geological Society of India, v. 46, pp. 345-352.

Kulkarni, H., S.B. Deolankar, A. Lalwani, B. Joseph, S. Pawar (1995) : Hydrogeological Framework of Deccan Basalt Groundwater Systems, India. Hydrogeology Journal (Springer-Verlag), v. 8(4), pp. 368-378.

Kulkarni, H.C., S.B. Deolankar (1997) : Dugwell Inflows from Shallow Deccan Basalt Aquifers. Journal, Geological Society of India, v. 49, pp. 705-714.

Larsen, B., A. Gudmundsson (2010) : Linking of Fractures in Layered Rocks : Implications for Permeability, Tectonophysics, Vol. 492, Issue 1, pp. 108-120.

Lie, H., A. Gudmundsson (2002) : The Importance of Hydraulic Gradient, Lineament Trend, Proximity to Lineaments and Surface Drainage Pattern for Yield of Groundwater Wells on Askøy, West Norway, NGU Bulletin, 439, pp. 51-60.

Mehta, V. K., P.J. Sullivan, M.T. Walter, J. Krishnaswamy, S.D. DeGloria (2008) : Impacts of Disturbance on Soil Properties in a Dry Tropical Forest in Southern India, Ecohydrology, 1, pp. 161–175.

Naik, P. K., Awasthi, A. K., Mohan, P. C. (2002) : Springs in a Headwater Basin in the Deccan Trap Country of the Western Ghats, India, Hydrogeology Journal, Vol. 10, pp. 553–565.

Negi, G. C. S., V. Joshi (1999) : Geohydrology of Springs in a Mountain Watershed : The Need for Problem Solving Research, Current Science, Vol. 71, No. 10, pp. 772- 776.

Peshwa, V. V., J.G. Mulay, V.S. Kale (1987) : Fracture Zones in the Deccan Traps of Western and Central India : A study Based on Remote Sensing Techniques, Journal of the Indian Society of Remote Sensing, Vol. 15, No. 1, Photonirvachak, pp. 9-17.

Peshwa, V.V., S.B. Deolankar (1990) : Remote Sensing of Shallow Unconfined Deccan Basalt Aquifers from Maharashtra State, India. Proceedings, International Symposium on Remote Sensing and Water Resources, IAH/NSRSD, Enschede, The Netherlands, pp. 515-523.

Space Applications Centre (SAC) (2011) : National Wetland Atlas. SAC, Indian Space Research Organisation, Ahmedabad.

Walker, B., J.A. Meyers (2004) : Thresholds in Ecological and Social–Ecological Systems : A Developing Database. Ecology and Society 9(2) : 3. Retrieved on 08.05.2015 (URL : http://www.ecologyandsociety.org/vol9/iss2/art3/)

Watve, A. (2013) : Status review of Rocky plateaus in the northern Western Ghats and Konkan region of Maharashtra, India with recommendations for conservation and management. Journal of Threatened Taxa. 2013; 5(5) : 3935–3962.

Watve, A., A.S. Thakur (2006) : Ecological Studies of Lateritic Plateau Habitats in Northern Western Ghats, pp. 22–28 in H. N. Pandey and S. K. Barik (eds.), Ecology and Conservation of Plants and Ecosystems in India. Regency Publications, New Delhi.

Widdowson, M. (1997) : Tertiary Palaeosurfaces of the SW Deccan, Western India : Implication for Passive Margin Uplift. In : Palaeosurfaces : Recognition, Reconstruction and Palaeoenvironmental Interpretation (ed.) Widdowson M, Geol. Soc. Spec. Publ. 120 221–248.

Widdowson, M., K.G. Cox (1996) : Uplift and Erosional History of the Deccan Traps, India : Evidence from Laterites and Drainage Patterns of the Western Ghats and Konkan Coast; Earth Planet. Sci. Lett. 137, pp. 57–69.

Widdowson, M., Y. Gunnell (1999) : Lateritization, geomorphology and geodynamics of a passive continental margin : The Konkan and Kanara coastal lowlands of western peninsular India; Spec. Publ. Int. Assoc. Sediment. 27, pp 245–274.

Widdowson, M. (1997) : Tertiary Palaeosurfaces of the SW Deccan, Western India : Implication for Passive Margin Uplift. In : Palaeosurfaces : Recognition, Reconstruction and Palaeoenvironmental Interpretation (ed.) Widdowson M, Geol. Soc. Spec. Publ. 120 221–248. Widdowson, M., K.G. Cox (1996) : Uplift and Erosional History of the Deccan Traps, India : Evidence from Laterites and Drainage Patterns of the Western Ghats and Konkan Coast; Earth Planet. Sci. Lett. 137, pp. 57–69.Widdowson, M., Y. Gunnell (1999) : Lateritization, geomorphology and geodynamics of a passive continental margin : The Konkan and Kanara coastal lowlands of western peninsular India; Spec. Publ. Int. Assoc. Sediment. 27, pp 245–274.

Research Paper

Lateritic Plateaus in the Northern Western Ghats, India; a Review of Bauxite Mining Restoration Practices

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Abstract

The northern Western Ghats are characterised by plateaus and hilltop carapaces formed from ferricretes rich in aluminium ore. Ferricretes in Western Ghats are home to a high number of endemic species, many with extremely limited distribution. The heterogeneity of microhabitats on ferricretes supports a great diversity of plant and animal communities. With little overburden and a high percentage of recoverable metals they are targeted for mining which leads to removal of all soil, vegetation and microhabitats. Vegetation and faunal diversity of unmined sites from Kolhapur district were studied providing reference data used to discuss restoration efforts on two mined sites in the region. Restoration efforts have faced ecological and legal hurdles. The international literature for the restoration of bauxite mines fails to demonstrate any successful model to return the species assemblage to a pre-mining profile.

Restoration practices fail to adequately replicate microhabitat heterogeneity; often restoring sites to a different ecosystem from the original. The present mining policies do not take cognizance of the special nature of plateau habitats, ecology or the ecosystem functions they provide. We suggest a moratorium on mining of the high level lateritic plateaus in Western Maharashtra is justified until the biodiversity value and ecosystem services of the sites are fully understood and can be weighed against the economic gains from mining.

1. Introduction

Mining for fossil fuels, metals and minerals is essential for human society (Azapagic, 2004) and that demand has increased since industrialization. It places a pressure on the legislature to prioritise the values society places on access to materials without necessarily fully assessing or valuing the environmental costs of that access (Hilson and Basu, 2003; Laurence, 2011). Environmental Impact Assessment (EIA) is mandatory for mining in India by the 1994 notification under the Environmental Protection Act (EPA, 1986). In an EIA, mitigation measures are proposed in an Environment Management Plan (EMP) to avoid or reduce environmental and social impacts (Paliwal, 2006). The EIA should iterate the expected impact on the environment, its biota and the ecosystem services they provide together with the proposed measures to remove, reduce or compensate for the detrimental effects of mining (Drayson and Thompson, 2013). The weaknesses in the EIA process and its' implementation in India (Paliwal, 2006) have led to poor mitigation of the impact of mining.

Mining causes irreversible changes to the landscape, the environment and ecosystem services available to rural communities. Iron-ore mining in Karnataka (Krishnaswamy *et al.*, 2003) and in Goa were opposed by environmental and social activists and scientists for detrimental effects on environment and livelihoods. In the Western Ghats, mining is known to affect freshwater biodiversity (Molur, 2011), disrupt hydrological and sediment linkages (Krishnaswamy, *et al.*, 2006) and reduce species richness and community assemblages in amphibians (Krishnamurthy, 2003). Impacts of mining in ecologically sensitive areas of India are summarized by Vagholikar and Moghe (2003). The sustainability of bauxite mining in the Western Ghats is questionable (Phillips 2012).

Bauxite is one of the important ores found in the state of Maharashtra and mining leases have been granted on lateritic plateaus since 1968 (Directorate of Geology and Mining, 2015). The Western Ghats-Sri Lanka Biodiversity Hotspot was established in 2000 (Myers *et al.,* 2000). The Western Ghats are recognised as being one of the three most threatened biodiversity hotspots in the world (Cincotta *et al.,* 2000). Ferricretes in the northern section of the Western Ghats (NWG) are recognised as fragile habitats with high levels of endemism. They are described by Bharucha (2010) as hotspecks- miniscule areas of species concentration, varying in size from five to a few hundred square meters falling within or far outside today's recognized hotspots where species packing of diverse groups, including many endemics is found. New bauxite mining proposals in Northern Western Ghats (NWG) have been strongly opposed due to their predicted negative impacts on environment and society. In response to the opposition, mining companies have undertaken model restoration efforts at some sites. It has been argued that present models of restoration can successfully mitigate environmental impacts of bauxite mining and hence permissions to operate new mines on lateritic plateaus should be granted. Decision making regarding environmental clearance (by the State Environmental Authority) or forest clearance for diversion of forest land for mining (by the State Forest Department) has become a long drawn out process as environmental, social and corporate interests clash repeatedly over mining applications in Northern Western Ghats.

The present review was undertaken to discuss issues in restoration of bauxite rich ferricretes in NWG of Maharashtra.

The specific objectives of our study were,

1. To document vegetation and select fauna from unmined ferricrete as reference sites.

2. To discuss ecological, social and legal aspects of restoration on mined ferricrete using information from the reference sites.

High altitude ferricrete sites from Kolhapur and Sindhudurg districts were chosen for the review.

2. Materials and Methods

2.1 Study area

The Western Ghats (WG) are a 1500km long range of hills with an erosional escarpment on their western edge. In the northern section the lateritic soils form wide, flat indurated platforms on hill crests and ridges between 15°60′ and 18°20′N and at 800-1400m above mean sea level (ASL) (Widdowson and Cox 1996). These indurated platforms are ferricretes, or "sadas" in Marathi. The ecology and biodiversity of the ferricretes in the NWG has been described by Porembski and Watve (2005), Lekhak and Yadav (2012) and Watve (2013). Unique floral and faunal elements on ferricretes were documented by Joshi and Janarthanam (2004); Giri and Bauer (2008); Bhattarai, *et al.* (2013); Rogers and Padhye (2014).

Ferricretes in the WG are between 6 and 30m thick (Goudie, 1973). Bauxite occurs as thick capping on basalt in the Kolhapur district (Balasubramaniam and Paropkari, 1975). According to recent estimates of Directorate of Geology and Mining (Govt. of India, 2014) 133.111 million tonnes of bauxite reserve are present in NWG of which ferricretes in Kolhapur district have 83.53 million tonnes. They have little overburden and are covered by herbaceous vegetation unlike most other ferricretes in the world, which have a soil overburden and forest cover. Some ferricretes in Kolhapur have been mined since 1968 and new mines are proposed in the region.

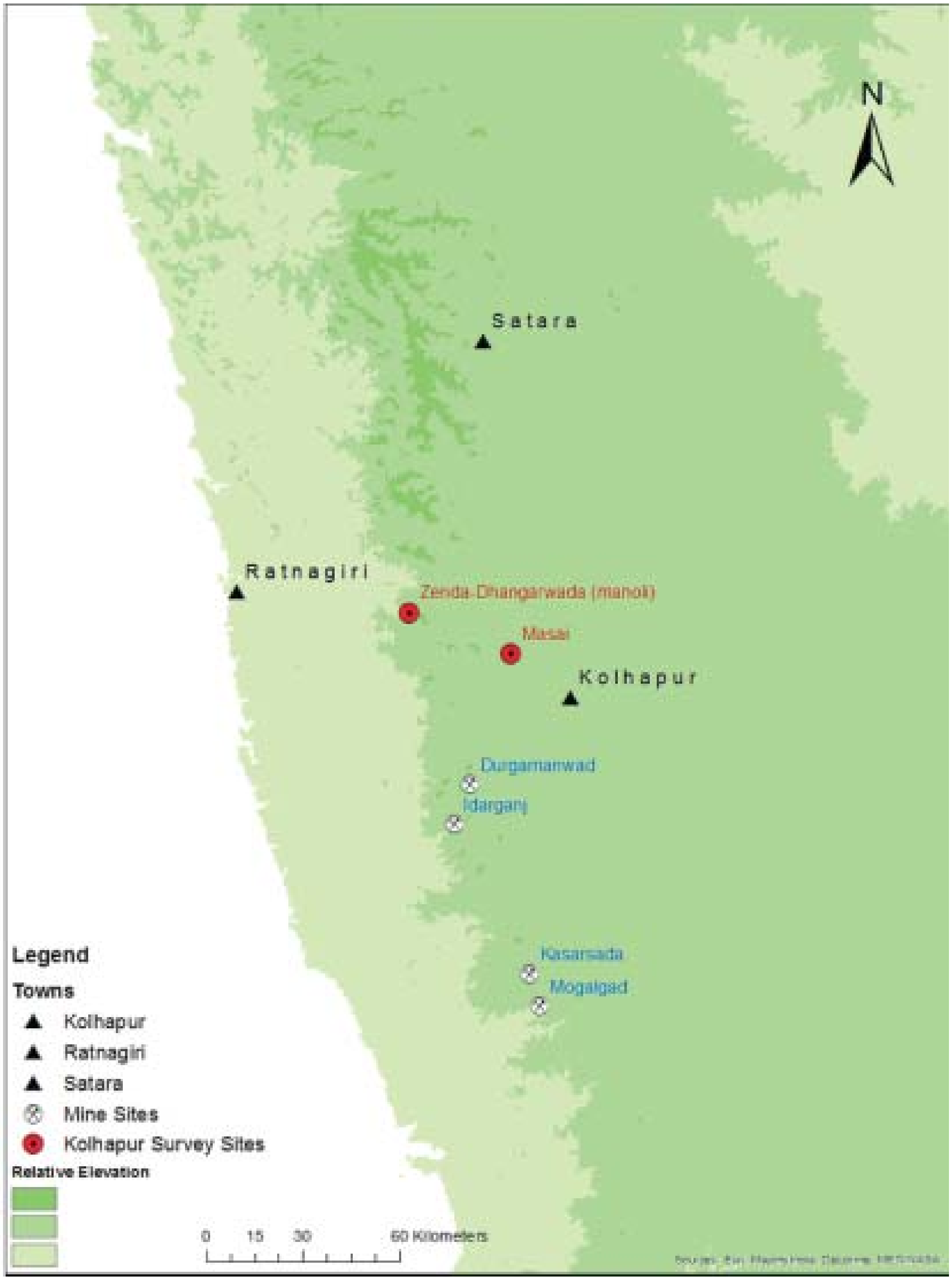
2.2 Methodology

In order to answer the questions, "Does mining change ferricrete biodiversity?" and "are current restoration practices adequate?" we analysed the steps in restoration and its documented outcomes from mined sites. Microhabitat diversity, plant communities and selected faunal groups were observed on two unmined sites (Masai and Zenda), which provide reference for comparing restoration efforts on mining sites at Kasarsada and Durgamanwad. Table 1 gives details of the sites where the observations were carried out.

Direct observations were used for both quantitative and qualitative data regarding the habitats. Plant communities in diverse microhabitats were documented on two sites, Zenda and Masai between 2005-2014 as a part of ongoing study of ferricretes in NWG.

The wide variety of possible measures of biodiversity has been discussed in the literature. Biological surrogates are representative taxa that are known to change in species composition and abundance reflecting a wider group of species. They can be used as measures of richness, endemism, rarity, and complementarily of taxonomic or functional groups that are presumed to be indicators of biodiversity patterns at large. Gaston and Blackburn (1995) divide surrogates into following groups : (i) the species richness of indicator groups (delimited on the basis of taxon or function); (ii) the levels of various environmental parameters (e.g. precipitation, primary

Map 1. Mined and un-mined sites in elevation context with town locations for location referencing



productivity, temperature, and positional correlates such as latitude, longitude and altitude); and (iii) the numbers of higher taxa (e.g. genera, tribes, families). For the present study, indicator groups of fauna were selected as surrogates for biodiversity pattern. Quantitative ecological observations of the selected faunal surrogates (amphibians, formicidae and aquatic coleopteran) were made on Zenda and Masai sites. Two of the mined sites, Kasarsada and Durgamanwad, where restoration has been carried out were visited for comparison. Observations were also made on Mogalgad and Idarganj sites.

Secondary information was collected from published papers and EIA, EMP and reports on mitigation and restoration projects of mined ferricretes. Policies and guidelines from the Ministry of Environment and Forest regarding mines are reviewed with special reference to bauxite mining in sensitive habitats within a global hotspot. Literature on mining and its impacts in India is limited. Kumar *et al*., (1995) conducted afforestation studies on laterites and mine dumps in Goa. Environmental and social impacts of bauxite mining are studied by Lad and Samant (2012). Kulkarni *et al*., (2013) have documented the technical restoration efforts by HINDALCO on two bauxite mining sites. Publications on bauxite mining in other countries were reviewed.

3. Results

Ferricretes in Kolhapur district are separated from each other by erosional valleys. The distance between the sites varies from 1km linearly within a cluster to 10kms-50kms between the clusters. The plant communities on ferricretes are similar to each other but differ widely from those occupying surrounding weathered landscapes. Bhattarai *et al*., (2012) in their studies on Kas plateau in Satara have noted hydrology to be one of the key factors driving specialisation with 80% of the hydrogeomorphic species in the study area plateau tops. Scarcity of soil, extremes of climate, especially temperature and rainfall, influence vegetation on ferricretes where cryptogams and ephemerals are dominant. It has been shown that species richness of plateau communities is related to the range of available micro-habitats (Katwate, *et al*., 2013, Rahangdale and Rahangdale 2014).

3.1 Species diversity and endemism on sites

Endemic, habitat specialist species with limited distribution are reported from study sites. For example *Eleocharis wadoodii* S.R. Yadav et al. *(Masai), Indigofera dalzellii* Cooke, *Impatiens lawii* Hook. F. and Thomson *(Zenda, Idarganj)*. Unique assemblages of amphibians, aquatic invertebrates and formicidae, novel species, critically endangered and data deficient species are present on ferricretes.

The two selected sites Masai and Zenda ferricretes, have microhabitats characteristically seen on ferricretes. Sixty three species of annual herbs were seen on Masai plateau of which 18 are endemic to WG. Fifty four species of annual herbs were seen on Zenda plateau of which 28 are endemic to WG. Amphibians include *Sphaerotheca dobsonii* (Boulenger, 1882), *Indotyphlus* cf. *battersbyi* and the common *Hoplobatrachus tigerinus* (Daudin, 1803) on Masai and *Indirana* cf. *beddomii* and *Fejervarya* spp. on Zenda. Ants (Formicidae) species recorded on Masai and Zenda included *Myrmicinae Crematogaster subnuda, C.rothneyi* and *C.dohrnii; Camponotus irritans; Myrmicinae Monomorium* four spp; *Myrmicinae Pheidole* two spp; *Ponerinae Pachychondyla spp*. *Formicinae Polyrhachis* three spp; The list is illustrative of the range of species, not exhaustive. The range of pool microhabitats enable a wide range of habitat specialists to co-exist. For example *Dytiscidae Microdytes svensoni* requires very shallow water, ideally slowly moving as found on the exposed rock areas of a ferricrete. It coexists along with *Gyrinidae Orectochilus Patrus* spp. that require deeper pools with a much longer hydroperiod.

3.2 Description of Microhabitats and ecological functions

A brief description of microhabitats seen on these two sites is given below. Ecological functions reported for the microhabitats are included in Table 2.

3.2.1 Exposed rock surface

All rock surfaces exposed for enough time are covered in a crytpogamic or Biological Soil Crust (BSC). On ferricretes they are comprised of a vegetative complex of cyanobacteria, cyanobacterial lichens and bryophytes. They provide basking areas for many reptiles.

3.2.2 Loose and semi buried rocks

Rocks comprising of the parent material, varying in size from less than 10mm to more than a meter were common on unmined plateaus (Photo 1). This habitat is an important feature of all less disturbed sites such as Zenda, Idarganj and Mogalgad. On Masai, boulders have been removed by villagers for construction. Boulders have BSC, chlorophytic lichens, as well as niches for higher plants to establish. Moss cushions and ferns, lithophytes such as *Hoya* spp., orchids (*Aerides, Dendrobium*) are frequently found on boulders.

They provide refugia for a wide range of invertebrates, reptiles and amphibians as well as elevated display points essential for many breeding amphibians.

3.2.3 Rock crevices

Rock crevices provide a microclimate for mosses, ferns and some angiosperms. *Indopoa paupercula (Stapf)* Bor, *Tripogon bromoides* Roth, *Fimbristylis tenera* Schult are dominant in crevices. *Neanotis spp. Glyphochloa* spp. are common in crevices. They provide refugia for amphibians, reptiles and invertebrates and as such permit some resident amphibians to persist on the site through the dry months.

3.2.4 Soil filled depressions

Shallow soil filled depressions (less than 30cm depth) on Zenda as well as Masai sites have high species richness of herbs and include *Paspalum canarae* (Steud.) Veldkamp, *Smithia spp*., *Habenaria spp*. *Pycreas spp*., *Jansenella griffithiana* (C. Muell.) Bor, *Coelachne minuta* Bor, *Linum mysorense* B.Heyne ex Wall amongst many others. Deep soil filled depressions (soil depth greater than 30cm) have tall herbaceous vegetation or low woody species.

Areas with soil depth more than 1m on Zenda site support woody vegetation of *Carissa congesta* Wight, *Catunaregam spinosa* (Thunb.) Tirveng., *Xantolis tomentosa* Raf. *etc*. Forest patches of *Memecylon – Syzygium-Actinodaphne* type are seen on undisturbed sites such as Zenda and Idarganj but the vegetation is generally low, 3-5m high due to strong winds and extreme climate on the plateau tops. *Ficus* spp. establish in deep clefts along the plateau edges. All sites have a rich fauna of Formicidae with genera associated with forest including *Myrmicinae (Crematogaster* spp.) and *Formicinae (Polyrachis* spp.).

3.2.5 Ephemeral Flush Vegetation (EFV)

Ephemeral Flush Vegetation (EFV) grows on gently sloping areas that allow slow seepage of rainwater through existing vegetation (Photo 5). It is a dominant community on unmined sites, and covers large areas of ferricrete sites. The community is dominated by *Utricularia* spp. (*U. purpurascens* Grah., *U. albocaerulea* Dalz., *U. praeterita* P. Taylor) and *Eriocaulon* spp. (*E. sedgwickii* Fyson, *E. eurypeplon* Koern., *E. stellulatum* Koern., etc.) (Photo 5). *Swertia minor* (Griesb.) Knobl., *Cyanotis fasciculata*, *Drosera indica* L., *Dichanthium spp.* and some other small ephemerals are common.

3.2.6 Depressions filled with water pools

During the monsoon, water accumulates on the plateaus filling depressions of all sizes. Pools of various depth on the sites range from 'micro pools' (up to 20 mm), to shallow pools (20-150mm deep), deep pools (150 – 300mm) and finally semi-permanent ponds (>300mm in depth). Pool complexes with varying hydroperiods are not common in the wider landscape and are a valuable ecological resource (Brendoncket *et al*. 2015).

These are sites for aquatic invertebrates. Temporal changes in aquatic invertebrates were seen from early occupants derived from the egg banks and aestivating larvae of permanent residents (e.g. Odonata and Coleoptera) joined later by active dispersers. Nymphs of several genera of Heteroptera were observed on the Masai and Zenda. The communities in ferricrete pools shift in phases with early ephemeral taxa such as the Hemipterans of the genus *Micronecta* dispersing and late emergers replacing them.

The vegetation in the pools and on the margin can be broadly classified as flooded terrestrial vegetation and aquatic vegetation. Aquatics like. *Marsilea spp*., *Rotala spp.* and members of Cyperaceae (*Cyperus spp*., *Pycreas spp*.,*)*, Poaceae (*Eleusine indica* Gaertn., *Oryza sativa* L.) are frequent in deep water bodies on plateaus. *Polygonum plebeium* R. Br. form dense growth on dried up pond soil. Aquatic invertebrate species richness is correlated with the amount of vegetation in a pool. (Thorpe *et al*., in press).

Micro pools are used by a number amphibian species to deposit spawn in, some species' larvae remain in the pool with others grazing on the BSC on the wet surfaces of the boulders.

Shallow pools (Photo 3) are highly ephemeral in nature and are colonised by small aquatic coleopteran adults which are known to be active dispersers *Dytiscidae Microdytes* spp., *Hydroporinae Clypeodytes* spp. and *Hydrophilidae Regimbartia* spp. Larvae of a number of anuran species can be found alongside the invertebrates. Vernal pools are a scarce and recognised habitat that are recognised as being worthy of protection (Gioria in Yee 2015, Ch.7).

Some *deep pools* may retain water for a month or so even after the rain stops. Their vegetation is mostly similar to shallow pools but may also have floating hydrophytes. They have a rich invertebrate fauna which varies in community assemblage and species richness between high level sites and those below the escarpment. Members of the order Odonata, sub-orders Anisoptera and Zygoptera use the pools as breeding sites. Aquatic coleopterans belonging to five families and 31 genera have been recorded from pools on unmined ferricretes (Table 1). Water Scorpions (Family

Nepidae) are frequently encountered. Coleopterans only found in deeper pools include *Hydrophilidae Hydrobiomorpha* spp. and *Hydrophilus* spp.; *Dytiscidae Cybister* spp., *Gyrinidae (Dineutus indicus and Orectochilus Patrus* spp.) Hemiptera Heteroptera are represented by 7 families and 8 genera (Un-mined sites, Table 1). Decapoda are frequently encountered belonging to the family Potamidae with a number of species observed.

Semi-permanent ponds retain water almost till end of winter and may be dry or with little soil moisture during the summers. Their vegetation consists of typical hydrophytes including green algae, *Nymphoides* spp., *Ludwigia* sp., *Persicaria glabra* (Willd.) Gomez and *Crinum viviparum* (Lam.) R. Ansari and V.J. Nair.

In Amboli, trees overhanging such pools are used by foam nesting amphibians for example *Rhacophorus malabaricus*.

3.2.7 Drainage channels

At places, drainage channels of 100mm width or more but very little depth are seen running downhill into small puddles. *Cryptocoryne* spp. occupy the sides of such drainage channels.

3.2.8 Escarpment walls

Steep escarpment walls support a wide diversity of snails, aquatic coleopterans, frogs and cryptogamic flora during wet period. Mammals such as mouse deer, sloth bear and civets use the escarpment walls and caves as refugia and breeding sites. The invertebrate communities of the seeps along the escarpment edges are under researched.

3.3 Ecosystem services

Ferricretes provide supporting, provisioning as well as cultural ecosystem services. Provisioning services are principally water, fodder and to a minor extent medicinal plants together with fish and crabs for food.

Grazing and use of rock pools by wild animals as well as livestock is seen on all the unmined ferricretes in study area. Many plateaus are grazed by domestic livestock during the monsoon. Fodder is also harvested and carried off for use after the monsoon period.

Loose rocks have for a long time provided building material for the construction of dwellings and enclosure walls or simply to demark boundaries.

Lateritic plateaus are essential for recharging perennial springs (Buono, 2013). Zenda and Masai ferricretes have perennial springs along the edges, on which villagers are heavily dependent. Villages gain irrigation and drinking water (Lad, 2009) originating from the plateaus. In addition it enables a range of aquatic habitats to persist below the high level plateaus well beyond the end of the rains.

Fish and crab collection from plateau ponds is common in monsoon. Medicinal plants such as *Swertia densifolia* (Griseb.) Kashyapa, *Iphigenia* spp. are collected from the plateaus.

Supporting services include pollination. The mass flowering of plants provides an intense resource for a number of pollinators which provide an essential ecosystem service for a range of crops in the surrounding area (Hobbhahn, *et al.* 2006).

Cultural services including religious and more recently recreational uses are also provided by ferricretes. Most ferricretes have locally important shrines and memorial stones. The caves below Masai plateau are believed to have been used by Pandavas, mythical characters from Indian epic Mahabharat. This plateau also has historical significance and has become a significant tourist destination due in part to its proximity to Kolhapur. Two temples of the goddess Masai are important shrines visited by thousands of people annually. A temple with ancient carvings is present on the Zenda ferricrete. Regulatory services such as those for water (holding capacity and purification) and carbon sequestration have not been studied so far.

3.4 Unique features of ferricretes

Future research, especially on invertebrates and cryptogams will surely reveal high diversity and yet unknown ecological functions and as such they have significant biodiversity and educational value. Many new and endemic species have been described from ferricretes in the NWG region. *Ceropegia jainii* Ansari and Kulkarni, *Merremia rhyncorhiza* (Dalz.) Hall. f. are endemic threatened species reported from Amboli ferricretes. Amphibian species such as *Raorchestes ghatei* (Padhye 2013), *Indirana chiravasi* (Padhye 2014) Amboli Toad, *Xanthophryne tigerina* (Biju *et al*., 2009) were reported from one or a few sites in this region. Endemic and threatened species restricted to one or few ferricrete sites have also been documented from Satara district and in low level ferricretes (Watve, 2013). The scientific findings suggest that each ferricrete site may have unique and as yet undescribed biodiversity, owing to its functioning as "habitat island" (Thorpe *et al.* in press and Lewis *et al.* in press). Biodiversity of ferricretes differs widely from that of the surrounding weathered landscape. The scarcity of soil, extremes of environmental changes lead to formation of plant communities specific to each microhabitat which are not seen elsewhere.

The microhabitats and associated plant and animals communities described above are characteristic of ferricrete habitats. Hence, one can safely assume that these were present on the mined ferricrete sites in the past. In the absence of baseline documentation from mining sites the restoration can be compared with these reference sites.

3.5 Impacts of mining and restoration efforts

In the NWG, Bauxite mining follows the open cast mining model. In the mining process overburden of soil and vegetation is removed (Photo 2). Ore is removed by blasting or ripping with bulldozers and exported from the site for processing. Open cast mining completely removes the ferricretes surface, hence none of the microhabitats and plant and animal communities described above can be sustained on an active mining site. A wider secondary effect is impact of the removal of resources from visiting groups, for example birds and predators who hunt in the open space afforded by the plateau or those affected off site, for example stream communities in water bodies fed by springs below the site. The primary and secondary impacts have to be mitigated and compensated in the restoration process.

3.6 Mitigation

Mitigation is the process of preventing, reducing or offsetting any adverse impact of development on species resident on the site prior to commencement of work (Drayson and Thompson, 2013, Maron *et al*., 2012). Ecological restoration (Benayas 2009), habitat restoration (Miller and Hobbs 2007) or ecosystem reconstruction (Cooke and Johnson 2002) have the simple sounding objective of reversing the damage or degradation caused by human activity. Within that broad remit there are subsets of activities that can be usefully considered when planning works to achieve the ideal of 'no net loss' of habitat, populations or the resources necessary for their long term persistence (Miller and Hobbs 2007; Maron *et al*., 2012; Drayson and Thompson 2013). It belies the significant difficulties involved in replacing the previous communities and the resources they need to exist as self-sustaining communities. The restoration process should address not only the biodiversity but the ecosystem services that had previously been provided by the site. The provision of some ecosystem services are correlated to biodiversity and therefore an improvement in one will help the other. In the context of a site subject to open cast mining that may seem a difficult target to achieve but it must remain the primary objective. In some models, translocation of fauna is included, but this is difficult for almost all taxa.

3.7 Restoration

Two options are available for restoration: the traditional restoration based on natural recolonization and technical restoration where the processes involved, from land reclamation to species introduction, are all managed.

3.7.1 Outcome of traditional Restoration

The results of natural recolonization can be seen on partially mined or abandoned sites in the study area. Observations on Idarganj and Zenda sites show that the parts of the area that were explored for testing the ore quality, about 20-25 years ago are still almost barren areas in the midst of intact plateau vegetation. They lack the habitat heterogeneity of an undisturbed site. A thin BSC has established on these areas, but only select species of EFV, which have wind-dispersed seeds in large quantities (*Eriocaulaon spp., Utricularia spp., Hedyotis spp*.) have recolonized despite a seed source being adjacent. Tropek *et al.,* (2012) point out that, significantly similar sites close to the restoration site are essential if rare pioneer species are to be able to recolonise, on Indarganj and Zenda recolonization is patchy. Some taxa will face specific difficulties. For example many tropical tree species' seeds are heavy and hold a large amount of free water giving them a very limited viability period and restricted dispersal reliant on suitable vectors (birds and mammals) remaining active in the post mining area. Other plant groups who depend on rare habitats such as those dependent upon rocky vernal pools will not be available unless the surrounding undisturbed source habitat has such resources within the relevant dispersal range.

3.7.2 Limitations of technical Restoration

The second option is technical restoration. In theory, technical restoration can be undertaken in steps, for example : restoration of substrate, re-creation of microhabitats, re-establishment of cryptogrammic crusts and later higher order flora, introduction or establishment of faunal communities of invertebrates, vertebrates, development of ecosystem processes interlinking flora and fauna and simultaneous refurbishing of ecosystem processes. Continuous monitoring to ensure self maintenance of the ecosystem will be required.

In practice, several challenges have been noted by Kulkarni *et al.,* (2013) who have carried out technical restoration of Kasarsada and Durgamanwad mining sites (Photo 6).

- Lack of porosity of the clay layer left after ore removal damaging downslope springs. They use machines to scratch the surface of hard clay layer and machines to create cracks which can later be filled up.
- Lack of or scarcity of restoration material (soil/ overburden) leading to import of exotic material. They used two types of substrate; soil from surrounding intact plateau and silt from village waterbodies.
- Extreme sun, wind and weather conditions unsuitable for growth of most tree species except those locally adapted species present prior to mining.
- Challenges in restoring water drainage.
- Preference of the clients regarding the forest model of restoration owing to the directions of the monitoring and evaluation committee. (Restoration sites are regularly inspected by committees appointed by regulatory bodies such as Pollution Control Board, Ministry of Environment and Forest, Indian Bureau of Mines etc. Forest model is a well recognized model for restoration of mining sites, hence any deviation is likely to invite criticism from the monitoring committee.)

Availability of substrate is the first challenge in technical restoration. Removal of ore leaves a hard layer of clay, poor in porosity and poor in nutrients at the same time destroying habitat integrity and all microhabitats unsuitable for growth of vegetation. This poses a major challenge in restoration as the clay layer is devoid of organic matter, has no fissures and is unsuitable for establishment of BSC which is a soil precursor on ferricretes. Standard procedure in mining restoration includes storage of overburden and backfilling. This is possible when large amount of overburden of soil is present. Hence it is unsuitable for ferricretes which have small amount of overburden and a limited quantity of soil. A seed bank stores seeds as a source for planting in case seed reserves in nature are destroyed. Imported soil will lack the seed bank of endemic and adapted species and may contain propagules of invasive species. So far there are no techniques or seed banks established for propagation of ferricrete plants nor are mycorrhizal associations and dispersal vectors fully known. Thus, restoration has to rely on existing seed banks or natural colonization process automatically excluding many species. Leaving a part of ferricrete surface intact during mining did retain seed banks, but the amount of recoverable seed material is very small, as most species are wind dispersed and thus scatter very small sized seeds over wide areas. This makes collection or storage of seeds very difficult. Similar issues exist regarding fauna for replacing communities. Ecological details for almost all ferricrete specialists are absent from the literature.

Waterhouse, *et al.*, (2014) found that soil microbial communities are sensitive to restoration process and the only way of preserving them was to remove, carefully store and replace the top 300mm of topsoil at the same time limiting the depth of storage piles. This process was also suggested for the conservation of soil invertebrates by Majer *et al.*, (2013). Mycorrhizal association of plateau plant species are not known but are common in low nutrient systems such as lateritic plateaus. This aspect has not been considered in bauxite mining restoration efforts in the study area.

In Durgamanwad, silt was procured from village tanks in surrounding areas, for plantation purposes (Kulkarni et al. 2013). However, it is a poor alternative as silt is very different material from the original sandy – loam soil found on plateaus and has seeds of ruderal and invasive species alien to ferricrete habitats. Disturbance and importation of alien material (for construction fence) has been demonstrated to introduce potential invasive plants along the fence-line on the Kas plateau, a ferricrete in Satara district.

Soil from an intact plateau is a better option, but may not be available in large quantities as the soil layer on a ferricrete is generally shallow or inaccessible, located in depressions and surface cracks. Removing soil from intact ferricretes would also disturb an unmined and intact ecosystem extending the area disrupted. In Durgamanwad, soil was collected from adjacent unmined plateau and spread on the hard face to start restoration. However, without the BSC and without the crevices, most thinly spread soil material is just washed away during the heavy rains as the surface topography did not provide for depressions to allow soil to accumulate. It is thus critical for successful restoration to allow for and to encourage the formation of biological crust over a topographically heterogeneous surface before undertaking plateau flora restoration, but there is no established technique for this and natural formation of BSC takes several years.

Storage of overburden at a depth over 1m damages the biota within the spoil (Waterhouse *et al.*, 2014). In the active mining sites it was seen that the piled up overburden is quickly colonized by *Senecio spp*., *Blumea spp*., *Themeda spp*., *Heteropogon spp.* from surrounding scrub vegetation, which will add their seeds into soil. Backfilling, if practised, does not rebuild the plateau surface or the surface drainage pattern as was present in the intact habitat and hence cannot support the plant or animal communities of the pre-mining stage.

One of the major problems observed on restoration sites was the lack of heterogeneity in micro-habitat provision, specifically the absence of boulders, rock pools of all depths, shallow depressions or crevices which are all essential microhabitats for the re-establishment of amphibians, reptiles, invertebrates and flora. Kulkarni *et al.* (2013) mention recolonization of common shrub and tree species on restored areas. EFV species *(Utricularia spp., Eriocaulon spp.)* were also seen naturally colonizing restored areas. However, establishment of geophytes (*Crinum spp., Chlorophyum spp.) and* lithophytes was not seen due to absence of boulders and deep crevices.

Restoring the drainage pattern and diversity of aquatic habitats in the mined out area is a major challenge. Large pools of rain water form in excavated areas on the plateaus (Photo 4). However, the water was mostly used for mining tasks, such as washing of vehicles, sprinkling water over ore to reduce dust and for plantation activities. Due to this, the water was in regular use and aquatic flora seen on reference sites (*Cyperus* spp, *Pycreas spp. Eleocharis, Oryza* etc.*)* is absent. Such tanks do not have the low angle edge providing shallow areas required by many aquatic invertebrates (Gioria in Yee 2015 Ch. 7). Amphibian and invertebrate fauna that require aquatic vegetation cannot establish. Except a few large mammals, restoration of invertebrates or herpetofauna has not been reported.

Legal issues in restoration

Norms regarding EIA of projects such as mining were very weak and prescriptive in India until 1998. Major amendments in Environmental Law made in 2006 make it necessary to conduct EIA and Social Impact Assessment (SIA), for certain projects. Recent EIAs of proposed bauxite mining at Girgao, Ringewadi ferricretes (EIA, 2013) were conducted during March 2011 to May 2011 (summer) as the Terms of Reference (TOR) set by the Ministry of Environment and Forest asked for single season, non-monsoon data. As a result the EIA and EMP completely missed out the details of the seasonally diverse plant and animal communities. EIA of Mogalgad site (EIA, Mogalgad, 2013) lists characteristic ferricrete species. However, EMP of the site gives suggestions regarding plantation of trees, mostly exotic, aliens such as *Acacia spp*. *Casuarina spp*., etc. The EIAs do acknowledge the presence of waterbodies and springs in the villages but importantly do not comment on the impact of mining on these ecosystem services. In the absence of rigorous EIA and baseline data, it is not possible to create a sound EMP or to assess the success of restoration efforts.

EIA of Durgamanwad, Kasarsada and Idarganj mines were conducted several years ago, when the understanding of lateritic plateau ecosystems was extremely poor. The leases were not renewed mainly because of environmentalists protesting on various grounds against mining (Vagholiar and Moghe, 2003). Idarganj mining was stopped on the basis of unique biodiversity values and the presence of the plateau in Radhangari Wildlife Sanctuary, at present Sahyadri Tiger Reserve. On Durgamanwad site extension of the mining lease and forest clearance was refused as it was within 10kms aerial distance from the Radhanagari Wildlife Sanctuary. On Kasarsada site, lease was not renewed and the site was returned to forest department. In both the cases, continuation of restoration efforts by the corporate agency is unlikely.

As per the notification (G.S.R. 330(E) Part II, Section 3, Sub-section (i) 10/04/2003) issued by the Government of India, Ministry of Mines Final Mine Closure Plan is to be prepared and approvals are to be taken as a part of the Mine Closure Plans. Final Mine closure activities are to be started towards the end of mine life and may continue even after the reserves are exhausted and/or mining is discontinued till the mining area is restored to an acceptable level by the appointed government regulatory bodies. However, restoration being a long term and dynamic process, the time period required to consider a restoration as "acceptable level" also needs to be finalized. The financial and technological responsibility to maintain the restoration at the acceptable level post mine closure, ensuring no degradation occurs after withdrawal of agencies also needs to be clearly stated and shared by the mining companies and government or private owners of the land.

The Wildlife Protection Act (1972) is only applicable to designated protected areas (National Parks, Wildlife Sanctuaries) and wildlife in different schedules but sites such as Zenda or Mogalgad are not included in protected areas. Plateau fauna, dominated by invertebrates and cryptogams is not included in the schedules of WPA and therefore does not get any special protection.

Kulkarni *et al*., (2013) mention that regulating agencies only recognize specific models of restoration which are forest, grassland, agriculture etc. while plateau (ferricrete) flora restoration could be considered only in later stages. There is so far, no legal obligation on the mining company to restore a ferricrete to its unique pre-mining biodiversity. In case of Kasarsada and Durgamanwad, the forest (tree plantation) model was chosen in consultation with the company as *"it is well recognized by regulating and monitoring authorities and an easier model to restore to, with well established technology"* (Kulkarni et al. 2013). This limited the possibility of restoration of original biodiversity of ferricretes on this site. It is necessary for the regulating and monitoring authorities to understand the importance of restoration to pre-mining habitat. To restore to an alternative ecosystem will automatically exclude all specialist species. Some specific social issues are also presented by mining restoration. None of the studies or EMPs offer economic assessments which weigh the pros and cons in terms of valuation of livelihood impact of the loss of ecological services against the gain in terms of employment, infrastructural development or social uplifting of the rural communities in sustainable manner. In the pre-mining stage, the ferricrete habitats are common property resources, and villagers have rights of access and withdrawal of fodder, medicinal species, water and worship at shrines. This access had continued even in Reserve Forest (RF) areas. However, during the mining stage, the areas are secured by the company to prevent access of local people and livestock. This is a necessary procedure considering the valuable ore, machinery and also regular blasting for minerals, which makes the area risky to access. Abandoned mines pose many risks, due to dumps, deep waterbodies etc. Allowing free-access to restored areas post-mining may not be feasible as it can lead to disturbance in the restoration process. The sustainability of the restoration, after the end of mining lease is questionable, as the corporate body is not under any legal obligation to continue restoration when the lease ends.

The legalities regarding grant of access to local communities post-mining or post-restoration have never been clarified. Certain community rights over RF areas or even private areas are recognized under present laws. For example, the Forest Rights Act (2006) and Biological Diversity Act (2002). It is unclear if the same rights will continue after mine closure. This will have long-reaching effect on the sustainability of the restored ecosystem, e.g. if local communities do have the rights to using the restored area for collection of forest produce (fodder, fuel etc.), then the model of restoration will need to be planned and executed in a manner to allow extractive activities at sustainable level. Otherwise over extraction may lead to loss of the restored biodiversity. It is not known if grazing and extraction are regulatory processes which create and maintain the plateau ecosystem so their exclusion may directly lead to a novel ecosystem even if the site is appropriately restored.

Global restoration scenario with special reference to bauxite mining

The published records of post bauxite mining restoration from northern WG bring out the challenges in restoration of the plateau flora. They do not offer any evidence of restoration leading to return of the site to the same flora and fauna as previously existed on the plateau sites, or to local reference sites.

The international evidence of post bauxite mining restoration is uniformly negative in the long term. Mining followed by restoration of all types leads to a shift in community structure from the pre-mining assemblage, even after 37 years, irrespective of the restoration model or level of expenditure (Majer *et al.* 2013; Courtney, *et al.* 2014). The changes affect species at all scales from microbial to vertebrate. Herath *et al.* (2009) found that restored laterite sites shared only 12-37% of shrub species with natural sites. Gould (2012), also working on post bauxite mines, found plant community composition was significantly different from un-mined sites after 23 years with key framework species absent. Using ants as bio-indicators, Majer *et al.*, (2013) found the community was still measurably different to reference sites 37 years post mining. In a meta-analysis of 20 studies using invertebrates to assess post bauxite mining recovery Majer *et al.,* (2007) found tree monoculture damaged recovery. The shift in plant community assemblage is reflected in birds both in numbers and species richness (Brady and Noske 2010). Intra-specific relationships must therefore be considered when assessing recovery and not just the presence of individual species (Majer *et al.,* 2007). In spiders the community on mined sites was still distinct from reference forest sites but there appears to be a trajectory, with the oldest mined site being more similar to reference forest than younger mined sites (Majer *et al.,* 2007). However, even when pre-mining diversity is achieved the species mix of invertebrates may differ (Majer *et al.,* 2007).

Alcoa has noted success in recolonization of vertebrate groups post bauxite mining. In mammals, recolonization after 10 years is linked to resource availability in terms of food and shelter and the species source pool (Nichols and Grant 2007). Total of 95% of bird species were found to recolonize. They do not comment on the 5% that did not recolonise and that small group may include rare species (Nichols and Grant 2007). However, they have compared their success with some other studies of restoration and concluded that rates of bird recolonization vary, being more rapid for mesic forested areas but not so for semi-arid shrub-steppe areas. The figure in reptiles was similar with 87.5% returning, but reptile species numbers and abundance tend to be lower in restoration than in unmined forest (Nichols and Grant 2007). They have suggested that variable habitat requirements of the vertebrates species need to be understood and where possible met in a cost-effective manner to ensure their successful recolonization after restoration. Robust and long-term monitoring of mined and restored sites will be required to check if biodiversity in Western Ghats also responds in ways similar to that elsewhere. At present such long-term studies are lacking. Therefore, success of restoration efforts of mines, especially bauxite mines remains unknown.

Phillips (2012) suggests that bauxite mining in Andhra Pradesh is unsustainable owing to environmental and social impacts. Therefore, there is a substantial case to refuse the mining applications at sites such as Mogalgad, Ringewadi, Burumbal, Girgaon, Dhangarwada in Kolhapur district in order to protect the unique floral and faunal communities and ecosystem services.

Conclusion

Any conclusion, as would any EIA, will be based upon incomplete knowledge of the biota and ecology of the high level ferricretes. Therefore our comments need to be considered as a view based upon our study, published literature and knowledge at this point in time.

Based upon our own findings and those published by others of post mining restoration outcomes we find :

- New species are being described from the high level plateaus that are known to be, or are suspected to be, unique to a single site. Given the rate of discovery of new species is relative to exploratory time and taxonomic effort it seems reasonable to hypothesise that every high level plateau can be expected to house unique taxa.
- A ferricrete, together with its unique micro-habitat heterogeneity and ecosystem services, cannot be recreated by ecological restoration to the pre-existing community. Current restoration practice has failed to recreate the range of micro-habitats or hydrological patterns that existed pre-mining.
- No evidence was found that the ecosystem services provided by a high level ferricrete could be, or have been, replicated.
- Current legal requirements do not recognise ferricretes as a non-forest ecosystem and therefore the current legal restoration guidelines are outmoded.
- The current legal framework does not identify the need to preserve ecosystem services for the communities around the ferricrete.
- The current legislative requirements exclude assessment of off-site systems impacted by the application, for example stream and escarpment communities.
- Detailed long term scientific research examining success of mine restoration, and establishment and recolonization of diverse taxa, is lacking.

Therefore mining of any ferricrete plateau is likely to cause irreplaceable loss of unique species, ecosystem services and key biogeographic features of one of India's and the world's most biodiverse locations. A similar impact is anticipated for ferricretes in the Konkan, however we recognise the impact of changes in hydrology and landscape may be less around low level ferricretes than for the high level plateaus. In the view of irreplaceable loss of unique and sensitive biodiversity and critical ecosystem services, bauxite mining in the Western Ghats biodiversity hot-spot should be subject to an immediate moratorium until the biodiversity value and ecosystem services of the sites are fully understood and can be weighed against the economic gains from mining. At the same time, mine closure plans should be implemented with the application of ecological restoration practices to the currently worked mining areas and old abandoned bauxite mines in the region to ensure at least partial mitigation of the impacts.

References

Azapagic, A. (2004) Developing a framework for sustainable development indicators for the mining and minerals industry. *Journal of Cleaner Production, 12* (6), 639-662.

Balasubramaniam, K. S., and Paropkari A. (1975) Mineralogy and genesis of bauxites of Nagardaswadi Plateau, Kolhapur District, Maharashtra State (India). *The Canadian Mineralogist, 13(3),* 222-226.

Benayas, J., M.,R., Newton,A.,C, Diaz, A., and Bullock, J.M. (2009) Enhancement of biodiversity and ecosystem services by ecological restoration : A

meta-analysis. *Science*, *325* (5944), 1121-1124.
Bharucha, E.K., (2010) Current ecological status and identification of potential ecologically sensitive areas in the Northern Western Ghats. Report by : Institute of Environment Education and Research; Bharti Vidyapeeth Deemed University. Pune, Maharashtra, India.
Bhattarai, U., Tetali, P., and Kelso, S., (2012). Contributions of vulnerable hydrogeomorphic habitats to endemic plant diversity on the Kas Plateau, Western Ghats. *SpringerPlus, 1*(1), 25.
Biju, S., Van Bocxlaer, I., Giri, V. B., Loader S. and Bossuyt, F. (2009). Two new endemic genera and a new species of toad (Anura : Bufonidae) from the Western Ghats of India. *BMC Research Notes 2*(1), 241.
Brendonck, L., M. Jocqué, K. Tuytens, B. V. Timms and B. Vanschoenwinkel (2015). Hydrological stability drives both local and regional diversity patterns in rock pool metacommunities. *Oikos 124*(6) : 741-749.
Buono, J. and Thomas, R. (2013). Natural Springs in the Western Ghats : A Vital Resource Under Threat: Overview, Best Practices and Policy Recommendations for Ensuring Biodiversity and Sustainable Drinking Water. Grampari. [Online]. Available at : file:///G:/Documents/Documents/BiogeographyHydrologyBuono,%20J,%20Anatomyu%20of%20a%20spring%20system.pdf (Accessed : 07/08/2015).
Cincotta, R.P., Wisnewski, J. and Engleman, R. (2000). Human populations in the biodiversity hotspots. *Nature, 4040* (6781), 990-992.
Cooke, J. A. and Johnson, M. S. (2002). Ecological restoration of land with particular reference to the mining of metals and industrial minerals : A review of theory and practice. *Environmental Reviews 10*(1), 41.
Courtney, R., Harris, J. A. and Pawlett, M. (2014). Microbial Community Composition in a Rehabilitated Bauxite Residue Disposal Area : A Case Study for Improving Microbial Community Composition. *Restoration Ecology, 22* (6), 798-805.
Directorate of Geology and Mining, Govt. of Maharashtra, Nagpur. (2014) http://www.mahadgm.gov.inInternalPage.aspx?Antispam=nm9WddrsTcbandMineralInformationID=6andMyAntispam=pPiwE6B0r42 Downloaded on 10 October 2014.
Drayson, K. and Thompson, S. (2013). Ecological mitigation measures in English Environmental Impact Assessment. *Journal of Environmental Management, 119* (), 103-110.
EPA, (1986). The Environment Protection Act http://envfor.nic.in/legis/env/env1.html Downloaded on 10 October 2015.
EIA, (2013). Environment Impact Assessment report on Bauxite Mining for Ex servicemen Welfare Association (Girgao, Mhalasavade, Ringewadi, Kolhapur District. http://environmentclearance.nic.in/writereaddata/EIA02072015U37EH4MLFinalEIAExservicemenn.pdf. Downloaded on 10 October 2015.
EIA, Mogalgad, 2013. Executive summary of Draft EIA and management plan report. Mogalgad Bauxite Mine. Hindalco. http://mpcb.gov.in/notices/pdf/Exe%20sum_Hindalko_Mogalgad.pdf
Escolar, C., Martínez, I., Bowker, M. A., and Maestre, F. T. (2012). Warming reduces the growth and diversity of biological soil crusts in a semi-arid environment : implications for ecosystem structure and functioning. *Philosophical Transactions of the Royal Society of London B : Biological Sciences,367*(1606), 3087-3099.
Gaitonde, N., and Giri, V. (2014). Primitive breeding in an ancient Indian frog genus *Indirana*. *Current Science, 107* (1), 109-112.
Gaston, K.J., and Blackburn, T.M. (1995). Mapping biodiversity using surrogates for species richness : macro-scales and New World birds. *Proceedings of the Royal Society of London,* B 262, 335–341.
Giri, V.B. and Bauer, A.M. (2008). A new ground-dwelling *Hemidactylus* (*Squamata : Gekkonidae*) from Maharashtra, with a key to the *Hemidactylus* of India. *Zootaxa 1700*, 21-34.
Goudie, A. (1973). Durricrusts in tropical and sub tropical landscapes. Claredon Press, Oxford.
Gould, S. F. (2012). Comparison of Post-mining Rehabilitation with Reference Ecosystems in Monsoonal Eucalypt Woodlands, Northern Australia. *Restoration Ecology, 20*(2), 250-259.
Goldsbrough, C., Hochull, D. and Shine, R. (2003). Invertebrate biodiversity under hot rocks: habitat use by the fauna of sandstone outcrops in the Sydney region. *Biological Conservation, 109*, 85-93.
Herath, D. N., Lamont, B. B., Enright, N. J. and Miller, B. P. (2009). Comparison of Post-Mine Rehabilitated and Natural Shrubland Communities in Southwestern Australia. *Restoration Ecology, 17* (5), 577-585.
Hilson, G. and Basu, A. J. (2003). Devising indicators of sustainable development for the mining and minerals industry: An analysis of critical background issues. *International Journal of Sustainable Development and World Ecology, 10*(4), 319-331.

Hobbhahn, N., Küchmeister, H. and Porembski, S. (2006) Pollination biology of mass flowering terrestrial *Utricularia* species (Lentibulariaceae) in the Indian Western Ghats. *Plant Biology, 8* (6), 791-804.

Joshi, V. C., and Janarthanam, M. K. (2004). The diversity of life-form type, habitat preference and phenology of the endemics in the Goa region of the Western Ghats, India. *Journal of Biogeography, 31*(8), 1227-1237.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B. and Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature, 403*(6772), 853-858.

Katwate, U., D. Apte and Raut, R. (2013). Diversity and distribution of anurans in Phansad Wildlife sanctuary (PWS), Northern Western Ghats of India. *Journal of Threatened Taxa 5*(2), 3589-3602.

Krishnamurthy, S. V. (2003). Amphibian assemblages in undisturbed and disturbed areas of Kudremukh National Park, central Western Ghats, India. *Environmental Conservation, 30* (3), 274–282.

Krishnaswamy, J., Mehta, V. K., Bunyan, M., Patil, N., Naveenkumar, S., Karanth, K. U., N. Jain, P. Bhargav, and Gubbi, S. (2003). Impact of iron ore mining in Kudremukh on Bhadra river ecosystem. Report submitted to WCS India.

Kulkarni, J., Moghe, K., Gour-Broome, V., and Sekhsaria, P. (2013). Restoration of Bauxite mines, Western Ghats, Maharashtra. *Ecological Restoration, 40* , 26-34.

Kumar, S., Bisht, N. S., and Rao, R. N. (1995). Afforestation of Lateritic Pans of Goa – a Case Study. *Indian Forester, 121*(3), 176-178.

Lad, R. and Samant J. (2009). Environmental and Social Impacts of Mining in the Western Ghats : A Case Study of Warna Basin http://cdn.livediverse.eu/wp-content/uploads/2009/10/Mining-Paper.pdf Downloaded on 27 September 2012.

Laurence, D. (2011). Establishing a sustainable mining operation : an overview. *Journal of Cleaner Production,19,* 278-284.

Lekhak, M. M. and Yadav S.R. (2012). Herbaceous vegetation of threatened high altitude lateritic plateau ecosystems of Western Ghats, southwestern Maharashtra, India. *Rheedea, 22*(1), 39-61.

Majer, J., Heterick, B., Gohr, T., Hughes, E., Mounsher, L. and Grigg, A. (2013). Is thirty-seven years sufficient for full return of the ant biota following restoration? *Ecological Processes, 2*(1), 1-12.

Majer, J. D., Brennan, K. E. C. and Moir, M. L. (2007). Invertebrates and the Restoration of a Forest Ecosystem : 30 Years of Research following Bauxite Mining in Western Australia. *Restoration Ecology, 15(S4)*, S104-S115.

Maron, M., Hobbs, R. J., Moilanen, A., Matthews, J. W., Christie, K., Gardner, T. A., Keith, D. A., Lindenmayer, D. B. and McAlpine, C. A. (2012). Faustian bargains? Restoration realities in the context of biodiversity offset policies. *Biological Conservation, 155*, 141-148.

Michael, D. R., Cunningham, R. B. and Lindenmayer, D. B. (2010). Microhabitat relationships among five lizard species associated with granite outcrops in fragmented agricultural landscapes of south-eastern-Australia. *Austral Ecology, 35,* 214-225.

Miller, J. R. and Hobbs, R. J. (2007). Habitat Restoration – Do We Know What We're Doing? *Restoration Ecology, 15*(3), 382-390.

Molur, S., Smith, K.G., Daniel, B.A. and Darwall, W.R.T. (Compilers) (2011). The Status and Distribution of Freshwater Biodiversity in the Western Ghats, India. Cambridge, UK and Gland, Switzerland : IUCN, and Coimbatore, India : Zoo Outreach Organisation.

Nichols, O. G. and Grant, C. D. (2007). Vertebrate Fauna Recolonization of Restored Bauxite Mines – Key Findings from Almost 30 Years of Monitoring and Research. *Restoration Ecology, 15*(s4), S116-S126.

Paliwal, R. (2006). EIA practice in India and its evaluation using SWOT analysis. *Environmental impact assessment review, 26*(5), 492-510.

Padhye, A., Modak, N., Dahanukar, N. (2014). *Indirana chiravasi*, a new species of Leaping Frog (Anura : Ranixalidae) from Western Ghats of India. *Journal of Threatened Taxa 6*(10), 6293-6312.

Padhye, A.D., Sayyed, A, Jadhav, A. and Dahanukar, N. (2013). *Raorchestes ghatei*, A new species of shrub frog (Anura : Rhacophoridae) from the western Ghats of Maharashtra, India. *Journal of Threatened Taxa 5*(15), 4913-4931.

Padhye, S., Rabet. N. and Ghate, H. (2015). First faunal inventory of large branchiopods (Crustacea : Branchiopoda) of Western Maharashtra, India with taxonomical and distributional comments. *Zootaxa, 3904*, 208-222.

Phillips, J. (2012). Using a mathematical model to assess the sustainability of proposed bauxite mining in Andhra Pradesh, India from a quantitative-based environmental impact assessment. *Environmental Earth Sciences, 67* (6) : 1587-1603.

Porembski, S., Becker, U. and Seine, R. (2000). Islands on Isalnds : Habitats on Inselbergs. In : Bartholott, S. P. A. W. (ed.) Inselbergs, Biotic Diversity of Isolated Rock Outcrops inb Tropical and Temperate Regions.

Berlin : Springer.
Porembski, S. and Watve, A. (2005). Remarks on the species composition of Ephemeral Flush Communities on paleotropical rock outcrops. *Phytocoenologia 35* (2-3), 389-401.
Rahangdale, S. S. and Rahangdale S. R. (2014). Plant species composition on two rock outcrops from the Northern Western Ghats, Maharashtra, India. *Journal of Threatened Taxa 6*(4), 5593-5612.
Rogers, D. C., and Padhye, S. (2014). A new species of *Streptocephalus* (Crustacea: Anostraca : Streptocephalidae) from the Western Ghats, India, with a key to the Asian species. *Zootaxa, 3802*(1), 075-084.
Sand-Jensen, K. and Hammer, K. (2012). Moss cushions facilitate water and nutrient supply for plant species on bare limestone pavements. *Oecologia, 170*(2), 305-312.
Silas, E. G. and Dawson D., E. (1961). Amphipnous indicus, a new synbranchoid eel from India, with a redefinition of the genus and a Synopsis to the species of Amphipnous "Muller''. *Journal of the Bombay Natural History Society, 58*(2), 366-378.
Tropek, R., T. Kadlec, M. Hejda, P. Kocarek, J. Skuhrovec, I. Malenovsky, S. Vodka, L. Spitzer, P. Banar and Konvicka M. (2012). Technical reclamations are wasting the conservation potential of post-mining sites. A case study of black coal spoil dumps. *Ecological Engineering 43*, 13-18.
VaÇulik, A., Kounda-kiki, C., Sarthou, C. and Ponge, J. F. (2004). Soil invertebrate activity in biological crusts on tropical inselbergs. *European Journal of Soil Science, 55*, 539-549.
Vagholikar, N., and Moghe, K. (2003). Undermining India: Impacts of mining on ecologically sensitive areas. Kalpavriksh, Pune.
Waterhouse, B. R., K. L. Adair, S. Boyer and Wratten, S. D. (2014). Advanced mine restoration protocols facilitate early recovery of soil microbial biomass, activity and functional diversity. *Basic and Applied Ecology 15*(7), 599-606.
Watve, A. (2013). Status review of rocky plateaus in the northern Western Ghats and Konkan region of Maharashtra, India with recommendations for conservation and management. *Journal of Threatened Taxa 5*(5), 3935-3962.
Widdowson, M. and Cox, K. G. (1996). Uplift and erosional history of the Deccan traps India: Evidence from laterites and drainage patterns of the Western Ghats and Konkan coast. *Earth and Planetary Science Letters, 137*, 57-69.
Yee, D. A. (Ed.) (2015). Ecology, systematics, and the natural history of predacious diving beetles (Coleoptera : Dytiscidae). Springer

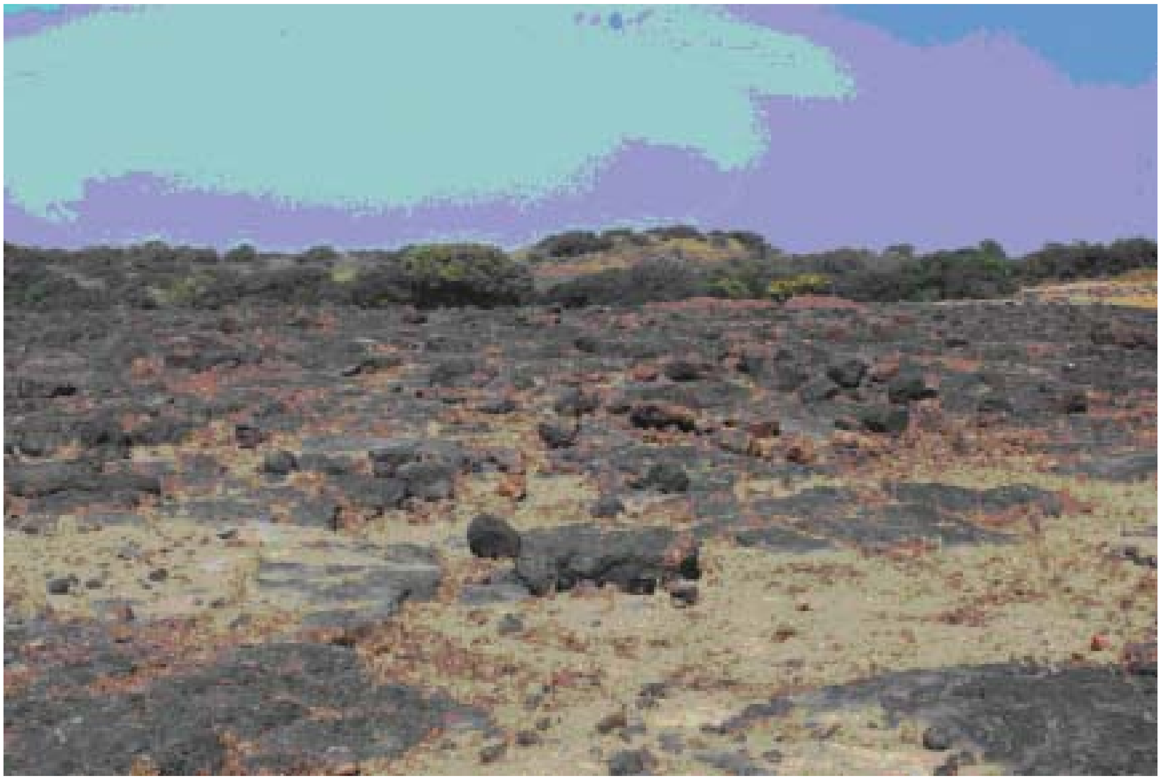


Photo 1 : Ferricrete surface from unmined area: (Mogalgad)

Photo 2 : Exposed layers after overburden removal (Durgamanwad)

Photo 3 : Shallow pools on ferricretes (Masai)

Photo 4 : Water accumulated on excavated area (Durgamanwad)

Photo 5 : EFV Vegetation on Zenda site

Photo 6 : Tree plantation with imported soil

Table 1 : Site details, [Reserve Forest (RF). Wildlife Sanctuary (WLS)]

Site Name	Zenda-Dhangarwada (manoli)	Masai	Durgamanwad	Kasarsada	Idarganj	Mogalgad
Altitude m ASL	1020	950	900	1000	1000	1029
Latitude	N 16º55′58.3"	N16º49′02.6"	N16º27′8.98"	N 15º55′22.34"	N16º20′27.86"	N 15º49′56.55"
Longitude	E 073º47′42.0"	E74º04′39.7	E73º57′52.94"	E 74º7′50.69"E	E73º55′14.61"	E 74º9′33.83"
Rainfall	600-800cm	600-800cm	600-800cm	600-800cm	600-800cm	600-800cm
Remarks	Mining proposed but proposal for forest diversion refused.	Not proposed	Lease not renewed due to proximity to Radha-nagari WLS	Lease not renewed	Permission refused as the site is within Radha-nagari WLS	Mining permission granted
Land ownership	Mostly RF area and some revenue land	RF area	Privately owned and RF area	RF area	Radhangari WLS	Mostly Private and some RF area
Status of Mining	Most area unmined Portion of revenue land is being mined	unmined	Mined with restoration on part of the site	Mined with restoration on part of the site	Mining stopped	Mining yet to start
Micro-habitats	All micro-habitats seen	All micro-habitats seen	Restored forest and EFV	Restored forest and EFV	All micro-habitats seen	All micro-habitats seen

Table 2 : Ecological functions of microhabitats

Habitat	Ecological Functions
Biological Soil Crust (BSC) composed of cyanobacteria, cynolichens,	• Breaking down the ferricrete surface, producing biological and mineral detritus, a soil precursor (Porembski et al 2000; Escolar et al 2012,), Enchytraeid worms add considerably to the detrital component of soil precursors (Vaçulik *et al* 2004) • Carbon and nitrogen cycling • Niche creation for higher plants (ex. *Murdannia semiteres* a thin layer of humus specialist) (Watve 2013) • Food source for amphibian larvae (Gaitonde and Giri 2014). • Changing thermal capacity of rock by modifying reflectance
Boulders	• Moss cushions facilitate vascular plant colonization (Sand-Jensen and Hammer, 2012) • Refugia for invertebrates (Araneae, Chilopoda, Diplopoda, Scorpiones,). • Refugia for amphibians and reptiles (Lewis *et al* in press; Thorpe *et al* in press; Goldsbrough *et al* 2003) and for Synbranchoid eels. • Refugia for novel amphibian species (Giri and Bauer 2008). • Breeding sites for reptiles, egg deposition beneath loose rocks has been recorded (Pryce *et al* in press). Micro-pools on large rocks are utilised by specialised anura for egg deposition and larval development e.g. *Xanthophryne tigerina* (Giri and Bauer 2008). • Elevated calling points for male amphibians, basking sites for squamata. • *Cheilanthes sp.* (Silver fern) and other perennials such as *Hoya* sp., *Dendrobium* sp., *Eria* sp. establish on semi buried rocks.
Crevices	• Refugia for amphibians, reptiles, desiccation tolerant plants species. • Establishment of plants less tolerant to desiccation (Porembski *et al*., 2000). refugia for reptiles (Michael *et al*., 2010).
Pools	• Vernal pools are recognised internationally as a rare habitat and worthy of preservation (Yee 2015). • Refugia for tadpoles • Breeding resources for a wide range of invertebrate families including Coleoptera, Hemiptera, Odonata, Nepidae amongst them. • Sites for brachiopod crustaceans, at least three orders are recognised from ferricretes (Padhye *et al* 2015)., synbranchoid eels and other fish

Impacts of Windfarm Development Activities on Rocky Plateaus - Discussions on Chalkewadi plateau, Dist. Satara, Maharashtra

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Abstract

Rocky plateaus are ecologically very important as they harbor special diversity and are part of catchments of major rivers of Maharashtra. Detailed studies on the components and fragility of rocky plateau ecosystems are sparse. Recently, the instances of these plateaus being subjected to various land use changes without detailed assessments, have affected the balance of the complex ecosystem and the services offered by them. Windfarm development is one major activity on the rocky plateaus for which little data is available on ecosystem level impacts.

Results of the present study describe the Chalkewadi plateau complex, Satara district and impacts on the plateau surface brought about by the development of a high-density windfarm. Broad observations were made on the changing land use, microhabitats and associated vegetation. Manual analysis of Google Earth images of the plateau was done to understand the nature and scale of the ground-level disturbance.

Results show that even though the actual area under windmill establishment is relatively smaller compared to the total plateau area, its environmental footprint is relatively large. The network of temporary and permanent roads, created to erect and operate the windfarm, has dissected the habitat and corridors of wildlife movement. An increase in road kill incidences was observed. Roads have also initiated erosional features all along the plateau surface. Disturbance due to windfarms is widespread on the plateau with the only exception being in the Reserve Forest area and disconnected smaller plateaus.

Our results complement conclusions from other studies regarding negative impacts of windfarms on birds and reptiles. Thus overall impact of windfarms, in terms of habitat destruction is significant and should be studied in depth before establishment of wind farms.

Establishment of windfarms on ecologically sensitive areas should be avoided as far as possible. However, we recommend good ecological management practices that could reduce the impacts, if wind farm establishment is inevitable. The recommendations can be applied to other plateaus in Sahyadri where windfarms are already in place.

Keywords : *Sahyadri, Northern Western Ghats, Rocky plateaus, Windmills, Windfarm impacts, Area mapping, Ecological management plan*

Introduction

Historically, wind energy was harnessed mainly for sailing ships and for water pumps as a source of mechanical energy. The first windmill used for electricity generation was in July 1887, in Scotland. Since then to the current date, technological advancement has improved the windmills and technology for use in alternate power generation. Today it has gained popularity as clean energy.

India has been active in producing wind energy since 1990s and today is one of the leading manufacturers of wind turbines. The total installed capacity of wind power in India on 31st March 2012 was 17351.60 MW that reportedly saved 89.72 million tones of coal and 118.29 million tones of CO_2 emissions. The wind energy generation capacity in India is 49130 MW as per the official estimates of the Indian Wind Atlas, (2010) by the Center for Wind Energy Technology (C-WET). There are many regulatory and policy incentives for wind power like accelerated depreciation, renewable energy certification, direct subsidies, excise duty exemption, and sales tax concession, due to which wind energy farms are becoming popular among industries and wealthy individuals. Even conversion of land under forests has been allowed for installation of wind farms. In Maharashtra, many areas in the Western Ghats section were identified as suitable for windfarm establishment leading to windfarm development on mountain tops.

The Western Ghats is a mountain range traversing Western India from Gujarat to Kerala with north-south length of almost 1600 km. It is separated from the Arabian Sea by the narrow belt of Konkan – Malabar coastal area. In W. Ghats, high elevation, torrential rains, high speed winds, extreme temperatures, humidity and hilly topography give rise to a specialized, sensitive ecosystem with rich biodiversity. It is identified as a global biodiversity hotspot owing to high endemism and high anthropocentric pressures on biodiversity. Northern Western Ghats, known as Sahyadri, are characterized by flat tops and rise to an average elevation of 1000 m, reaching 1400 m in some areas (e.g. Kalasubai, Mahabaleshwar). The range is mainly composed of basalt, an igneous rock formed due to cooling of Deccan trap lava flows. The Deccan traps are mostly flat, thus giving rise to flat-topped mountain ranges. Erosional forces have worked over millions of years and changed the flat tops to gradual or steep free falls at many places. Many plateaus have weathered to form layers of lateritic soil supporting vigorous growth of woody vegetation, e.g. forests of Bhimashankar and Mahabaleshwar. However, extensive rocky plateaus exist throughout the range.

Watve (2013) has discussed the rocky plateaus as a specialized habitat with endemic biodiversity that were grossly neglected in the past. Studies by Lekhak et al. (2012) and Bhattarai et al. (2012) have given detailed descriptions of microhabitats on rocky plateaus, their associated plant diversity and endemism. Rocky plateaus are subjected to extreme wet and extreme dry conditions in monsoon and in summer respectively. The organisms living on such plateaus have evolved to adjust to these conditions.

'Ecosystem services' rendered by these habitats to

Image 1 and 2 : Images showing plateau in two extreme conditions – summer and monsoon immediate local communities have been documented. Buono and Thomas (2013) document the community's dependence on spring water that are recharged by deep soil profiles of these plateaus. This emphasizes the importance of these landscape features as water catchments for local populations. Other major services include mass blooming ephemerals which supports pollinators and nutrient supply to lower areas.

Rocky plateaus were designated as 'wastelands' in Government records. In the Wastelands Atlas of India by the National Remote Sensing Centre and Ministry of Rural Development (2010) rocky plateaus feature under "Category 22" (barren rocky /stony waste areas). The anthropological definition of wasteland is the areas where woody vegetation doesn't grow. However, in nature there is no wasteland. Even these apparently barren, extensive rock patches of laterite support dense ephemeral vegetation with mass flowering in monsoon. (Image 3 and 4).

Image 3 and 4 : Extreme conditions on plateau during summer and monsoon.

Due to high velocity winds at altitudes above 1000m, they were considered suitable for wind farms. The development work was also facilitated by the ease in procuring rocky plateau land, which did not have much of cultivated or residential areas.

One of the highest density windfarms in Maharashtra has been installed near Chalkewadi village of Satara dist, Maharashtra. It is one of Asia's largest windfarms with installed capacity of 210 MW, and having approximately 1000 windmills on plateau area located on the top of Northern Western Ghats ranges.

Environmental impact assessment studies are not mandatory for windfarms. Very few studies address the impact of windfarms on avifauna in India, as per Pande et al. (2013). The objective of our study was to document impacts of wind farm installations and operations on the surface of rocky plateau site. We also suggest best practices for reducing the ground level impacts of the windfarms which will help protect the biodiversity during the operations phase.

Methods

This paper reports studies conducted on Chalkewadi plateau from May 2006 to July 2015. It is an ongoing study and will continue after 2016 as well. There are two aspects of the study, field observations and mapping of land features and changes over time.

Field observations were taken every month on a line transect which started from wind farm at Chalkewadi, near Thoseghar, an approach from Satara and ended at diversion to Wan-kusawade. These observations are combined with various spot surveys depending upon need and area observations. Observations included :

1. Biodiversity
2. Micro-habitats like ponds
3. Alteration to habitat and its impacts
4. Area analysis – various habitats, roads, windmills, etc.

An open source tool for 'area mapping' was selected. The field observations were supported by marking of specific points using GPS and the coordinates were marked with necessary notes. These were marked on the Google Earth map. Images from 2002 were available and were compared with the present observations and images. The analysis of the maps, area calculations using Google Earth Pro and secondary data available regarding the rocky plateau habitats was used for the discussion on impacts of windfarms. It is understood that use of better aerial images and use of tools like GIS will impart more accuracy to this study.

Study area

The study area chosen for observations and mapping is extensively spread between Chalkewadi near Thoseghar and Patan, a taluka place in Satara District. For the purpose of this paper, it is termed as the Chalkewadi-Patan Plateau. This area is part of the catchment of the Koyna reservoir, located to the east of reservoir, in close proximity to the Koyna Wildlife sanctuary. It also comes under the proposed buffer of Sahyadri Tiger Reserve.

Chalkewadi-Patan Plateaus are spread between 17^0 41′42.01″N, 73^0 48′04.98″E (North extremity of the plateau) and 17^0 24′51.38″N, 73^0 50′47.10″E (South extremity of the plateau), with average highest elevation of 1137 m.

Image 5 and 6 : Map of Maharashtra showing district Satara and Map of District Satara showing location of Chalkewadi plateau complex

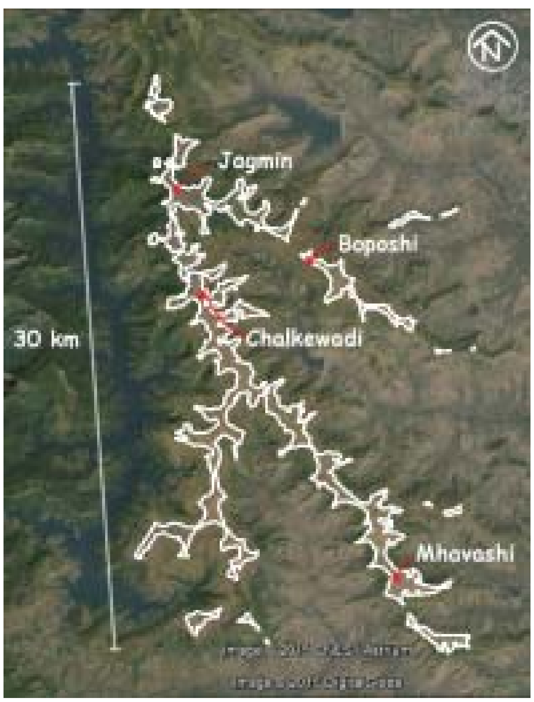

Image 7: Image showing extent of rocky plateaus of Chalkewadi – Patan complex

Being in Sahyadri, this plateau receives high rainfall. The annual rainfall of nearby Koynanagar is reported to be 4,957.3–5,666.1 mm (S. Nandargi and S. S. Mulye, 2012).

This plateau has a maximum width of 3.6 km with aerial length of 30 km approximately. The plateau complex consists of narrowly connected small plateaus or isolated plateaus having different names as per the villages, e.g. Sada Waghapur. It has a gradually undulating flat top with presence of gullies, streams, patches of vegetation and few depressions.

Plateau habitats can be categorized into terrestrial or aquatic microhabitats. Based on the soil depths and vegetation, terrestrial habitats can be further divided into open rocky patches, grasslands on areas having soil cover (both with ephemeral monsoon flora), shrub clusters and dense clusters of trees (Image 8). Terrestrial herbs include members of Fabaceae, Eriocaulaceae, Lentibulariaceae, and Rubiaceae.

Aquatic habitats are ephemeral pools, perennial ponds, and monsoon streams. Ephemeral pools form in shallow depressions and support aquatic flora

Image 8: Various habitats on rocky plateau

including *Aponogeton satarensis* and *Eriocaulon tuberiferum* (both endemic to Western Ghats). Aquatic invertebrates such as tadpole shrimps, beetles, larvae of dragonflies and damselflies are found in ephemeral pools. Fish and endemic frogs like *Ncytibatrachus humayuni* and *Rana aurantiaca* are found on the plateau.

A new species of spider, *Tylorida sataraensis* Kulkarni, 2014, is associated with perennial streams. In this study, ten plateaus were surveyed across northern Western Ghats. Among these sites, T. sataraensis was observed only at Chalkewadi and Kaas plateaus. Based on its current known distribution, the species would likely fall under IUCN status Critically Endangered (CR) following Criteria B1ab(iii)+ B2ab(iii) (IUCN 2012). Among the threats observed in the study area, loss of vegetation cover and removal of laterite rocks are likely to be direct threats to *T. sataraensis.* Such microhabitat degradation, if permitted to continue, could reduce the amount of shaded areas and alter the micro-strata required by the species for web construction. (Kulkarni S and Lewis T, (2015)).

The newly reported Satara gecko, (*Hemidactylus satarensis*) (Giri and Bauer, 2008) is also likely to be found in the study region.

The following table illustrates list of plants seen at Chalkewadi with respect to various habitats.

Habitat type	Flora
Rocky Area	*Begonia crenata* *Crustose lichens (Parmeliaceae)* *Cyanobacteria* *Cyanotis spp.* *Indigofera dalzelii* *Lepidagathis prostrata* *Neanotis spp.* *Nostoc spp.*
Area with thin soil cover	*Adelocaryum coelestinum* *Ceropegia jainii* *Drosera spp.* *Eriocaulon spp.* *Exacum pumilum* *Habenaria spp.* *Hedyotis stocksii* *Hygrophila serpyllum* *Impatiens balsamina* *Impatiens lawii* *Impatiens oppositifolia* *Indigofera dalzelli* *Jansenella spp.* *Murdannia spp.* *Paspalum canarae* *Peristylus spp.* *Pogostemon deccanensis* *Rotala spp.*

	Senecio dalzellii
	Smithia spp.
	Utricularia spp.
Clustered Vegetation	*Actinodaphne angustifolia*
	Allophylous cobbe
	Bridelia retusa
	Catunaregam spinosa
	Colebrookea oppositifolia
	Emblica officinalis
	Fluggea leucopyros
	Glochidion ellipticum
	Gnidia glauca
	Memecylon umbellatum
	Pavetta crassicaulis
	Scutia indica
	Syzygium cuminii
	Zizyphus rugosa
Water Bodies	*Aponogeton natans*
	Aponogeton satarensis
	Crinum viviparum
	Eriocaulon sedgwickii
	Limnophila spp.
	Ludwigia octovalvis
	Myriophyllum oliganthum
	Nymphoides spp.
	Persicaria glabra
	*Rotala flori*bunda

It also shows that there are close linkages of plants with habitats and disturbance to the integrity of habitats may impact flora negatively.

This plateau complex is privately owned mainly by the local villagers and windfarm companies. A part of the plateau, towards the reservoir is owned by State Forest Department. The wind farm on these plateaus was established around 2002, on privately owned lands by locals which were purchased by the company. It has been operational with more than 900 windmills and supportive infrastructure.

Findings

Field observations were started in 2006 with the aim of documenting seasonal changes in biodiversity and impacts of installation and operations of the windfarm.

Establishment of windmills is an intensive development on a plateau. It includes road laying, excavations, use of cement-concrete for piling for the windmill, poles, transformer rooms, guest houses, supportive service development, storage of oil, chemicals, movement of cranes and creating plain surfaces for them, etc. All of this has some impact on ground and thus on habitat. (Refer to image 12)

Windfarms cannot be built without large scale construction of roads. These linear roads have the following impacts :

a. Have changed the freshets and streams
b. Have created few areas with water storages
c. Road construction has led to extraction of murum-soil-rocks from surroundings
d. Dissected the habitat (refer to image 11)
e. Created habitats for herbs like Neanotis lancifolia, Senecio sp, which are indicators of degraded or changed habitats,
f. Initiated road kills (refer to image 12),
g. Increased erosional features along road.

2. Many dirt roads are in use on the plateau. Their condition deteriorates over time. Owing to this, vehicles start driving along the shoulders and then off road and stray into the open areas. This destroys the habitats along roads leading to

Image 9 and 10: Monsoon streams and insectivorous herb Utricularia sp.

widening of present roads and formation of off-shoots.

3. Fan-throated lizards were observed during their pre-breeding season. They were seen using supports and wires for poles, fences, white stones marked along road for courtship displays. Even the number of lizards along roads seems to be high, but this needs to be validated with detailed studies of this and similar habitats. In one visit 13 males and 14 females were observed in one transect of 1 km x 10 m along road in the month of June. These lizards have the risk of getting killed by vehicular traffic.
4. The plateau is subjected to heavy downpour and periods of fog during the months of June through November. This initiates algal growth on windmill blades which reduces the efficiency of windmills. To overcome this, the algal layer is washed off periodically with cleaners and detergents every year. There would be a definite impact of the chemical residue on the soil, habitat and water bodies, but it has not yet been studied.
5. It was also observed that the locations where any earth moving / digging / material removal has happened in rocky areas, different floral diversity associated with loose soil flourish in next few years. Examples are road sides, trenches, sub-surface pipeline works where *Neanotis lancifolia* can be seen which is not abundant on rocky areas otherwise.

Further studies are required on each of the above observations.

Image 11 and 12 : Roads dissecting habitats and effects on minor fauna such as fan throated lizard

Area mapping

Land Classes in a pre and post Windfarm scenario

Area mapping was based on identifying and delineating various habitats on plateau. The following natural habitats and human-centric areas are found on a typical plateau, with or without windmills.

1. Water Bodies : This includes **natural streams** originating on the plateau only during the monsoon season as well as manmade or naturally formed small or large **pools**, which are either seasonal or perennial.
2. Area with soil cover : There are intermittent areas on the plateau that have soil cover of varying depths. Depending upon the depth, vegetation character in these areas changes. Predominant vegetation in these areas is herbs and shrubs.
3. Clustered Vegetation : A continuous tree cover is almost absent on the plateau. Still there are few areas where one can find sparse or dense tree clusters, combined with shrubs.
4. Rocky Area : The areas with laterite, where specialized species of algae, grasses and herbs in rock crevices are present.
5. Human Settlements : Historically few communities have stayed on the plateau and conducted activities like rain fed farming, house construction, etc. These areas are included under settlements.

Post-windfarm scenario

Addition of windmills requires roads, supporting structures, canteens, guest houses, scrap yards,

Image 13 : Various plateau habitats: indicative figure

Image 14 : Windmill infrastructure

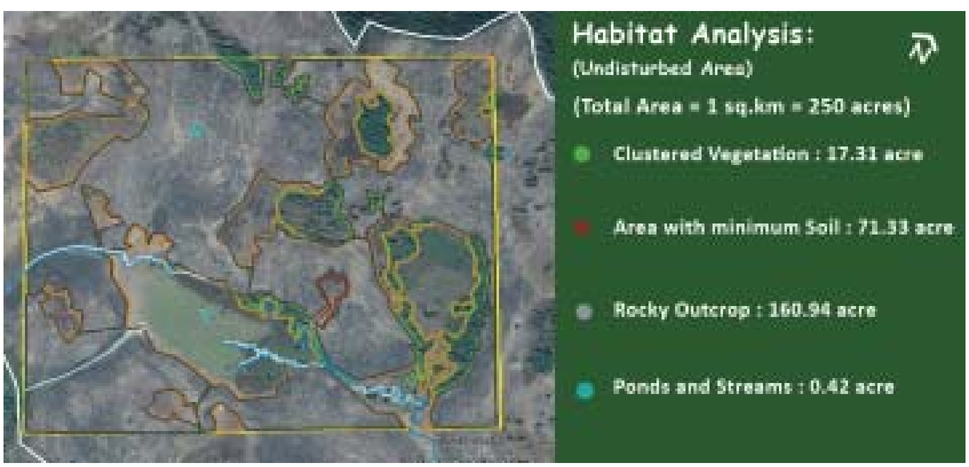

Image 15 : Habitat analysis of area where windmills are not present substations and such other facilities. This takes up significant portions of land.

The following section explains the mapping method used for the entire complex.

An area of 1 sq. km. was chosen from no-windmill areas and windmill affected parts to know the distribution of the original, undisturbed habitat structure vs. disturbed habitats.

Habitat Analysis of 1 sq. km. Area in no-windmill and windmill-affected regions :

No-windmill area : The area which is not affected by direct impacts of windmill. Human activities of local population like grazing, fuel wood extraction and fire continue in this patch. These activities have the effect of disturbing natural habitats.

1 sq km = 250 acres

No.	Habitat	Area (in acres)	Percentage (%)
1	Clustered Vegetation	17.31	6.92 %
2	Area with soil cover	71.33	28.53 %
3	Rocky Area	160.94	64.38 %
4	Water bodies (streams, ponds)	0.42	0.17 %
	Total	250	100 %

Windmill-affected area : This area comes under direct influence of establishment and maintenance activities of windmill farms. Here the area covered by windmill activities that directly affected the natural habitats was recorded.

1 sq km = 250 acres

No.	Habitat/ land class	Area (in acres)	Percentage (%)
1.	Area with soil cover	91.26	39.92
2.	Rocky Area	113.27	45.30
3.	Water bodies (streams, ponds)	5.94	2.59
4.	Clustered Vegetation	1.46	0.584
5.	Settlement	22	8.8
6.	Area under windmills	2.059	0.90
7.	Area under roads	14.07	6.15

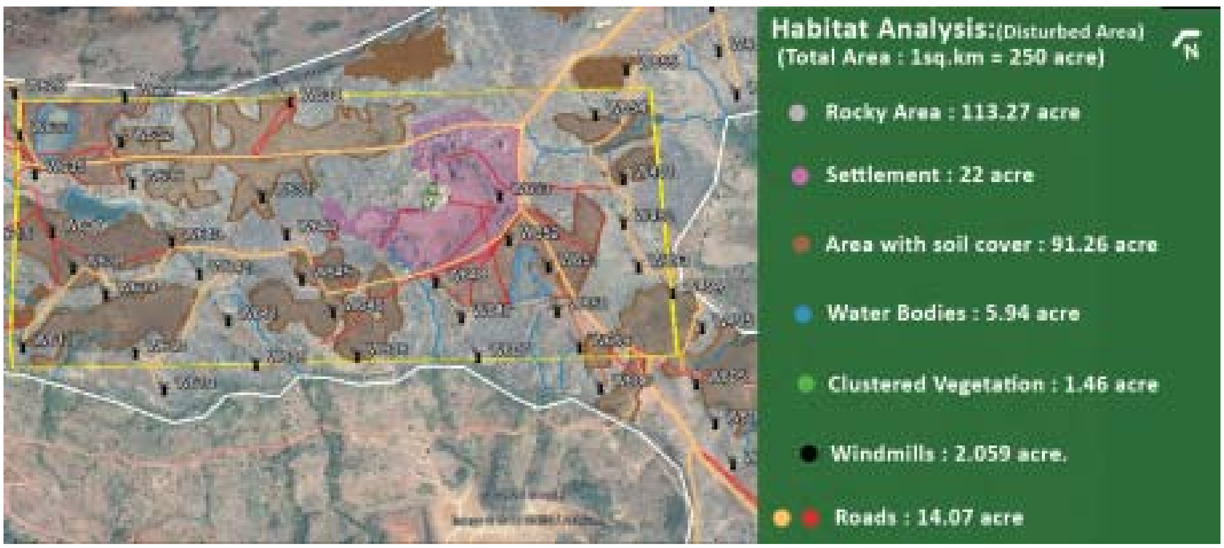

Image 16 : Disturbed area due to development of windmill

Road analysis

The roads seen on plateau are divided into 4 categories according to the measurements and utilization

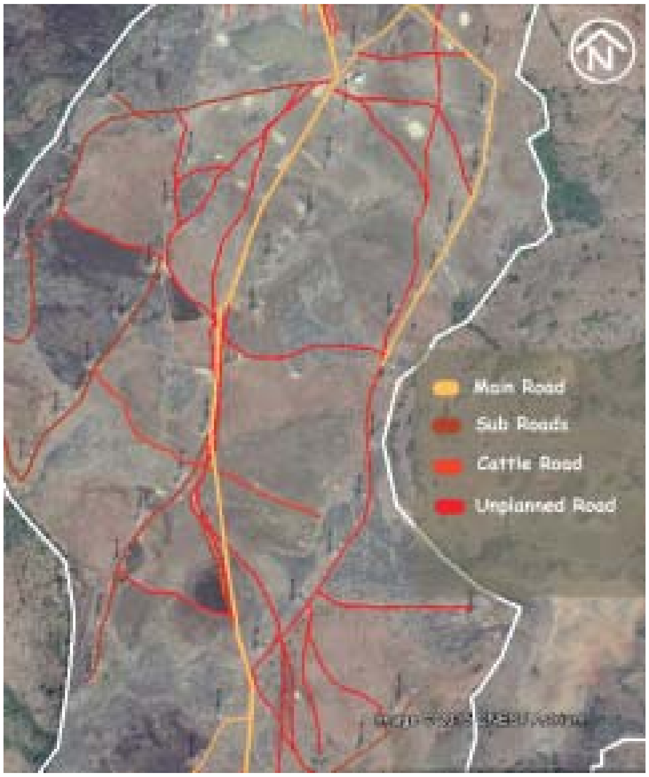

Image 17: showing all major types of road present on the plateau.

Main Road:
Length: 148.7 km, width: 8 m

Sub Road (Joining Main road and Windmill):
Length: 105.39 km, width: 3.5 m

Cattle Road:
Length: 21.38 km, width: 1.2 m

Unplanned (off-road) Roads:
Length: 81.47 km, width: 3.0 m

The typical width for each road type was measured on ground and on Google Earth and averaged for calculation purposes.

Out of these categories, the main roads and sub-roads to windmills are necessary, but the unplanned roads are result of bad quality of main roads. If the quality of roads is maintained properly, then these temporary roads will not develop which are of length of 82 km.

Micro-habitats dissected by roads

Few unplanned road stretches were selected by non-random sampling method for analyzing which habitat it has affected. The following table shows the roads, locations and impacted habitats.

17^{0}34′50.15″N, 73^{0}49′26.09″E
Habitats disturbed : Areas with soil, Rocky areas, Clustered vegetation

17^{0}33′44.77″N, 73^{0}51′39.30″E
Habitats disturbed : Areas with soil, Rocky areas

17^{0}32′26.91″N, 73^{0}50′15.92″E
Habitats disturbed : Areas with soil, Rocky areas

17^{0}32′09.04″N, 73^{0}50′34.56″E
Habitats disturbed : Areas with soil, Rocky areas

Plateau Land use | Area statement

From this mapping exercise, area calculation was done for each habitat type and land use for the plateau complex. The following tables give details of area under each type.

No	Land use		Area (acres)	Percentage (%)
1	**Total area** under Chalkewadi-Patan plateau complex		17134.6	100
	Area of plateau without windmills		5038.6	29.4
	Area of plateau with windmills		12096	70.6
2	Habitats before windmill establishment over entire Chalkewadi-Patan plateau complex			
	a	Rocky Area	9786.3	57.1
	b	Area with Soil Cover	6831.4	39.9
	c	Clustered Vegetation	300.7	1.8
	d	Water Bodies	129.2	0.8
	e	Human Settlement	86.5	0.5
3	Land use change post windmill establishment			
	a	Main Roads	297.4	
	b	Subroads	92.2	
	c	Windmill Structures	67.9	
	d	Windmill Support Structures	27.0	
	e	Unplanned Road	24.4	
	f	Cattle Road	6.4	
		Direct destruction of habitats - Total	515.4	4.3
4	Road analysis			
	Total Area under roads		420.5	100.0
	a	Main Roads	297.4	70.7
	b	Sub-roads	92.2	21.9
	c	Unplanned Road	24.4	5.8
	d	Cattle Road	6.4	1.5

Note : Data analysis presented is based on the google imagery of January 2016. The numbers and area calculation may differ if more accurate methods like GIS software are used.

From the mapping, following analysis can be made :

1. Total area under plateau is bifurcated as area with windmill farm (70.6%) and area without windmill farms (29.4%). The areas that do not have windmills are the plateaus which are either disconnected small plateaus or area under 'reserved forest'. The area with windmills is privately-owned lands.
2. The area with windmill establishment (12096 acres) has the related support infrastructure, particularly roads, amounting to 515 acres where the original habitats have degraded.
3. This infrastructure is spread across the entire 12096 acres of plateau area. Even though the percentage of area under direct disturbance is relatively low, almost 4%, the remaining 96% area is indirectly affected.
4. It was observed that the road network has significant impacts on the habitat.

Image 21 shows a network of main road along with the off-roads. It is evident that due to channelization of flows of rainwater, the soil erosion on east side of the road is initiated. Being a very high rainfall area, high intensity rains and the flows thus formed tend to erode more. Eventually, changes in topography result in heavy degradation.



Images 18, 19 and 20 : show widening of main roads, vehicles preferring the temporary roads and effects of these temporary roads on the vegetation growth and water flows.

Image 21 : Soil erosion initiated due to road work

Another impact of roads is trampling of vegetation and compacting of ground. Both have serious effects on population of the ephemeral plant vegetation, ultimately affecting the food chains, overall food web, and energy and material flows in the natural eco-system. There is an increase in number of road kills of frogs and reptiles, specifically *Sarada superba* which display openly during breeding seasons. Thus one major impact of roads is fragmentation of micro habitats.

richness and diversity reduced considerably with increase in trampling intensity.

Another impact, though not documented in these specific locations is bird collisions due to windmill blades and poles. Some studies have analysed the number of birds and mammals being affected due to windfarms. One such study at a similar location in the Sahyadri region by Pande et al (2013) tries to evaluate the risks of bird collision. It estimates a collision index

Image 22 and 23 : Multiple unplanned roads are seen in 2nd image

and observes reduction in avian activity with progress of wind farm installation. It states that despite the small footprint of area covered by an individual wind turbine, the associated infrastructure development causes wider habitat modification and destruction resulting in a displacement of birds. The annual average collision rate was 1.9 birds per turbine.

Bird collisions with wind blades and installations can cause irreversible damages to their populations and food chains. So, such establishments could be high-risk areas for avifauna.

The high number of fan throated lizards (*Sarada superba*) displaying boldly on this plateau in areas devoid of any vegetation also indicates lack of their predators which would be raptors. The network of windmills, poles, overhead wires and changes to local wind flows due to sweeping windmill blades may be responsible for this.

The operation and maintenance of wind farms

Also compacting of ground directly affects percolation of rain water and recharging of the spring systems on which the entire life and economy in surrounding villages depend. So even if the current extent of land impacted is low, the gradual increase in such temporary roads will affect recharging in future.

Comparative images (22 and 23) of the same spot in Nov 2005 and Nov 2012, show appearance of multiple temporary roads along the main road, clearly indicating that as the main road's quality deteriorated (also evident from field observations), vehicles start creating new roads that are almost parallel to the main road.

Discussion

The effect of walking / vehicle plying on plateau through trampling on the seasonal vegetation has been observed on Kaas, a rocky plateau north of current study location (Agarwal, 2014). It showed that species involves large amount of oil which is stored on site and prone to occasional spillage and leakage. Moreover, there are cleansing agents required for maintenance and the vehicles introduce emissions in the atmosphere. The collective effect of all these elements may be to pose significant threat to sensitive biodiversity, especially those in ephemeral pools in monsoon, e.g. shrimps.

These are few of the impacts locally observed and mapped, and similar impacts can be envisaged for other plateaus in Sahyadri having wind farms or proposed for wind farms.

There are also examples where forest was cut open for providing road access to establish windmill farms, creating greater impact on surrounding area. Image 24 shows a windmill installed in vegetated patch near Gothane, even though enough area is available in open habitat for installation. In image 25 it can be seen that an access road is created through dense forested patch in Padharwadi for catering to a very small number of windmills. It will be worth computing the cost-benefit of such actions against the long-term cost of ecological

Image 24 : Area near Gothane showing few windmills are established by clearing the forest

Image 25 : Windmills established at Padharwadi near Bhimashankar showing road cutting through dense forest cover to cater to a very small number of windmills services provided by the forests in Sahyadri.

The society is largely unaware of these environmental impacts of windfarms. Wind energy is considered to be a clean energy which can reduce fossil fuel use and related pollution. Researchers have studied the efficiency of windfarms with respect to their impacts on environment. Rosenbloom (2006) shows that wind power does not meet expected energy claims, however it has significant impacts on environment and neighbouring human settlements. Nulkar (2013) reports that in India windmills produce power on an average about 20% of their installed capacity, mainly due to intermittent winds. Mearns (2014) estimates the global wind power load factor to be 22.7%, while for India it is 19.9%. Using these studies, the actual electricity produced in the Chalkewadi windfarm complex could be as low as 1,008 MWH against the installed capacity of 5,040 MWH.

Example of existing roads: Total length of roads in the image (excluding the cattle road, i.e. the one shown in orange colour) is 8.27 km. Refer to image 26.

Image 26

Researchers conclude that windmills cannot be justified on the basis of 'installed capacity'. The other indirect impacts like use of fossil fuel during the process of manufacturing-installation-running, the pollution caused during manufacturing, and impact on land during installation and running of wind farm are much higher than otherwise understood, putting a question mark on this "green" energy.

Recommendations

The developments in these sensitive habitats are growing at a very fast rate. Thus it is now important to have an integrated plan that will take into consideration how habitats can remain intact. It is necessary for such an integrated plan to demonstrate that it can achieve sustenance of ecosystem services, protect biodiversity, and benefit local communities.

Below we provide a hypothetical example of how better road planning can reduce environmental impact and habitat disturbance. The location is near Jambhekar wadi.

The integrated plan should include the following measures :

1. High priority should be given to an optimally-designed road network that helps maintenance of

If the roads are planned and constructed properly, total length of road in would be 4.47 km. This will have less impact or disturbance to the overall habitats. Refer to image 27.

Image 27

the facility, yet minimizes ecological disturbance. It is recommended to develop roads with optimum lengths without any duplication or inefficiency, and with proper finished surfaces.
2. All temporary roads must be closed and their surfaces should be restored naturally to seamlessly merge into original habitats.

3. Areas that are not being used directly for any of the infrastructure activity but are in possession with the windmill companies should be reserved as ‘conservation areas’.
4. Long-term protection to such ‘conservation areas’ from windmill farm related activity should be ensured and contractually required.
5. Identify, design and implement waste management systems. It is seen that wind farm staff, villagers and tourists are littering these areas with disposable plastics, EPS (expanded polystyrene), etc. Even the liquid waste created at facilities like canteen or guest houses must be treated properly. Stricter waste management guidelines should be provided by local authorities, with penalties for violation.
6. A few seasonal ponds could be created using natural locations suitable for storing water.
7. Use of oils, diesel, tar etc should be carefully monitored. Any kind of spilling or leakage on natural habitats should be avoided and be a cause of penalties.
8. The cleaning agents used for washing windmill components should not contain toxic chemicals or mechanical cleaning should be preferred. The state’s pollution control board should provide guidelines related to cleaning and what kind of cleaners are permitted.
9. Training and awareness for the windfarm management team is necessary to implement the above recommendations. Such training or awareness sessions will be required for all management levels and ground working personnel.
10. Windfarm operators, whether public companies or private individuals or companies, should be required to publish an Environmental Compliance and Sustainability Report every year providing details of their compliance and the measures they have undertaken to ensure sustainability.
11. An ‘Environmental Monitoring Authority for Windfarms’ should be constituted by the state government with representation of environmental experts from NGOs. This authority should have the rights to inspect windfarms at periodic times to monitor environmental compliance and report violations and other observations to the government.

Implementing such measures should be the primary responsibility of windmill companies and it should be integrated in planning, installation and operations.

Along with this, it is necessary to have changes to the policy framework to achieve clarity on how we intend to protect the remaining miniscule percentage of forests. EIA studies for wind farms should have integrated ecological management plans.

Conclusion

From this exercise of area mapping, it is seen that the most disturbing factor is road development. Even though the length of roads necessary to achieve development is approx 254 km, its impacts are spread over entire area.

The 82 km of unplanned roads in Chalkewadi could be certainly avoided or reduced if roads were designed and executed optimally.

We should reconsider whether such modern development on fragile plateaus is necessary. It is necessary to evaluate the economic gain from windmills against the loss of biodiversity and ecosystem services of these plateaus.

It is necessary to initialize practices that integrate ecological and environmental sustainability considerations in windfarm projects and start implementing them immediately on ground. For the plateaus with existing windfarms it is feasible to integrate such conservation practices. In fact habitat development and improvement of natural processes by soil and water conservation measures can become a CSR activity of windmill companies.

Considering the long term impact of such projects on the natural capital on which the human race depends, it is necessary to question our lifestyle and developmental patterns that feed our increasing demand for electricity.

There is scope for further study in various aspects of habitats and biodiversity, ecosystem stress, and alteration in ecosystem services offered by the specialized habitats like rocky plateaus caused by windfarms.

References

Agarwal, P. (2014). Effect of Tourism on Kaas Plateau. http://www.rufford.org/rsg/projects/prerna_agarwal

Bhattarai, U., Tetali, P., and Kelso, S. (2012). Contributions of vulnerable hydrogeomorphic habitats to endemic plant diversity on the Kas Plateau, Western Ghats. Springer Plus, 1(1), 25.

Buono, J., Thomas, R. (2013) ‘Natural Springs in the Western Ghats : A Vital Resource Under Threat : Overview, Best Practices and Policy Recommendations for Ensuring Biodiversity and Sustainable Drinking Water’. Grampari. [Online]. Available at : https://www.researchgate.net/

publication/236592267_
Chauhan, D. , S. Agarwal, M. K. Suman (2013). Wind power scenario in India – A review, International Journal of Scientific and Research Publications, Volume 3, Issue 9, September 2013 ISSN 2250-3153 .
Mearns, E. (May 2014). The efficiency of wind power. http://euanmearns.com/the-efficiency-of-wind-power/
Giri, V. B. and Bauer, A. M. (2008). A new ground-dwelling Hemidactylus (Squamata : Gekkonidae) from Maharashtra, with a key to the Hemidactylus of India. Zootaxa, 1700, 21-34.
Halkema, J. A. (n.d.). Wind Energy: Facts and Fiction – A half truth is a whole lie.
India Wind Energy Outlook | 2012, by Global Wind Energy Council, World Institute of Sustainable Energy and Indian Wind Turbine Manufacturing Association.
Jaber, S. (July 2013). Environmental Impacts of Wind Energy. Journal of Clean Energy Technologies, Vol. 1, No. 3.
Lekhak, M. M., and Yadav, S. R. (2012). Herbaceous vegetation of threatened high altitude lateritic plateau ecosystems of Western Ghats, southwestern Maharashtra, India. Rheedea, 22(1), 39-61.
Nulkar, G. (Dec 2013). The truth about windmills, Journal of Ecological Society, Vol 25.
Pande, Satish, Anand Padhye, Pramod Deshpande, Aditya Ponkshe, Pranav Pandit, Amit Pawashe, Shivkumar Pednekar, and Rohan Pandit. "CEPF Western Ghats Special Series : Avian collision threat assessment at Bhambarwadi Wind Farm Plateau in northern Western Ghats, India." Journal of Threatened Taxa 5, no. 1 (2013) : 3504-3515.
Price, T. J. (May 2005). "James Blyth - Britain's First Modern Wind Power Engineer". Wind Engineering 29 (3) : 191–200.
Rosenbloom, E. (2006). A problem with wind power. Linked table "Size Specifications of Common Industrial Wind Turbines." http://www.aweo.org/windmodels.html (accessed September 12, 2015).
Watve (2013). Status review of Rocky plateaus in the northern Western Ghats and Konkan region of Maharashtra, India with recommendations for conservation and management. Journal of Threatened Taxa 5(5) : 3935–3962; doi : 10.11609/JoTT.o3372.3935-62.
Indian Wind Atlas (2010) by the Center for Wind Energy Technology (C-WET), mnre.gov.in/file-manager/UserFiles/Presentations.../Gomathinaygam.pdf
Wastelands Atlas of India by the National Remote Sensing Centre and Ministry of Rural Development (2010), http://www.dolr.nic.in/wasteland2010/maharastra.pdf
Kulkarni S, Lewis T (2015) Description of male Tylorida sataraensis Kulkarni, 2014 (Araneae, Tetragnathidae) with notes on habits and conservation status. Biodiversity Data Journal 3 : e4451. doi : 10.3897/BDJ.3.e4451
S. Nandargi and S. S. Mulye, 2012, Relationships between Rainy Days, Mean Daily Intensity, and Seasonal Rainfall over the Koyna Catchment during 1961–2005, The Scientific World Journal Volume 2012, Article ID 894313, 10 pages?, doi : 10.1100/2012/894313

Changes in Ecological Landscape Pattern and Land Use from 1985 to 2014 in the Panshet Dam Catchment

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Abstract

The Sahyadri, the northern part of Western Ghats in the state of Maharashtra, India, are one of the most fragile ecosystems on Earth. There are major changes in the original ecosystem and land use in the Sahyadri over the past two centuries.

A ground survey was conducted by Ecological Society, Pune in 1985 as well as in 2014 to assess current land use and status of biodiversity in the Panshet dam catchment situated in Sahyadri. This study probes to understand factors responsible for decline of biodiversity and changed land use. We highlight the extent and causes for change in land use.

The study attempted to quantify this change by carrying out manual digitization of multispectral WV-2 satellite images by visual interpretation and ground truthing and compare with the study done by Ecological Society in 1985.

The mapping of the catchment area shows that areas towards western escarpment i.e. away from the dam wall have retained better vegetation cover while degradation is evident in eastern parts of the catchment.

Such studies will be useful for land use planning, understanding cost-benefits of nature conservation, assessing restoration potential, and developing conservation-restoration strategies on a regional scale. We recommend similar vegetation and land use class mapping for all dam catchments in the Western Ghats.

Keywords : *Sahyadri, Northern Western Ghats, Panshet, Pune, Land use pattern, Landscape, forest, GIS mapping, visual interpretation, vegetation class mapping, landscape-based ecosystems management, dam catchments*

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Introduction

The Western Ghats

The Western Ghats (WG) stretch nearly 1600 km along south-west peninsular India and stand testimony to several million years of geological history. The WG are the mountain range that is separated from the Arabian Sea by a narrow strip of the coastal plains of India. The hill range of WG has been recognized as one of the world's 35 biodiversity hotspots, i.e. a region of rich biodiversity threatened with destruction. It is one of the world's eight hottest hotspots and declared as a World Natural Heritage site by UNESCO (Unesco, 2012).

There have been many studies about biodiversity and ecosystems of the W. Ghats, documenting changes in forest vegetation, threats, and conservation needs. Even though they do not contain specific mentions of forests and ecosystem health in Western Ghats, the Gazetteers of past governments mention the richness of flora and fauna present in immediate surroundings of town centers present at that time. From these references, it is evident that the forests of Western Ghats were more or less intact till 1836-37, when the revenue survey was introduced by the British India government. After this, forests in Western Ghats started converting slowly into cultivation plots for hill millets locally, and into monocultures of timber species as well as tea plantations in Southern parts. For several decades, the conversion for cultivating hill millets was low relative to the overall area of WG and there was a chance of it regenerating into a secondary forest during fallow period.

Land use change accelerated in the 20th century with the development of irrigation reservoirs in these high rainfall areas – the key reasons being submergence of fertile valley bottoms, hill communities being displaced to higher slopes, cultivation of slopes for millets, and extraction of coal for urban centers due to easy access to these remote parts (Gadgil 1979). This continued through the British period and after India's independence.

A study by (Jha, Dutt, Bawa, July 2000), which uses GIS mapping over 40,000 sq km of area in Southern Western Ghats showed 25.6% loss of forest cover in 22 years (1973 to 1995). It was also observed that the dense forest was reduced by 19.5% and open forest by 33.2%.

In Sahyadri, the number of reservoirs is very high, with almost all the rivers dammed in the source area. A similar situation was documented by (Gadgil M, 1979) and (Gole P., 1985) in their studies in dam catchments of Panshet, Warasgao and Mulshi near Pune.

Rationale for the study

"Land is the basic component of the natural resource system of any country. Natural resources are fundamental to sustainable economic development in most countries, particularly Asian developing countries where agriculture remains an important source of economy. Natural resources are increasingly subjected to intensive population pressure, widespread poverty and expansion of industrialization and urbanization. The rapid change in the socio-economic patterns of these countries has inevitably and adversely affected the natural resources. Natural resource problems have now become a major concern of development planners as they attempt to promote rapid development. These problems are partly caused by mismanagement of resources through serious exploitation." (Onchan Tongroj, 1993)

The above quote is pertinent in case of Sahyadri, where the forest cover is fast depleting due to development pressures. The reasons include agriculture, new roads, widening of existing roads, farm houses, recreational sites, hill stations, townships, horticulture and greenhouses, small-scale industrial units, and large-scale industrial activity like SEZs or new plants.

Availability of data and observations regarding ecological landscape of Panshet catchment from 1985-86 triggered the present study. We planned to assess land use changes occurring in the Panshet catchment after almost 30 years as this may guide further directions in planning.

Study area

Location and Physiography

The Panshet dam catchment, which is the area for the present study, lies in Sahyadri (Northern Western Ghats). It is situated at approximately 40 km west of Pune city and is a major irrigation and water supply project in the region.

The dam catchment is spread over 118.6 sq km, extending from 73°26′7.947"E and 18°17′43.641"N to 73°37′44.686"E and 18°23′14.33"N with elevations ranging from 626 m at valley to 1134 m at the ridge line (Pole village). The waterbody of Panshet dam is spread over 14.5 sq. km.

The River Ambi, an eastward flowing river originates at Dapsar and is bound by two main hill ranges running west to east separated by average distance of 6.6 km (Figure 1, 2, 4).

The catchment of Ambi comprises of twenty five mini watersheds (Figure 3).

Rainfall

The rainfall data shows variation from average annual 9000 mm at Western escarpment at village Dapsare, to 2100 mm at village Panshet where the dam is built. The 1985 study by Ecological Society divided the catchment into 4 zones (Figure 5).

Distribution of rainfall becomes an important factor as it decides natural vegetation character in the valley.

Figure 1, 2 : Location : Panshet dam catchment

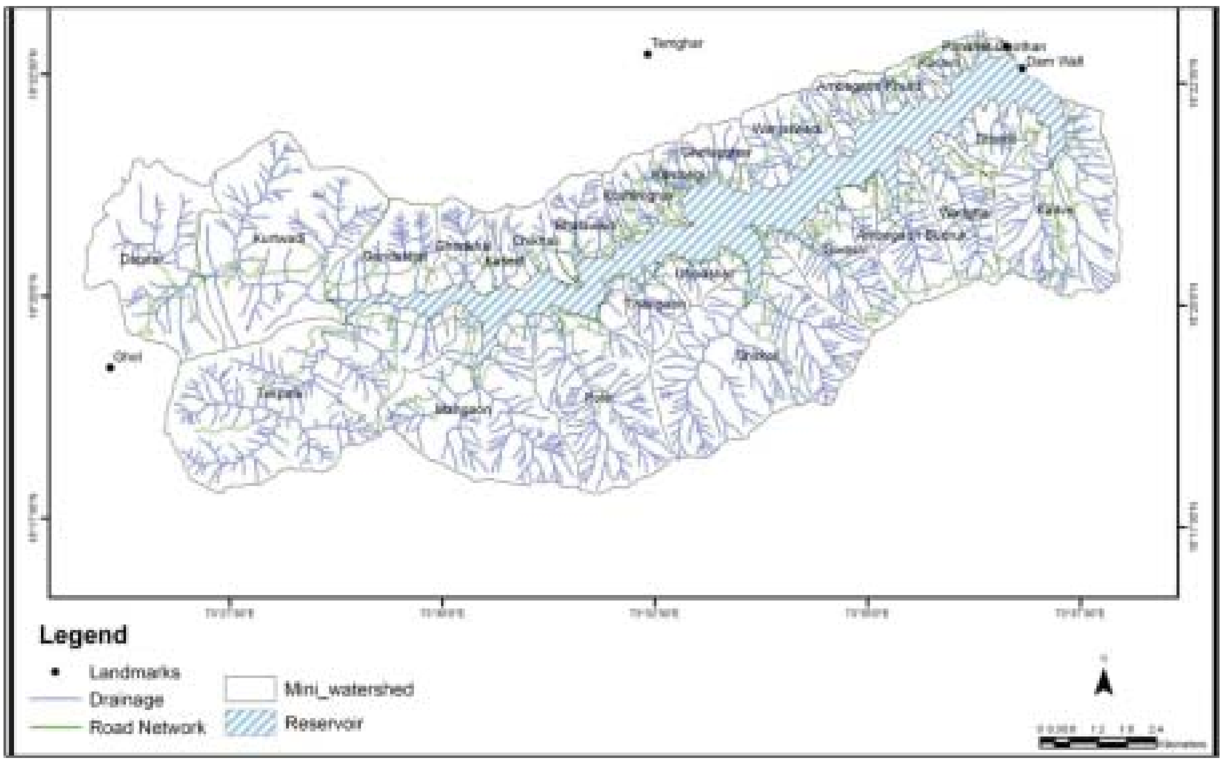


Figure 3: Hydrology of Panshet dam catchment

Figure 4: Physical map : Panshet catchment

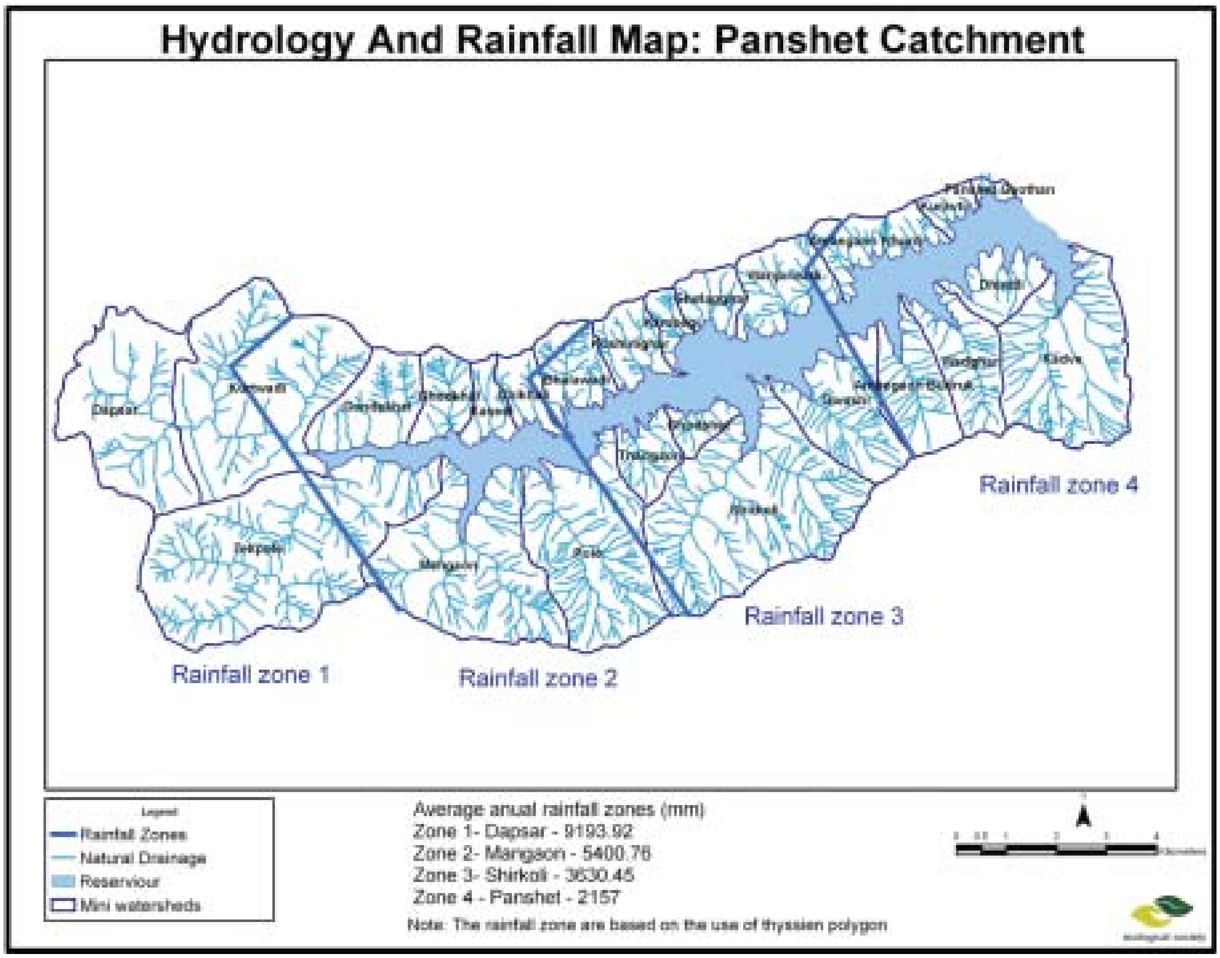


Figure 5: Panshet catchment : Rainfall zones

The variability in precipitation and topographical features create a wide range of vegetation types from semi-evergreen forests to moist deciduous, scrub to open grasslands and rocky outcrops.

Earlier Studies about the Study Area

Earlier studies of the Panshet catchment have studied the ecosystem, biodiversity, socio-cultural practices like Sacred Groves and land use. (Gadgil, M. and Vartak, V.D., 1976) mention that hill slopes fairly remote from the villages were still covered by some forest. Until about twenty years before the time of this study, the whole region was much better forested, particularly because the peasants left valuable trees standing even when they cleared a plot for cultivation.

The upper hill slopes were clothed by a rich natural forest of the semi-evergreen type, constituted into state-owned forest reserves. These forests were hardly exploited due to lack of transport facility. Prof. Gadgil also mentions a flourishing tanning industry at Bhor, near Panshet which was entirely based on Hirda (*Terminalia chebula*) collection from forests in these catchments which gradually declined as majority of forests were cut for coal by 1960. (Gadgil M, 1979)

Prof. Gole, with his detailed study of Panshet catchment in 1983-84 with respect to the ecosystem and socio-economic aspects, concludes that construction of the dam and allied activities led to speedy destruction of the original forest ecosystem in the catchment. The major reasons leading to this destruction are : submergence of fertile land, social dynamics of communities and resettlement, and construction of a ring road giving access to the urban market for coal. (Gole P., 1985)

Objectives of the 2014 study

The objectives of the present study (2014) are given below :

1. To prepare land use, land cover (LULC) maps for the Panshet catchment and to derive area estimates of vegetation and human land use classes
2. To survey and document biodiversity in various land classes
3. To evaluate degree of degradation by comparing the present data with data from 1985 study. We planned to use the 1983-85 primary data set as a reliable record of past biodiversity status
4. To prepare a restoration potential map

Land use and land cover is an important component in understanding the interactions of the human activities with the environment. Keeping these factors in mind GIS techniques and traditional surveying methods were used to get a real picture of the present land use and biodiversity status of the catchment.

Methodology

GIS analysis

High spatial resolution multi-spectral satellite image was used for visual interpretation. Standard WorldView-2 (4 band) images for 2013-14 were used. Land Use-Land Class (LULC) mapping for 2014 was obtained by manually digitizing the image. Data from the 1983-85 study was used to create a digital version of Land Use-Land Class mapping of that time.The datasets were then incorporated in ArcGIS 9.2 to convert that data into meaningful information.

Note : In case of smaller objects like ponds, water tanks, small shifting cultivation patches etc, the scale was temporarily changed.

Methodology Steps

The following methodology was adopted :

1. Generation of maps for all the input layers.
2. **Hydrology :** The natural drainage pattern was digitized taking toposheets as base. The contour pattern was studied and accordingly the drainage, mini-watersheds and entire watershed boundary was delineated. The drainage pattern was updated with the help of the false color composite (FCC).
3. **Rainfall :** Based on secondary data from the Meteorological Department**,** the project area was divided in four zones considering the average annual rainfall. The zones were derived based on the Thiessen polygon method.
   a. Zone 1- Dapsar- 9193.92 mm
   b. Zone 2- Mangaon- 5400.76mm
   c. Zone 3- Shirkoli- 3630.45mm
   d. Zone 4- Panshet- 2157mm
4. **Mapping of Stream Habitat :** The streams were digitized from the satellite image. The habitat of riparian zone along the rivers was mapped.
5. **Ground Survey for biodiversity and land use classes :** A Stratified Random Sampling approach was followed for ground survey. Based on the past experience of the team in this landscape, analysis of Google Earth images, observations from reconnaissance visits, and variation in land classes, we selected 47 randomly distributed areas and completed their detailed on-ground biodiversity survey over a period of 6 months.

These randomly sampled 47 points represent all the vegetation classes as well as physical conditions in the valley. These 47 points also covered all rainfall zones. As the focus of the study was to map special biodiversity of the catchment, this methodology served us well. However, the overall observations were not restricted only to the selected 47 points. Biodiversity was observed all along the catchment.

The images available were of two different seasons; one for 18th May 2013 and another for 28th Jan 2014. They were both World view 2- 4 band multispectral pan-sharpened satellite images. Both the images were used simultaneously to eliminate any wrong classification. The scale was set to 1:3000 for almost the entire watershed area. The final layer was then re-checked for any mismapping.

During the ground survey of sample points, the latitude, longitude and elevation was collected with the help of a hand held GPS device. Associated biodiversity was documented in standard formats. This format includes Endemism, IUCN status, and legal status of each species. The other information is location, brief description, area, co-ordinates, altitude, dominant flora, old growth flora, tall canopy flora, species with IUCN status, Indian forest department's scheduled species and photos. Vegetation classes were identified based upon current floral composition. Vegetation composition also changes due to anthropogenic activities including agriculture.

As the land classes have been drawn by manual digitization, the maps are the true representation of the real topography. Due to this method, the possibility of inaccuracy creeping in due to automated classification has been ruled out.

Vegetation and Land Use Classes

Following are the natural and human-influenced vegetation classes which were mapped in the form of polygons. The determination of land classes is based on their key vegetation characteristics and is similar to that proposed in Ghate (2014).

No.	Class	Description
1	Open grasslands	Areas with grasses as the dominant community
2	Scrub	Areas which combine evergreen thorny scrub vegetation with interspersed grass patches
3	Sparse vegetation	Areas with not too many grass patches but large clusters or regenerating trees
4	Karvi (Carvia callosa) patches	Areas with uniform Karvi (Carvia callosa) patches
5	Karvi (Carvia callosa) and dwarf canopy	Areas with Karvi (Carvia callosa) patches and low height canopy trees
6	Dense shrubbery	Areas with dense shrubs of similar height
7	Sparse vegetation dominated by trees	Areas with shrub cover dominated by regenerating trees
8	Dwarf canopy forests	Areas with mixture of shrubs, regenerating dwarf trees
9	Mature forests	Areas with original forest vegetation
10	Tall canopy	Areas with fairly dense cover with tall canopy trees
11	Potential stream habitat	Areas of stream-sides with dense tree vegetation
12	Rocky outcrop	Areas with occurrence of rocks and boulders, and less soil cover
13	Free face	Areas with vertical rock faces (usually inaccessible) and retaining original vegetation of rocky outcrop

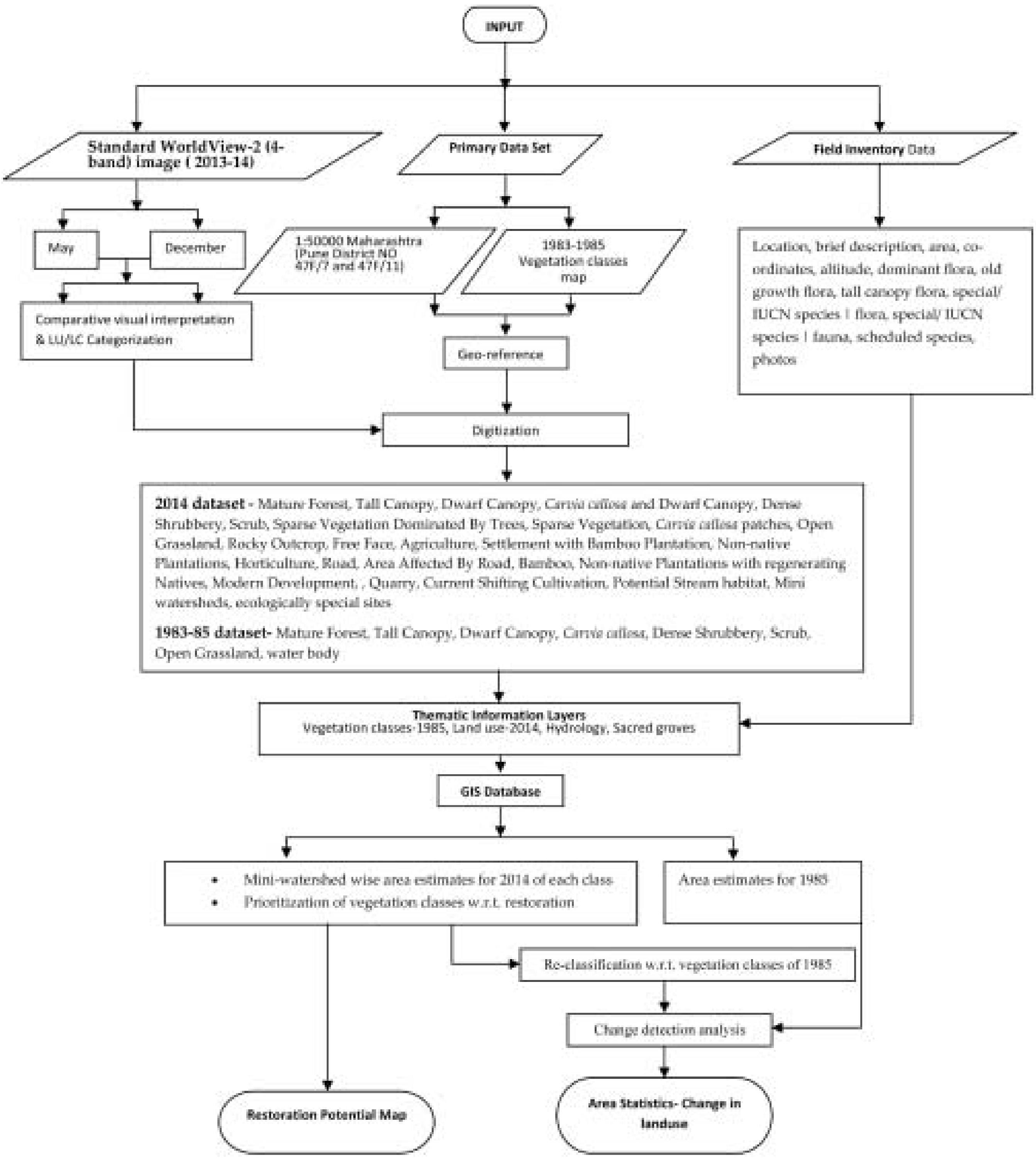
Table 1 : Vegetation classes

Apart from the above classes, there are man-made land use classes spread over the entire catchment. These are due to cultivation practices and modern developmental trends. These classes are :

No.	Class	Description
1	Agriculture	Permanent areas under cultivation, i.e. Paddy fields and other crops
2	Plantations a. Non-native Plantations b. Bamboo Plantation around Settlement c. Horticulture d. Old Non-native Plantations with regenerating natives	Plantations by local people, various government departments, or private land owners.
3	Road and Areas Affected By Road	Tar road and areas affected by road construction activity
4	Bamboo Plantation	Independent Bamboo plantation, typically for income generation
5	Modern Development	Farm house schemes, recreational sites, existing residential infrastructure, semi-urban areas, etc.
6	Quarry	Earth or stone extracted for construction
7	Shifting Cultivation Patches	A practice in this area which uses slopes for cultivation. These are patches of land used for cultivating hill millets for 2 or 3 years.
8	Settlements	Villages and areas around them

Table 2: Human-influenced land use classes

A chart describing the data collection and analysis process is given below :



Analysis

Primary Data set

Data was available in the form of tables, maps and text for the year 1983-85 (Gole P., 1985). In this earlier work, a hand drawn "vegetation classes" map was geo-referenced and then manually digitized. However, the vegetation classes were presented based on the species dominance. Hence, they were reclassified into new vegetation classes per our present classification and the 1983-85 map was re-produced by utilizing the association in table below. The association itself is based on the field observations of the authors and Ecological Society over the last several years in W. Ghats. Area estimates were carried out based on this map for the year 1983-85. This map is presented in Figure 8.

Land-use land-cover analysis for the year 2014

The satellite images used are shown in Fig. 6 and 7 (Note : Vegetation appears in red color).

Results and discussion

Land-use land-cover map for 1985 study

As discussed above, the historical data available was used to prepare 'vegetation classes' map of 1985 and an area statement was derived from it.

No	Species-dominant class as per [Gole P, 1985]	Reclassified class
1	Actinodaphne hookeri Heissm, Glochidion hohenackeri Bedd	Dwarf Canopy
2	Bridelia squamosa Gehrm, Terminalia tomentosa W	Dwarf Canopy
3	Butea monosperma Taub, Xeromphis spinosa Keay	Dwarf Canopy
4	Dendrocalamus strictus Mees, Syzygium cumini Skeels, Strobilanthes Sp	Dwarf Canopy
5	Erythrina variegata Merr, Euphorbia neriifolia Roth	Scrub
6	Heteropogon contortus P. Beauv, Themeda quadrivalvis O. Ktze	Open grassland
7	Latana camara L	Open grassland
8	Latana camara L- Carissa congesta Wight	Open grassland
9	Mangifera indica, Memecylon umbellatum Burm, Syzygium cumini Skeels, Ficus spp	Tall canopy
10	Memecylon umbellatum Burm, Ficus sp	Tall canopy
11	Phoenix humilis Bess, Dendrocalamus strictus Mees	Dwarf Canopy
12	Reserved Forest	Tall canopy
13	Reservoir	Water body
14	Sacred Grove, Mangaon	Mature forest
15	Strobilanthes callosus Mees	Carvia callosa
16	Syzygium cumini Sxeels, Wendlandia ihyroidea, Macaranga peltata Muella	Dwarf Canopy
17	Terminalia tomentosa W and A	Open grassland
18	Terminalia tomentosa W and A, Emblica officinalis Gaeri	Open grassland
19	Woodfordia fruticosa Kurz, Lasiosiphon eriocephalus Ocme	Scrub

Table 3 : Table showing reclassification of species-dominant classes from the 1985 study

Note : As the 1985 map is a hand drawn map, there could be statistical inaccuracies in the area computation of the land classes. Yet, this is the best source available for a comparative study.

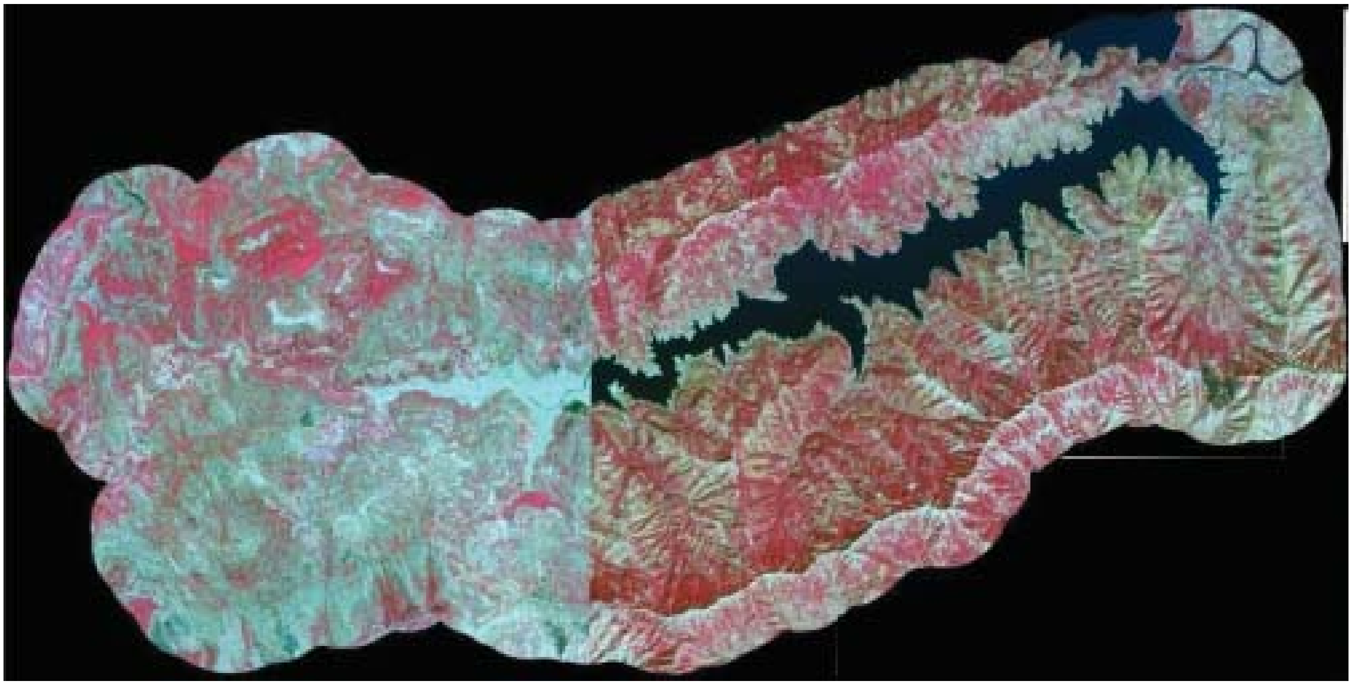


Figure 6 : Worldview -2 Pan-sharpened multispectral image – May 2013

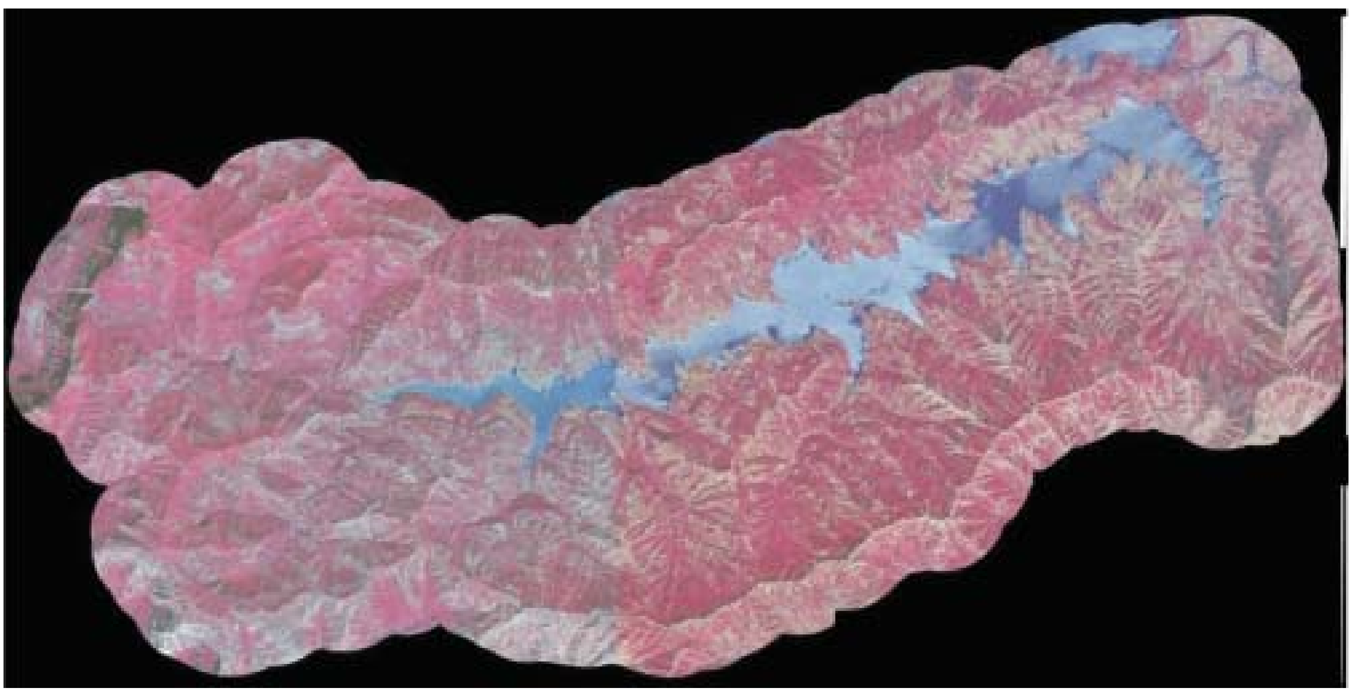


Figure 7 : Worldview -2 Pan-sharpened multispectral image – Jan 2014

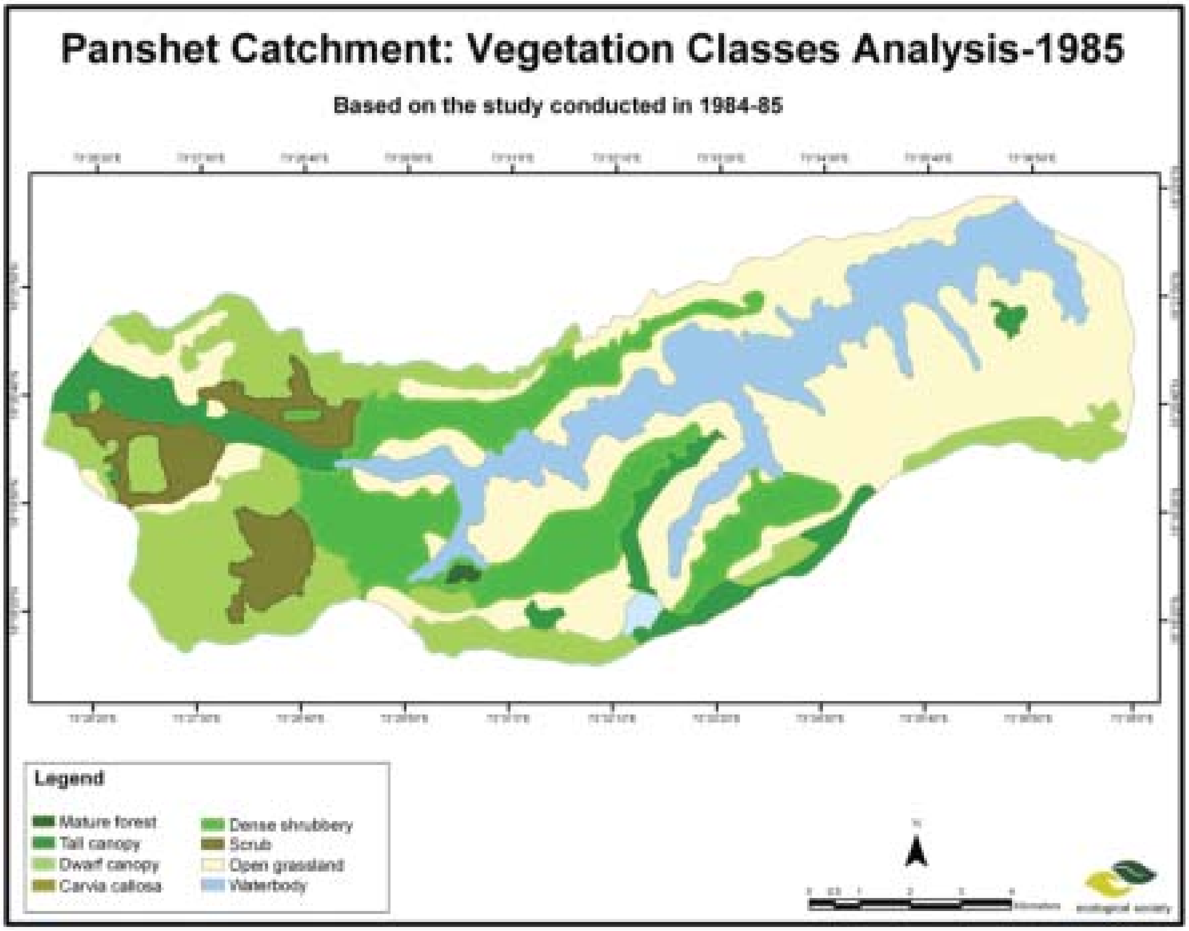


Figure 8 : Vegetation classes map - 1985

The area estimate for the above land use land cover map is given in the table below :

Area Statement for Panshet Catchment based on [Gole P,1985]

Sr. No	Class	Area (Acres)	Percentage of the total catchment
1	Dense shrubbery	4550.18	15.73
2	Dwarf canopy	5413.48	18.72
3	Carvia callosa	113.09	0.39
4	Mature forest	50.87	0.17
5	Open grassland	10507.10	36.34
6	Reservoir	4566.17	15.79
7	Scrub	1908.67	6.60
8	Tall canopy	1802.83	6.23
9	Human Use	Not assessed separately	NA
	Total	**28912.43**	**100%**

Table 4: Land-use land-cover area estimate for the 1985 study

Land-use land-cover map for 2014 study

Based on the land use pattern, the area under study was classified into 24 different classes. The classification was based on the methodology described earlier.

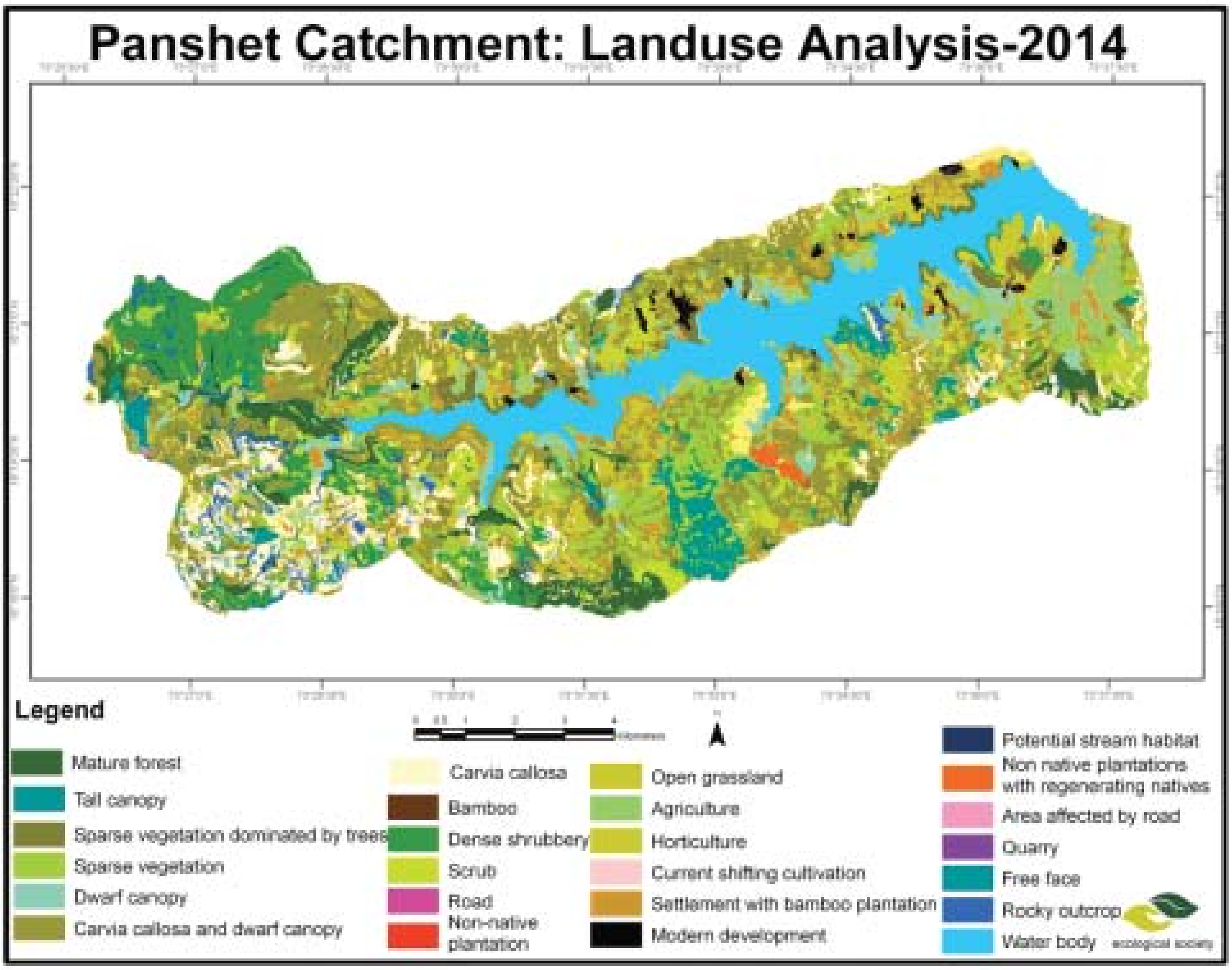


Figure 9: Land-use land-cover map - 2014

The area estimate for the above land use land cover layer is given in the table below :

Sr. No.	Vegetation Class	Area (Acre)	Percent (%)
1	Mature Forest	1542.16	5.26
2	Tall Canopy	1319.95	4.50
3	Dwarf Canopy	1026.05	3.50
4	Carvia callosa *and Dwarf Canopy*	*7034.84*	*23.98*
5	Dense Shrubbery	2052.47	7.00
6	Scrub	1502.26	5.12
7	Sparse Vegetation Dominated By Trees	821.31	2.80
8	Sparse Vegetation	1545.06	5.27
9	Carvia callosa *patches*	*2558.51*	*8.72*
10	Open Grassland	2616.16	8.92
11	Rocky Outcrop	651.97	2.22
12	Free Face	25.38	0.09
13	Agriculture	1571.16	5.36
14	Settlement, including nearby Bamboo Plantation	441.76	1.51
15	Non-native Plantations	289.7	0.99
16	Horticulture	44.94	0.15
17	Road	209.73	0.71
18	Area Affected By Road	27.98	0.10
19	Bamboo	1.25	0.00
20	Non-native Plantations with regenerating Natives	83.28	0.28
21	Modern Development	195.6	0.67
22	Quarry	3.56	0.01
23	Current Shifting Cultivation	158.21	0.54
24	Potential Stream habitat	34.61	0.12
25	Reservoir	3581.83	12.21
	Total	**29339.73**	**100%**

Table 5 : Area Statement of Vegetation Classes, 2014

Consolidated classes

Since the above classification had a large number of classes, the 24 land classes in the above table, except reservoir, were clubbed into 5 major land classes. This was based on the observations made during surveys and similarities in characteristics across land classes. Across these consolidated land classes, the status of biodiversity in the catchment was well-represented.

Consolidated Classes	Classes merged
Mature forest	Mature Forest, Tall Canopy, Potential Stream habitat
Dwarf canopy	Dwarf Canopy, Carvia callosa and Dwarf Canopy, Dense Shrubbery
Scrub	Scrub, Sparse Vegetation Dominated By Trees, Sparse Vegetation, Carvia callosa patches
Open grasslands	Open Grassland, Rocky Outcrop, Free Face
Human use	Agriculture, Settlement with Bamboo Plantation, Non-native Plantation, Horticulture, Road, Area Affected By Road, Bamboo, Non native Plantations with regenerating Natives, Modern Development, Quarry, Current Shifting Cultivation

Table 6: Table depicting the consolidated land-use land-cover classes, 2014 study

A qualitative description of these consolidated land classes is provided below.

Mature forest : The areas that have near original semi-evergreen vegetation, continuous canopy cover and represent the climax stage of forest.

Dwarf canopy: This class consists of dense shrubs and medium height trees in combination with Carvia callosa.

Scrub : This class contains areas with sparse, scattered vegetation, without much of canopy cover. This area is marked by some tress growing sparsely.

Open grasslands : This land class covers areas which are dominated by seasonal grass. It appears extremely dry and barren during the summer season. Grasses grow here only during the rainy season. It also contains exposed boulders of basalt- the significant rocks of Deccan plateau.

Human use : This class contains land use directly related to human interaction.

The table below provides an area statement for the 1985 study under the set of 5 consolidated land classes.

Land use	**Merged classes**	**Areas under** merged classes (acres)
Mature forest	Mature forests + Tall canopy	1853.70
Dwarf canopy	Dense shrubbery + Dwarf canopy + Carvia callosa	10076.76
Scrub	Scrub	1908.67
Open grasslands	Open grasslands	10507.10
	Total	**24346.23**

Table 7: Area Statement for consolidated land use classes, 1985 study

The table below provides an area statement for the 2014 study under the set of 5 consolidated land classes.

No.	**Land class**	**Area (acres)**	**Percent (%)**
1	Mature forest	2896.72	11
2	Dwarf canopy	10113.36	39
3	Scrub	6427.14	25
4	Open grasslands	3293.51	13
5	Human use	3027.17	12
	Total	**25757.89**	**100**

Table 7A: Area Statement of the consolidated land use classes, 2014 study

It is evident from present study that area under mature forests i.e. the near original semi-evergreen forest cover in Sahyadri is not sufficient (11%) and it is largely present in the high rainfall zone within catchment. The reason for the latter could be this zone is little away from city center and the fact that a direct road up to this zone was made recently (2010). Presence of Sacred Groves, the largest one at Mangao (~ 40 acres) has contributed majorly to this land class. So it is observed that preservation of mature forest is directly and inversely impacted by nearness and access from the city.

Analysis of changes in land-use land-cover classes from 1985 to 2014

As per Tables 7 and 7A, the total areas under the consolidated five land classes from the 1985 and 2014 are different. This is because the map of the 1985 study was originally prepared manually and then digitized in the 2014 study. However, the difference between the total areas of 1411.66 acres is only 5.5% of the total area from the 2014 study (refer to tables 7 and 7A). Since this is a relatively small percentage difference, we believe it is fair to compare the changes in land-use land-cover over the period 1985-2014. Here we have the following key observations :

- Area in acres under Mature Forest has increased significantly (1043 acres) from 1985 to 2014. This could be due to better protection of reserve forests. However as a % of total area, it is still low at 11% in 2014, as discussed above.
- Area under Dwarf Canopy has increased by an insignificant amount (36.6 acres) from 1985 to 2014.
- Area under Open Grasslands has decreased significantly (7213 acres) from 1985 to 2014. In the

1985 study, a relatively larger portion of the catchment was under shifting cultivation and this area was likely counted under Open Grasslands. Our 2014 socioeconomic study for the Panshet catchment (published simultaneously) points to three trends over the last 30 years : 1. Farmers have left more part of their land permanently fallow. 2. Where cultivation continues, the land under shifting cultivation has declined, and 3. Overall land under active agriculture has declined by around 33%. As a result of these trends, a large part of land which was potentially under shifting cultivation and classified as Open Grasslands in 1985 has returned to it's natural stage and is now in the stage of scrub land. This is also a possible reason for Scrub land increasing by 4518.46 acres from 1985 to 2014. Additional study is needed to confirm these trends. These changes are summarized in the table below.

mentioning that such intensification often results in exhaustion of resources and has undesirable effects on quality of human life in immediate surroundings. This adversely affects the local communities that are directly dependent on the quality of natural resources.

(Gole P., 1985) proposed a way out that will ensure a long life for reservoir, ensure ecological integrity and also protect local livelihoods, giving planned occupations for the local communities. However the current situation in the catchment has changed in the direction of further erosion of natural resources.

It is evident from our observations that man-made activities such as road constructions, modern development and construction have considerably increased, with irreversible impacts on natural ecosystems. The current and future threats to natural resources in this catchment come from uncontrolled, unplanned private developments.

Land use	**Area (acres)**		**Difference**
	1985	**2014**	
Mature forest	1853.70	2896.72	Increased by 1043 acres
Dwarf canopy	10076.76	10113.36	Increased by 36.6 acres
Scrub	1908.67	6427.13	Increased by 4518 acres
Open grasslands	10507.10	3293.51	Decreased by 7213 acres

Table 8: Changes in land use from 1985 to 2014

Additional results of the study are as follows :

- While the area under human use was not mapped separately in 1985, anecdotal evidence and the present study reveals a significant increase in modern developmental activities like farm houses, roads, etc. Modern Development, Roads, and Area affected by Road together constitute 433 acres and 1.5% of the catchment as per the 2014 study and trends indicate this is likely to grow over the next 1-2 decades.
- Change in land ownership from locals to developers has shown a positive impact on few areas where the shifting cultivation has stopped due to change in ownership. This was noted during the socio-economic surveys and is observed by local people over 2 decades.

Conclusion

(Gadgil M., 1979) has discussed the intensification of resource use with respect to dams and its consequences on forests in Sahyadri. It is worth

From the study it can also be said that given a chance, natural succession happens and takes nature to the next seral stage in the ecosystem development (e.g. Open Grasslands transforming into Scrub). However this is a relatively slow process compared to the present rate of degradation.

Due to importance of natural resources in Sahyadri, the future lies in sustainable landscape level management of the region that will safeguard the ecology and provide long-term benefits from well managed landscapes.

Such an integrated effort will need strong political will, ecologically-sensitive landscape-oriented planning and concerted effort for sustainable development from all sections of society.

References

1 An Enquiry into the status of animal and plant life in critical areas of Western Ghats in order to evolve a plan to conserve their biological diversity. Ecological Society. – By Gole P., 1985,

2 Applications of Geographic Information Systems, remote sensing and a landscape ecology approach to biodiversity conservation in the Western Ghats, Current Science, VOL. 73, NO.2, 25 JULY 1997 – By Shaily Menon, Kamaljit S. Bawa, 1997

3 Biodiversity Significance, Landuse Pattern And Conservation Of Malayattur Forests In The Western Ghats Of Kerala, India, Indian Journal of Fundamental and Applied Life Sciences ISSN : 2231-6345 (Online) An Online International Journal Available at http://www.cibtech.org/jls.htm 2011 Vol. 1 (4) October-December, pp.247-254/Sakthivel and Sreekumar

4 Changes in land use/cover using geospatial techniques: A case study of Ramnagar town area, district Nainital, Uttarakhand, India- By J.S. Rawat, Vivekanand Biswas, Manish Kumar

5 Dams and Tribal People in India, Contributed to World Commission on Dams - Amrita Patwardhan

6 Deforestation and land use changes in Western Ghats, India – by Jha, Dutt, Bawa, July 2000, Current Science, VOL. 79, NO. 2, 25

7 Eco-restoration potential in the degraded watershed areas of the western ghats Proceeding of International Conference SWRDM-2012, - by Amruta Kurane and Jay Samant Dept. of Environmental Science, Shivaji University, Kolhapur, DEVRAAI (Development Research Awareness and Action Institute)

8 Forest degradation in Western Ghats biodiversity hotspot : Resource collection, Livelihood concern and sustainability – by Priya Davidra, Pratheesh C. Mammen, J.P. Garrigues and Krista Roessingh, Department of Ecology and Environment Sceince, Pudducherry

9 Forest cover change detection of Western Ghats of Maharashtra using satellite remote sensing based visual interpretation technique – By Rabindra K. Panigrahy,*, Manish P. Kale1, Upasana Dutta, Asima Mishra, Bishwarup Banerjee and Sarnam Singh. Geomatics Solutions Development Group, Centre for Development of Advanced Computing, Pune 411 007, India, Forestry and Ecology Division, Indian Institute of Remote Sensing, Dehradun 248 001, India

10 Geospatial Mapping Of Potential Recharge Zones In Parts Of Pune City, Geological Society of India, Vol. 73, May 2009, pp.621-638- Duraiswami. R. A., Dumale. V., Shetty U.

11 Hills, dams and forests – by Gadgil M, 1979, Indian Institute of Science, Vol C2, Part 3, September 1979

12 Land use and land cover change detection through remote sensing approach : A case study of Kodaikanal taluk, Tamil nadu - by Prakasam.C, Department of Geography, The University of Burdwan

13 Land Use And Land Cover Dynamics of Nilgiris District, India, Inferred from Satellite Imageries – by American Journal of Applied Sciences 11 (3) : 455-461, 2014 ISSN : 1546-9239©2014 Science Publication doi:10.3844/ajassp.2014.455.461 Published Online 11 (3) 2014 (http://www.thescipub.com/ajas.toc) Corrosponding Author Nalina, P., 2T. Meenambal and 3R. Sathyanarayan Sridhar, Department of Civil Engineering, Avinashilingam University for Women, Coimbatore-641 10, India

14 Land Use Land Cover in the Western Ghats, India, Effects of Human Modification and Use on Protected Areas – By Malissa Hubbard, Elizabeth Norment, Paul Gerlach, May 2013

15 Land Use Pattern in India and Karnataka : A comprehensive Analysis – By Dr. Premkumara

16 Land Use Changes in India and its Impacts on Environment – By Shashi Chawla Department of Applied Chemistry and Environmental Sciences, Amity School of Engineering and Technology

17 Onchan, Tongroj. 1991. "Asian Agriculture : Perfomance and Issues with Special Emphasis on Thailand", paper presented at the APO Advisory Group Meeting, Tokyo.

18 Population Growth, Changes in Land Use and Environmental Degradation in India - By Ms. Soumya Mohanty, Research Scholar, IIPS.

19 Western Ghats Protection And Sustainable Development- Challenges Ahead - by Aditya Raju and *Dr. K. V. Raju, M G University Research Centre in Economics, S. H College, Thevara, Kochi, Kerala, India

20 WGEEP Report Executive Summary August 9, 2011

21 Ghate, K., Management of Forests in the Northern Western Ghats, Journal of Ecological Society, v. 26 and 27, 2014, pp. 29-42

22 UNESCO 2012 – India – UNESCO World Heritage Centre, http://whc.unesco.org/en/statesparties/in

23 Gadgil, M. and Vartak, V.D. (1976), Sacred groves of Western Ghats of India, Economic Botany, 30 : 152-160.

A Report on Socio-Economic Status in Villages of the Panshet Dam Catchment Region

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Abstract

In 1985, Ecological Society had conducted a detailed ecological and socio-economic survey of the Panshet dam catchment region near Pune. In 2014, thanks to a grant from Global Forest Watch, a detailed ecological survey was repeated for the region. A dipstick study was also conducted across six villages to assess the current socio-economic aspects and man-nature relationship in the region. Data on population, households, occupations, income, land use, agricultural practices, cattle, vegetation, forest resources, schools and other amenities, and social bonds was collected. These findings were compared with the 1985 study to assess ongoing changes in the catchment. We found that the process of degradation of forests has continued. As a result, the worsening of human-nature relationship has also continued. Decline in agriculture, lack of profits in ancillary occupations, migration out of the catchment, and land acquisition by urban property owners and developers, complicate the region's socioeconomic picture. Many of the 1985 study recommendations, if implemented with good governance, had the potential to nurture a sustainable, natural resource-centric economy in the region, however this did not happen. Going forward, a landscape ecological approach, managed by a quasi-government Catchment Authority, is suggested. The report makes recommendations for new implementation vehicles, such as a Model Eco-Sensitive Zone Initiative, a Landowner-Conservators' Collective, an Incubator for Sustainable Local Economy, and a Reverse Migration Program.

Introduction

Socio-economic studies from an ecological standpoint are designed to collect data to inter-relate status of ecosystems, land use, natural resources, vegetation, and biodiversity with human needs and actions. Such studies often include multiple objectives like assessment of :

1. Energy demand and its sources, food, forest resources, water demand and sources, land use, agricultural inputs, soil quality.
2. Occupations and livelihood in and of the community.
3. Migration of locals to the city from rural areas.
4. The local economy and its integration with urban economy
5. Health, happiness, and well-being
6. Man-nature relationship
7. Local problems and key demands of local populations

In 1985, Ecological Society had conducted a detailed ecological and socio-economic survey of the Panshet dam catchment region near Pune (Gole, 1985). Several villages in the catchment of river Ambi were submerged under the reservoir when the Panshet dam was built during 1957-61. These villagers could not be successfully rehabilitated in far-off alternative locations like Daund, and few came back to resettle on slopes in the Panshet catchment. Located on the middle contours of Western Ghats (altitude ~2500 ft), these 23 settlements comprised the study region of ~120 sq. km. The 1985 survey had studied the land use, occupations, natural resource use, economic status, and amenities of these communities in great detail.

In 2014, Ecological Society undertook an ecological survey in Panshet Catchment and Bhimashankar Wildlife Sanctuary of Western Ghats. While socioeconomic analysis was not a major objective of the survey, a dipstick study was undertaken to help us relate ecological survey findings with socio-economic changes in the region. This report summarizes the key findings of this 2014 study and provides comparison to the 1985 study. The study was undertaken with a questionnaire template of 55 questions. Eight families/ individuals across six villages (See Table 1) in the catchment area were interviewed. This data, coupled with discussions with other practitioners frequently visiting this area, forms the basis of our findings.

The author considered it important to compare the current data with that of the 1985 study for the following reasons :

- The 30 year period would allow an assessment of long-term socio-ecological changes or patterns in the region.
- A comprehensive study similar to (Gole, 1985) was also reported by (Brahme, 1986). Other than these two studies we have not come across any similar socio-ecological studies done in this region during the period from 1985 to 2015.

This study was a short and exploratory one and is not as exhaustive or comprehensive as (Gole, 1985) or (Brahme, 1986).

The Study Region

The Panshet dam, built on river Ambi, is located 40k.m. west of the city of Pune. The catchment of the river Ambi up to the dam wall is spread over 118 sq. km. across multiple rainfall zones in the Northern Western Ghats.

The lat-long range for the catchment is 73°26′7.947"E and 18°17′43.641"N to 73°37′44.686"E and 18°23′14.33"N with elevations ranging from 626 m at valley to 1134 m at the ridge line (Pole village). The reservoir itself is a little over 14 sq. km. The chart below shows the relative location of the Panshet catchment w.r.t the state of Maharashtra.

Key Socio-economic Findings

1. Population and Households: Owing to migration to large cities and to Panshet colony over the past 30 years, the population and households in the villages has mostly declined. This is more pronounced in smaller villages.

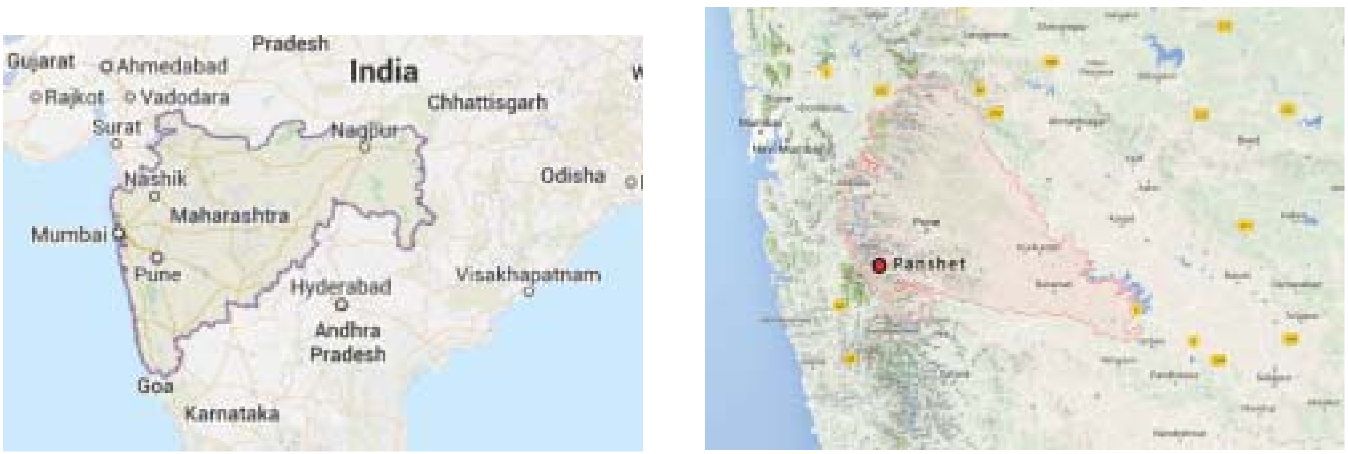

Figure 1: Location map of Panshet w.r.t state of Maharashtra and the Pune district

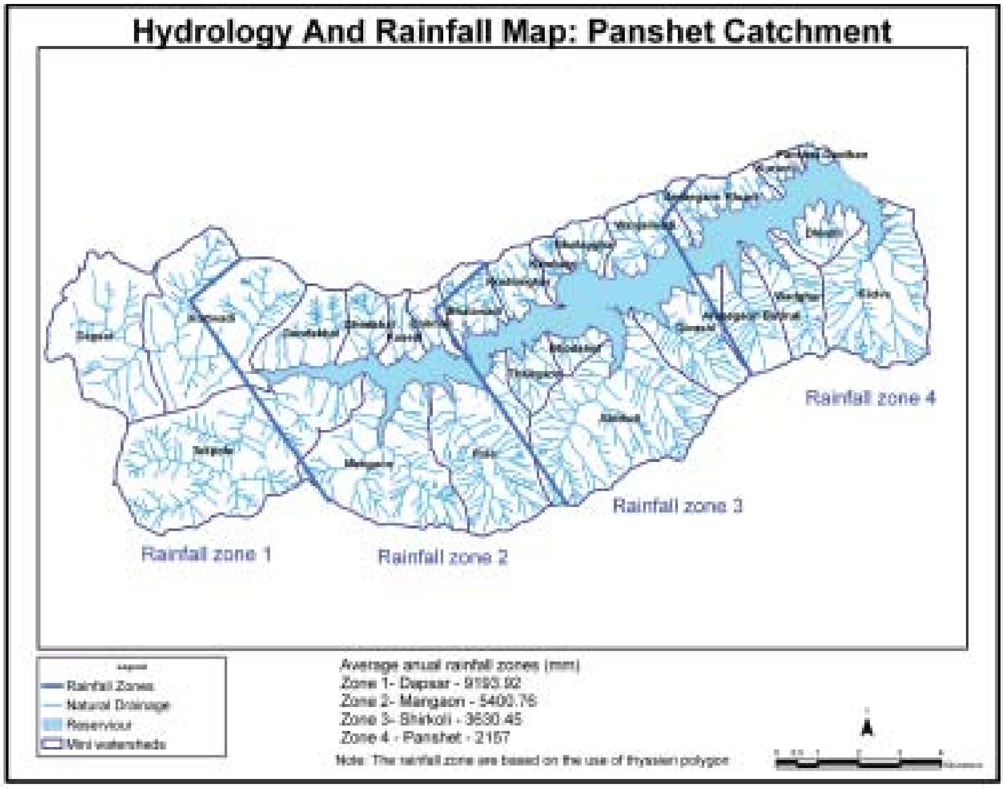

Figure 2: Villages and Rainfall Zones in the Panshet catchment

Table 1: Population by village

Villages surveyed	1981 census		2011 census		2014 interviews	
	Population	Households	Population	Households	Population	Households
Panshet gaothan	71	9	NA	NA	40-50	8-10
Ambegaon Khurd	339	65	129	33	90	10-12
Kadve / Kadhve	741	134	991	193	1300	170
Kambegi	95	21	55	12	50-60	10-12
Gondekhal	128	39	73	20	50-60	12
Dapsare	187	44	121	30	180-200	28

Note :

- 1981 census data retrieved from (Gole, 1985) and (Brahme, 1986)
- 2011 census data retrieved from http://www.census2011.co.in/
- While Kadve's population has increased, it should be noted that, being situated in a side valley, Kadve was not displaced when the Panshet dam was built, unlike the other 23 villages in Panshet catchment area.

The proportion of adults who have migrated out was 15% during 1985 (Brahme, 1986). While we could not ascertain the number as of 2014, it is expected to be much higher.

2. Occupations : Historically, the main occupation in the Panshet catchment has been rain-fed agriculture. Traditionally, a three-year shifting cultivation pattern of *Nachani* (*Eleusine coracana*), followed by *Varai* (*Panicum miliaceum*) followed by *Karale Teel* (*Guizotia abyssinica*) was common. This pattern is still followed at very few places. By 1985, traditional rice cultivation was already on decline (Gole, 1985).

Rain-fed agriculture continues to be the main occupation of those who stay in the villages. Farmers take crops of Rice and *Nachani,* for household consumption and not for sale. This was recorded in 1985 too. *Varai* and *Teel* are also being grown but declining. No cash crops are present. Thus, income from agriculture has continued to be at subsistence levels or below it. Small farmers hold 4-5 acres of farmland while a relatively large land holding comprises of 10-15 acre. There are families holding even 1-2 acres, due to successive distribution of holdings across generations.

There is variation in the rice yield across farmers. Farmers mentioned yields of between 100 to 500 kg/acre. Based on our study, such variation could be attributed to (1) Destruction of crops by wild boar, (2) Varying use of fertilizers like Urea by farmers, and (3) Less productive agriculture by some farmers due to relatively less availability of labour. Further analysis on agricultural yields and income will need a detailed survey.

Other occupations or supplementary income sources, especially when no agricultural land is available, are : Rearing cattle to sell milk, Cultivating and selling Bamboo or household items from Bamboo, Rearing goat and sheep for self and for others, Working with the Gram Panchayat (Village Council), etc. Other than the larger villages like Kadve or Panshet Colony, there are no signs of specialist services like barbers, carpenters, etc.

Based on our assessment, these supplementary occupations are not highly profitable or have not displayed a significant capacity to enrich a household. Two examples may be useful :

- According to (Gole, 1985) a pole of Bamboo fetched Rs. 10-15 in the mid-80s, before it made its way to the Pune market. Our 2014 interviews show that Bamboo now fetches Rs. 80-90/pc for *Meshi* variety, Rs. 30-40/pc for *Dhopil,* and Rs. 100/pc for *Kalak.* Assuming an average price of Rs. 75/pc, we see a price increase of 5.7% per year over the last 30 years, which is below India's CPI inflation rate of ~7% during this period, indicating the inability of this income source to help a household meet its expenses.
- The purchase rate for milk now stands at Rs. 30-32/litre, relative to Rs. 2.5-3/litre in 1985. An average annual rise of 9%, this is just slightly above India's inflation rate of ~7% during this period. Moreover, milk production is often unprofitable due to the increasing scarcity of fodder and rising prices of cattle. Milk selling and distribution has to deal with rising fuel and transportation cost.

Relative to 1985, other natural resource-centric occupations have closed down. Coal making from forest wood has reduced significantly, as has harvesting of *Hirda* (*Terminalia chebula*) tree produce. In 1985, 15% of the annual household income was estimated to come from mango and minor forest produce. In our study, sale of mango was not found to be significant. Similarly little evidence was recorded of sale of *Jamun* and other minor forest produce. Milk-vending pastoralist households (*dhangar*) who reside on higher mountain slopes, have also declined, mostly to single digits in any given village.

Many locals also end up working as agri-labourers on others' fields when such work is available. It pays Rs. 250/day (male) and Rs. 200 (female) but they get a chance to work only a few times a year. It paid only Rs. 90-100/day (male) and Rs. 50 (female) until just a few years ago.

One new occupation has emerged : household help / laborers / watchman / cook and similar services for occupants of urban owners' bungalows. These jobs pay about Rs. 100/day and in some small villages nearly 10% of the population is engaged in them. Some other new occupations are in the land business, serving urban buyers for fulfilling their real estate related demands. These include real estate agents, building contractors, craftsmen, consultants, architects, and others. Most of this, however, is visiting population.

3. Land Use : (Brahme, 1986) mentions loss of top soil due to shifting cultivation and deforestation as a top problem for the catchment. This was rendering an increasing area unfit for cultivation in the 1980s and afterwards. Today, shifting cultivation continues to be the dominant method for agriculture and continues to affect land use. Compared to 1985, the following changes are observed :

a. In the absence of land share arrangements or manpower, farmers have left part of their land permanently fallow.

b. Where cultivation continues, the land under shifting cultivation as well as fallow period is declining as farmers are trying to maximize output. They are ready to use chemical fertilizers extensively. (Gole, 1985) mentions that in Zone 1, fallow period was already shortening even in the mid-80s to 2-3 years. It was 10-15 years and 5-9 years in Zone 2 and 3 respectively. This process of decline in shifting cultivation has continued.

c. Overall land under active agriculture has declined. As per (Brahme, 1986), 1044 hectares i.e. 2578 acres was the cultivated land area in 1986. According to our 2014 ecological and land use survey, 1571 acres is under paddy cultivation while 158 acre is under shifting cultivation of *nachani, varai* or *teel.* This is a total of 1729 acres i.e. 33% reduction in land under cultivation.

Some of the land has been claimed in land deals by urbanites – mostly for non-agricultural use. The land ownership transfers started in 1970s/80s, caught momentum in the mid-1990s and continues today. It is likely that some of these land parcels have changed hands multiple times among urban land investors with surplus wealth. Even as the landscape appears rural, it is partially composed of urban ownership.

Anecdotal evidence indicates that land prices in the Panshet catchment increased from a mere INR 2000/acre in 1972 to INR 30 lakh/acre by 2011 (actual prices will vary based on location). This indicates an average annual increase of 20% over a 40-year period. Neither the farmers' profits from their agricultural income, nor the supplementary occupations come close to providing the kind of wealth creation potential that land sale itself provides. Most such land sold to urbanites is converted to non-agricultural status to facilitate construction and is lost to agriculture or forest for good.

4. Cattle : (Gole, 1985) noted qualitative depletion of habitat but even then a large number of families had cattle. By 2014, several farmers had sold off cattle due to lack of fodder, lack of use, or increasing costs. In some villages less than 20% households now own cattle (1-6 each) which is a historic low. Indicative data is provided in Table 2.

Those in the milk business own relatively more cattle. Majority of the cattle are native species. Farther in the catchment, transport increases the cost of selling milk.

Grazing commons (*gaayraan*) which existed in some villages are now ignored or barren. Cattle feeds on forest department's land, private open lands, and agricultural residue. Hence, cattle grazing continue to be a cause of the degradation of the forest ecosystem.

5. Quality of soil (agricultural land) is declining overall, as per the study respondents. There is a relatively higher use of urea mix than before, while organic manure also continues to be used. Farmers are realizing that though yields have improved in short run due to use of chemical fertilizers, the crops have also become more prone to diseases and quality of soil will decline over the long term.

6. Vegetation around villages is on a general decline over the last 20+ years. e.g. The *Hirda* trees, once common in this area, are now almost completely exploited. Both (Gole, 1985) and (Brahme, 1986) had pointed out the ongoing loss of vegetation and plant life. This, in turn, has affected economic activity and resource potential in the catchment.

7. Forest food and resources : The villagers' food habits have increasingly grown to be similar to urban tastes. *Nachni bhakri*, rice, and *varai* (*bhagar*) formed the staple diet in 1980s (Brahme, 1986). Today, the consumption of wheat has significantly increased.

Apart from some forest vegetables during the monsoon season or the seasonal mangoes and jackfruit, no other forest food is consumed. Villagers are heavily dependent on the forest for fuel wood – *Karavanda, Kaarvi, Ain* and if available *Bor,* being the

Table 2: Cattle population

Village		1985 study	2014 study
Dapsare	Human population	187	
	Households	44	
	Cattle (excl. sheep/goat)	218	
	% Cattle-owning households	*NA*	*20%*
	Average Cattle/household	4.95	2-4
Ambegaon Khurd	Cattle (excl. sheep/goat)	310	40-50

plants of choice. A few of them make items of household use from bamboo as a side occupation. Awareness of medicinal plants is on the decline, except for places like Dapsare which are closer to Sacred Groves or away from town centers.

Villagers admitted to cutting fuel wood from all over the catchment except sacred groves. Our ecological survey points out that even some sacred groves are under a process of degradation. e.g. In Gondekhal, a small sacred grove (*devrai*) is adjacent to the village. Cattle-grazing is allowed in this sacred grove. Dapsare has a sacred grove adjacent to the village. The sacred grove is respected and cattle-grazing/cutting does not seem to be too common in it.

As urban land owners fence off their properties, access to fuel wood has decreased.

8. Schools : Some of the villages have nursery schools (*Aanganwadis*) and schools till 8th grade, while some with lower population (e.g. less than 15 households) do not have any schools. Children from these villages have the option of walking to schools in nearby villages, which may be some distance away. The schools have teachers on government payroll. Due to the decline in population, the number of students enrolled is small. Absenteeism within teachers is also a problem. After 8th grade, the only option is to study at schools at Panshet colony. Many such students commute daily, which is tiresome and time-consuming, because there is only one bus scheduled during the day from these villages to Panshet town. Some others live in hostels in the town, but they are expensive. Due to urban integration, many of the young families have migrated to Pune, Mumbai, and other cities, and their children are studying in city schools.

9. Amenities : There are no Primary Health Centers or Ration Shops in these villages, though they are a necessity for the villagers. In case of health emergencies, the patients either have to be taken to places like Panshet or Khanapur and there is a risk of patients dying due to the lack of transport. Most villages are now electrified, which was not the case during the 1985 study.

10. Community Bonds : Our interviewees also mentioned that urbanites and people from other villages buying land has disturbed the locals' confidence in agriculture. Traditional ways of collaboration have deteriorated or vanished. The expertise and the patience with the land is fading away.

The recent erratic nature of monsoon (partly due to climate change) has also affected their behaviour. As the monsoon period is often short or unpredictable, the tendency is "I need to focus on my field first; I will help others only if I have any time left!" The teamwork in agriculture has stopped. The earlier arrangement of helping on each other's' fields involved taking turns and not money. Now money is being paid so relationships have become transactional.

Locals are now increasingly dependent on their urban relatives for money – some of those who got educated have relatively higher salaries and this reduces importance of local agriculture even more.

The urban property owners have created jobs, but not too many. A typical new bungalow/farmhouse can generate at most 3-4 jobs in the form of cooks, cleaners, guards, etc. Several urban owners and developers are from outside Maharashtra and they bring household labour from other states. As such, locals may not be necessarily benefiting due to this development.

11. Income : Average annual income will vary within the villages of Panshet catchment, depending on the main and supplementary occupation, land holding, financial aid from city-based relatives, etc. A more detailed survey is warranted for a good estimate. However, focusing on the lower economic stratum – those having 1-2 acres of land or no land, those who depend on the Public Distribution System for their daily food, those who depend on city relatives or on debt for any major financial needs – we felt that our interview data points to an income of Rs. 3,000-4,000 per month.

12. Problems identified by villagers : Villagers mentioned the following pain points during interviews :

- **a)** Destruction of crops by animals like wild boar, monkeys, and barking deer.
- **b)** Declining agricultural yields and degrading soil quality
- **c)** Poor public transport and connectivity to Panshet and Pune. There is only one bus per day scheduled to go to Panshet.
- **d)** Schools are not well managed. Students have to walk long distances wasting time.
- **e)** Most children residing here can get education only till 8th/9th (that too in Panshet) and later have to work in menial jobs like labourers, drivers or unskilled computer work.
- **f)** Farmers do not grow enough food to meet their sustenance needs. They have to buy food from the market or are dependent on aid sent by urban family members.
- **g)** Transport costs have increased rapidly. Producing and selling to the city is increasingly expensive.

h) Local governance bodies (*gram-panchayats*) are dominated by some families and may not hold regular meetings or pass information about government schemes to villagers.

Local communities in this region are seen to have a hand-to-mouth existence. There are daily struggles for food, fodder, and health services. They do not have major aspirations for local growth as their basic needs are not being met. Sometimes, their aspirations are not in harmony with local conditions. E.g. in Dapsare, villagers are unhappy because a nearby road connecting to Konkan cannot be built due to forest land reservations. They are also unhappy because the government has declared the area an Eco-Sensitive Zone and new construction activity is restricted. They feel this constrains 'development' of their area. They have no idea of what alterative growth models could be used.

Changes observed relative to the 1985 study

Salient comparisons with the 1985 study by Ecological Society may be useful :

- (Gole, 1985) wrote, *"The average family residing in the Panshet catchment today barely earns enough to sustain itself. The agriculture they practice is primitive, less productive, and generally harmful to the environment. The cattle they keep also produce less, do not get enough nutrition, and are a drain on the time and energy of the family"*. The present study shows that **these trends have either remained the same or worsened**. Farmers are relying on chemical fertilizers to produce more. Soil quality has declined. The number of cattle have declined significantly. The farmer of the Panshet catchment seems to be more or less at the same place socio-economically as 30 years ago.
- (Gole, 1985) also noted *"With the disappearance of the forest, their sources of income are also fast declining"*. **This process has worsened**. Not only income, but even knowledge of the forest and its produce has shown a decline from 1985 to 2014. The forest department has taken efforts to protect the forests, but a symbiotic relationship between the forest and people or preservation of any significant ecological niche (e.g. in food or livelihood) could not be seen. With a few exceptions, even the sacred groves have suffered from degradation. There is little interest among villagers to conserve local nature other than the sacred groves.
- (Gole, 1985) noted, *"The people…have to fall back on selling off remaining trees to charcoal merchants and to rely heavily on government subsidies"*. **The degradation of the forest has continued.** Charcoal was a temporary cash cow back then. Today, real estate is the cash cow. A farmer cannot justify continued productive use of land for agriculture when urban buyers offer several times his annual income for the same piece of land, especially in face of all the hardships in doing agriculture in the Western Ghats.
- (Gole, 1985) mentions an average income of Rs. 300/month in the catchment. Our estimate of income of Rs. 3000-4000/month for the lower economic stratum represents a 10-fold increase in 30 years, or 8.8% per year. This is only 1.8% per year after adjusting for inflation. Moreover, it is much lower than India's average monthly income of Rs. 5130 in 2011-12, indicating the lack of economic opportunity to those in the lower rungs of these communities. Those who do not have access to wealth-creating land are increasingly dependent on their city-based relatives.
- There is a depressed or negative feeling among most of the villagers who have been residing here. Decades of lack of facilities and poor governance have created this depression (e.g. healthcare, education, transport). Their next generation has little by way of development options and may need to migrate to cities.
- For new occupations and ideas, lack of manpower may prove to be an impediment as younger people have migrated out.

(Gole, 1985) envisioned an Eco-Development Plan for the catchment. His key recommendations are summarized in Annexure 1. Over the 30 years since this unique Eco-Development Plan was proposed, the recommendations have not received the attention they deserve from policy makers.

- As for recommendation #1 in Annexure 1, works related to soil conservation have happened sporadically based on various government initiatives. Plantations were traditionally of exotic species. Of late, attention is being given to indigenous flora for plantations on government-owned land, but we do not see significant evidence of this in the Panshet catchment.
- As for recommendation #2 in Annexure 1, our study found that the extent of shifting cultivation has reduced, but this is largely a function of farmer migration to cities, land sales to urbanites, and reduction in cultivation as an occupation. There is no policy thrust behind reducing shifting

cultivation through an awareness campaign or local measures.

- As for recommendation #7 in Annexure 1, some tourism activities have started, but they are largely driven by local and city-driven entrepreneurship, and not due to a supporting environment created by policy makers, neither can they be guaranteed to be environment-friendly. E.g. Such tourism creates waste like plastic bags and plastic water bottles, which chokes up ecosystem flows. A more systematic plan of job creation, while keeping sustainability in mind, needs to be designed and practiced in the Panshet catchment. Case studies like Velas (Nulkar, 2014) would provide useful inputs for such a plan.

Other than the above, there was no follow-up by the authorities on any of the recommendations. If they were actually implemented, these recommendations had the power to mitigate problems and pain points that we see today in 2014, as shown in Table 3.

30 years of forest restoration and conservation work, if facilitated by policy makers, would have created several ecologically rich pockets in the catchment, with significant economic returns to local communities.

In summary, strong and timely action on all the recommendations would have averted the ecological erosion, overdependence on urban economy, migration, and subsistence-level life of locals that we observed in present-day Panshet.

(Gole, 1985) had also warned : *"…this eco-*

Table 3

Pain Point (2014) as told by interviewees	**(Gole, 1985) recommendations which, if implemented, could have potentially mitigated the problem (numbering from Annexure 1)**
Destruction of crops by animals like wild boar, monkeys, and barking deer.	#4, 6, 8. Creation of the sanctuary, indigenous plantation, and protection of local forest would protect wild animals' habitat and there would be less chance of them wandering to fields
Declining agricultural yields and degrading soil quality	#1, 2, 6, 11 would have a direct impact in soil conservation
Poor public transport to connectivity to Panshet and Pune. There is only one bus per day scheduled to go to Panshet.	#17
Schools are not well managed. Students have to walk long distances wasting time.	#9
Most children residing here can get education only till 8th/9th (that too in Panshet) and later have to work in menial jobs like labourers, drivers or unskilled computer work.	#4, 5, 7, 8, 9, 10 – all of these have strong emphasis on local employment, vocational skills (including natural resource management) and would have averted both the decline in quality employment and migration to cities
Farmers do not grow enough food to meet their sustenance needs. They have to buy food from the market or are dependent on income sent by urban family members.	#3, 4, 5, 10 –indigenous plantations, horticulture, and agro-forestry would have created a path towards supplementary income and enrichment of farmers.
Transport costs have increased rapidly. Producing and selling to the city is increasingly expensive.	Virtually all the suggestions are about creating a strong local economy. Goods exported to the urban economy (e.g. fruit and timber) would carry enough pricing power to sustain rise in transport costs. For other services like nature tourism, urban customers would actually travel to Panshet.

development approach does not give room to stock measures of economic improvement such as road-building and industrialization…such measures…may do incalculable harm to the ecology of the region as well as its residents." **These grave concerns have unfortunately come true.** What we observe today in the Panshet catchment is a steady march towards urbanization through land sales, plotting, conversion of land to non-agriculture use and farm-house schemes, resulting in an increase in land movement, roads and vehicle activity.

(Brahme, 1986) had also proposed a similar eco-development plan. In addition, it had outlined specific redevelopment programs for the villages of Kuravati, Shirkoli and Mangaon.

Discussion and Recommendations

As the Western Ghats is a global biodiversity hotspot, the Government of India appointed the Western Ghats Ecology Expert Panel (WGEEP), which submitted its report in 2011, widely known as the Madhav Gadgil report (Gadgil, 2011), and in 2013, the High Level Working Group on Western Ghats (HLWG), known as the Kasturirangan report (Kasturirangan, 2013).

As a result of these studies, on March 10, 2014, the Ministry of Environment and Forests published declaration No. 624, which defined eco-sensitive zones in W. Ghats, the restrictions on development in these eco-sensitive zones, and the villages in various districts which come under eco-sensitive zones. As per our knowledge, the following villages from the Panshet catchment, all belonging to Velhe *taluk* of Pune district, are now under an eco-sensitive zone : Dapsare, Gholapghar, Balaodi, Kambegi, Kadave, Chikhali, Ambegaon BK, Kurtwadi, Kasedi, Gondekhal, Givashi, Ghodshet, Shirkoli, Tekpole, Mangaon, Pole.

Thus, a large part of the Panshet catchment is now under an eco-sensitive zone and the following activities are prohibited :

- Mining
- Thermal power plants
- Polluting industries designated by state or central pollution boards
- Construction/development projects amounting to >20,000 sq.m. of construction foot print

While this will benefit the environment, the regulation still leaves room for a large amount of urban development, including farmhouses, resorts, and roads. It is unfortunate that land sales to urbanites has become the main and only tool for wealth creation in this area. We believe that urban lifestyle and interference is likely to be a key cause of stress on ecosystems in this region going forward.

Considering this, it may be useful to evaluate the following approach going forward.

1. A landscape ecological approach is strongly recommended to be followed for the Panshet catchment and its surrounding areas. Many of these are similar dam catchments under eco-sensitive zones, with similar combination of ecological stresses and socio-economic challenges outlined above.
2. The landscape ecological approach should be multi-lateral, involving local and state government agencies, NGOs, local population, urban land owners in these areas, subject matter experts from academic and research institutes, and philanthropists. Such multi-lateral involvement will ensure that all stakeholders' interests are considered and a common vision for sustainable development is created for the catchment.
3. The specific recommendations of (Gole, 1985) on a comprehensive Eco-Development Plan, inclusive of a Wildlife Sanctuary, holds enormous merit in our opinion. If a sanctuary is not possible due to people displacement or land ownership issues, as much statutory and community protection of forests should be achieved as possible in the current situation.
4. A quasi-government entity, similar to the Catchment Authority proposed by (Gole, 1985) would still be very useful. Such an entity should take environmental sustainability, as defined by the Burtland Commission, as a founding principle. Nature conservation and restoration programs should be conceived and executed by this authority. Such a Catchment Authority should be an independent authority funded by the state government, Corporate Social Responsibility (CSR) programs, and from tax collections from locals, urban land owners, and tourists. It should work closely with the irrigation department, the forest department, and local village councils to impart the vision of a sustainable catchment.
5. Conservation programs must provide clear economic benefits to the locals to be effective. This would include short run benefits (e.g. monetary compensation, education, job-oriented training, job creation, inclusive decision-making in conservation planning) and long run advantages (sustainable extraction of forest resources, sustainable agriculture, direct marketing to consumers of agriculture and forest produce, well-planned housing, reliable water supply,

healthcare).

6. Urban citizens should volunteer in large numbers to make the conservation programs successful.
7. Primary and secondary schools in the Panshet catchment should receive educational resources, financial aid, and quality teachers with support from NGOs, government, philanthropists, and volunteers. Such schools should offer an eco-education stream linked to local ecosystems, which includes local biodiversity, forest conservation, natural resource management, sustainable agriculture, and basic vocational skills.
8. Urban land owners in these villages will be key influencers of this landscape as well as its conservation. The above-mentioned authority should take this into cognizance. It should catalyze nature conservation among urbanites and locals alike. E.g. Ideas like private sanctuaries on collective land of urban owners should be implemented. Such an initiative is already in progress by Oikos, an ecological consultancy, near Shirkoli village in the catchment.

Below we offer a set of new vehicles and ideas, mainly by way of example, to implement the above recommendations :

- Model Eco-Sensitive Zone Initiative for Panshet (MESZIP) : This should be an initiative of NGOs, local citizens, and urban volunteers who are interested in restoring nature while achieving sustainable economic development in the Panshet catchment. Their aim would be to demonstrate that Panshet catchment can become a Model Eco-Sensitive Zone and not go by way of urbanized hill stations like Lonavala over the next 2-3 decades. They should involve stakeholders like real estate industry, bureaucrats, forest dept., irrigation dept., farmers, land owners, schools, housewives, etc and hold ongoing sustainability education workshops for them. One of the outputs from MESZIP could be to work with NGOs and academics to evolve a Landscape Ecology Plan for the Panshet catchment (LEPP) in a scientific yet socially sensitive manner. They should also develop long-term CSR relationships with corporates who would be willing to fund ongoing conservation and restoration programs in the catchment. A successful example of such a working group is Jeevitnadi, Pune, which works on the cause of rivers.
- Landowner-Conservators' Collective (LCC) : This should be primarily composed of urban land owners who have bought or considering buying land in the Panshet catchment and who are interested in conserving nature. A few of them would have to play the role of a catalyst and bring everyone together. In collaboration with MESZIP and NGOs, they would develop conservation and restoration plans for patches of lands owned by them. This should fit within the LEPP. The LCC should facilitate collaboration on larger-scale initiatives like private sanctuaries, expanding community conserved areas, sharing of grass and forest output with locals in planned manner, etc.
- Incubator for Sustainable Local Economy (ISLE) : This incubator should be physically in the Panshet catchment with business and funding connections to Pune and promote ecological entrepreneurship, agro-forestry, horticulture, organic farming, simple eco-tourism, etc. Local youth, homemakers, and farmers would generate supplementary income through such opportunities and raise their annual income.
- Reverse Migration Program (RMP) : The declining population in the Panshet catchment poses a challenge in executing conservation programs even if funds are available. The increasing migration to cities creates a dependence on the urban economy and a feeling of emptiness locally. To break through this, a Reverse Migration Program should be considered. The study found that Panshet residents migrating to cities had low skill sets and had to choose low paying jobs, subsequently lowering their quality of life. Such people should be actively supported in moving back to the Panshet catchment. They should receive initial subsidies and cultivate family land or explore one of the above-mentioned entrepreneurship opportunities. Moreover, many city-dwellers are tired of city life and want to quit to get closer to nature. A pathway for them in terms of land purchase, guidance in conservation, agro-forestry, horticulture, or non-profit work could be facilitated under the RMP.
- Pune Volunteers for an Eco-Sensitive Panshet (PVEP) : The main beneficiaries of the Panshet dam are city dwellers in Pune who receive 24x7 supply of high-quality water. It would be worthwhile for them to give back by creating a legion of volunteers to donate labour, time, and funds (e.g. crowdsourcing) for conservation, education, and entrepreneurship activities specifically in the Panshet catchment. There are several examples of urban volunteers contributing successfully to nature education, indigenous plantation, exotic species control, Sacred Grove protection, etc in the catchment.

- Similar action vehicles could be considered for other dam catchments in W. Ghats where similar problems exist. It will be ideal to form a network of people and groups working on sustainable dam catchments in W. Ghats and their restoration. Such a network would facilitate research and field study, exchange of ideas, assessment of common problems, and support for their resolution.

To be effective, programs suggested above should work in collaboration with each other.

A landscape-based ecosystems management approach, government support for conservation, and a stop to further roads and real estate development will save this landscape. A good governance approach, with local and urban citizen participation is also essential. If nature conservation and restoration programs are designed to reward the local populations meaningfully and also create better soft infrastructure for the community, these could prove to be saviors of the region.

Acknowledgements

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Annexure 1

A summary of Eco-Development plan recommendations from (Gole, 1985)

1. Soil conservation measures on an urgent basis: Bunding and terracing of slopes, planting grasses that will hold the soil and provide nutritive fodder, planting suitable vegetation that will provide a wind-break and cover the ground against the impact of rain drops, etc.
2. As much reduction as possible in shifting cultivation and grazing as it results in forest degradation and accelerates soil erosion
3. Replacing cereal agriculture (which is not compatible with soil conservation) by horticulture for production of wood for fuel and timber.
4. Plantations exclusively with indigenous species, e.g. *Terminalia chebula*, which can provide economic returns as well as a link in the ecological food chain.
5. Plantations of high-yielding fruit like cashew and spices with careful management
6. Maintenance of the semi-evergreen and moist deciduous forests to support habitat and scenic beauty
7. Recreation activities that do not harm the habitat (e.g. hiking, angling, birdwatching, nature study tours) to generate local employment. While encouraging such tourism and creating related infrastructure (e.g. camping areas and tents), urban-style amenities like car parks, sports facilities, or video parlours should be strictly avoided. Boating should exclude power boats. Nature Information Centers should be created near select sacred groves like Mangaon, Shirkoli, and Gondekhal. These tourist activities, though seasonal, will create local employment. Transport to such locations would be by motor launch, thus avoiding the need for cars, larger vehicles, or any widening of roads.
8. A wildlife sanctuary spread over 5896 acres in the ecologically rich yet fragile area near the crestline, after relocation of its inhabitants by providing better opportunities elsewhere. This would protect the forest and also provide stability to the dam catchment. Such resettlement was possibly in theory, on land available with the Irrigation Dept. This displaced population would be given compensation and also supported to own cattle and form a milk co-operative.
9. Facilities like addition of a technical and vocational training school, hospital, consultancy for cottage industries, bee-keeping, sericulture, and dairy development, and other agro-based vocations.
10. Agro-Forestry Experimental Stations preferably on barren land owned by Forest Dept. or Irrigation Dept. Such land could be leased to voluntary agencies to develop experimental farm-cum-demonstration center for local cultivators. This would also include a nursery for local plant saplings, improved forage or fuel wood at cheaper rates, etc.
11. Raise overall vegetative cover by raising plantations of medicinal plants, quick-growing trees for fuel wood and timber, fruit trees, economically important flowering plants, improved varieties of grasses. Set up programs for such re-forestation on private land.
12. Monetary incentives for a villager where at least 25% families give up shifting cultivation, stall-feed cattle, and offer some land for agro-forestry. Such incentives could include Rs. 300/month (1985) in the form of subsidies for grain, other necessary articles, etc.
13. Creation of a new statutory authority called Catchment Area Development Authority to tackle

the problems of eco-development not just for this dam but for all such dam catchments (in W. Ghats and other mountains)

14. Identification of Sacred Groves areas within land held by Forest Dept and strict protection for such land. This would gradually lead to vegetational climax in such sacred groves, aiding revival of indigenous forest cover.
15. Initiate a separate Forest Range with a Range Forest Officer interested in flora and fauna of the catchment with adequate amount of staff and guards. This would also create local employment.
16. Careful definition of rights of Dhangar pastoralists on collection of wood and produce from forests.
17. Transport of wood and charcoal by trucks should be banned. On the other hand, local residents should get good bus service.
18. The total cost of the above Eco-Development plan was estimated in detail and it came out to Rs. 74 lacs (in 1985 rupees) or Rs. 1607/person over a five-year period. This was a reasonable investment to achieve indigenous plantation on 4900 acres of private holdings, to protect 4384 acres of forest land belonging to the Forest Dept., to create a new wildlife sanctuary, and to create a vibrant natural-resource-based local economy. This healthy local economy would result in doubling of the local per-capita income. Levels of education and vocational skills were also expected to go up.

References

- Gole, Prakash and Tetali, P. (1985). An enquiry into the status of animal and plant life in the critical areas of Western Ghats in order to evolve a plan to conserve their biological diversity, Vol. 1, Ecological Society
- Brahme, Sulabha and Tetali, P. (1986), Economic and ecological impact of Panshet reservoir : A study in problems and eco-development alternative, Gokhale Institute of Politics and Economics
- Report of the Western Ghats Ecology Expert Panel (WGEEP), 2011, Gadgil, M., et. al., Ministry of Environment and Forests, Government of India. Last retrieved on 21.11.2015 from http://www.moef.nic.in/downloads/public-information/wg-23052012.pdf
- Report of the High Level Working Group on Western Ghats (HLWG), 2013, Kasturirangan et. al., Ministry of Environment and Forests Government of India, 2013
- Nulkar, G., Lessons from Velas : Assessment of Eco-tourism as a Model for Conservation in Konkan, Journal of Ecological Society, v. 26 and 27 (2013-14), pp. 71-82

Alleviating Poverty

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Introduction

This essay is focused on an important subject discussed all over the country and the world, especially in political circles and among policymakers. There is a need established that to be able to pull individuals and communities out of poverty, we need that, meaningful employment is generated for a very large number of people. World over, certain approaches have been used by the policy makers which seem to increase the divide between the haves and have-nots. The policy of industrialization is leading nations into widening the gap between rich and the poor. It is also creating undesirable side effects by way of 'pollution' and depletion of resources at an ever increasing pace. This situation leads to the author's belief that something is not right. Such policies will not lead to sustainable livelihoods for masses. Hence this attempt to explore alternative policies, which could provide a viable approach to alleviating poverty.

Poverty alleviation is indeed a noble goal. All of us must also be seriously concerned about the difference in the standard of living between the rich and the poor. Moreover, our objective must be to see how the masses can live well and peacefully.

Around the world and within our country, being unemployed is not the best state to be in. Employment in this context is gainful occupation. The impact of such unemployment has been disastrous. This has led to militancy on one hand and ongoing unrest in many a city on the other. The way forward, as proposed since many decades and being followed incessantly, is "consumerism" to help us get out of this mess. Industrial mode of employment generation has been linked to production and productivity.

But all aspects of Industrial production are linked to use of natural resources to produce intermediate goods. This means any additional employment generated would dip further into the natural resource reserves. Can one think of a very different model of generating employment? Employment which does not dip into the reserves? Employment that can restore biological resources? There seems to be an opportunity for more thinking at the policy level to understand the root causes of unemployment and how we can tackle these for creating employment that can sustain, resulting in sustainable elimination of poverty.

The state of affairs

Could we find a holistic way to tackle the challenges that we ourselves have created? We seem to be hoping to fight fire by pouring even more oil through the consumerist route. However, there certainly is a way out. To understand this possibility, let us first look at the current state of affairs. While I have primarily restricted myself to Indian context, many of the reasons identified are more likely to be universal.

Let us understand what current policies are doing to the social and economic situation :

1. Public money is being used most in-effectively. Public money is expected to create much needed services required for everybody in the society. In India, the poor are a large percentage and need inclusion. A very small percentage of public money is being used for creating any public services and even less so to create anything useful to the poorer section of the public. A very large portion of public money actually serves the small percentage of 'the haves' rather than the poor. So called public facilities, sometimes inadvertently focus on the richer community rather than a much needed focus on the poorer community. A good example is building flyovers and widening roads

in an Indian context, instead of spending money in good public transport system. Most benefits of the wider roads and flyovers go to the car owners, who probably are responsible for just around 5% passenger road trips.

2. Education imparted to everybody is far too uniform and lacks the required context. There are a few inspiring programs being promoted by the likes of "Vigyanashram" (a vocational school based in Pabal, near Pune in Maharashtra) – but that is an exception than the rule. Education today does not focus on developing knowledge about local natural resources and how you can use these for developing sustainable local livelihoods. Resurrection of traditional knowledge is required to be presented and provided with modern methods and delivery to the next generation. Today's education continues to use the Macaulay system to create youth that is unable to think on their own. It is important to seriously upgrade the education system, if we are serious about enabling current and the next generations to live better.
3. There is no understanding provided and imparted to students of business, technology and economics that all of their endeavors directly or indirectly depend on the natural resource availability, health of ecosystems and ability of nature to provide ecological services. There is virtually no understanding created in the course of our education of the limiting factors and how one can sustainably use available natural resources. Considering the fact that material well-being is one crucial part of getting communities out of poverty, there seems to be a gap between availability of resources and how could these be best used in a sustainable manner, to address the large scale issue of equitable access.
4. The education is far too compartmentalized and specialized and connections between various disciplines such as natural sciences, social sciences, economics, technology and business are not visible to students of any of these individual disciplines. As a result, the multi-dimensional nature of our challenges is not drawn out in education. Does this also have a link to limiting opportunities for the poor or the rich failing to understand the problems they create?
5. It is very surprising that the educated from the rural centers have to always run to cities to find jobs - if at all - and are unable to relate with their local environment and resources. It might be argued that they do not see local opportunities as lucrative as they believe the opportunities in urban centers could be.
6. It looks like we have given in to the concept of inevitable urbanization and we are not willing to look at this as a problem and find solutions to contain this phenomenon. Most of the efforts are going in planning for this unviable growth of cities rather than focusing on finding a viable distributed approach to development (once development is defined in the right way!). This mode of unfretted urbanization is leading to urban poverty. As opportunities in urban areas increase, additional jobs in the organized sector are created. This opens up new opportunities for service job such as maids. These jobs are not secure and are not good enough in most cases to afford a decent living. Another example is construction workers, who move to the city and live in very harsh conditions.
7. We seem to be obsessed with the concept of growth (which is inherently unsustainable) rather than a concept of well-being and sustainability. Today's cities are an excellent example of this paradigm. Cities in the first place are a substantial drain on resources. Compared to typical rural areas, cities have orders of magnitude more ecological footprint on a per capita basis. If all of us lived in the cities today, we would be living in a "decidedly unsustainable world". Moreover, this phenomenon seems to be a root cause of deteriorating condition of the villages and people continuing to be poor in rural India in addition to becoming further burden on urban areas by migration and experiencing poor living conditions.
8. There is a serious confusion between essential and not so essential goods and services. Essential ones include food and optimum housing. Most innovations seem to be focusing on not so essential aspects leading to total imbalance in the way new businesses and products are created. A direct impact is seen through nominal rates of increase in prices of not so essential goods and services at the expense of skyrocketing prices of food items, and essential goods and services. Considering that masses consume these essential goods and services, poorer communities bear the brunt of these increased prices much more (as a large percentage of their income goes directly in procuring essential goods) than their richer counterparts who have a very small percentage of income used for purchasing essential goods.

9. Current economic model, the way it functions, further increases the gap between rich and the poor. The simple reason is the way any new investments are made by the private sector. These are typically made for 'consumer' who has capacity to buy more. This means that the resultant products of such investments favor those with better purchasing power even further, leading to further increasing poverty – or the perceived distance between the poor and the well off. These products are typically intermediate goods with price tags affordable only to the richer community.

These are some of the symptoms of the present state. Once we start questioning the current direction rather that assuming it is inevitable, we will find the alternate direction which is sustainable. Poverty alleviation and keeping people out of poverty does not seem to be a likely outcome of the current course of "consumerism and increasing natural resource exploitation" led policies. We need to find different ways to deal with the situation. The aspiration (to be rich and live highly consumptive lifestyle) driven policies are inherently asymmetric and would favor those with good disposable income. While this creates a feeling of merit driven progression, there is not enough carbon space, or resource space to help the poor to reach their level of aspiration. The hope is that as the rich get richer, poor will also move up the ladder and will reach their aspirations. Today, this hope is severely constrained by scarcity of critical resources and impacts of climate change.

Let us use our observations further to understand the approach to poverty alleviation. One of the most important observations is – cities are net consumers! This means that if only cities exist - there will be fewer producers and protectors of natural resources and many more consumers – an unsustainable situation in itself. This means we need to "develop" the producer centers well just to ensure that the current cites survive, if they need to survive at all. The "producers" are the villages and towns where one creates food and sustains other natural resources for the city factories and people to use. Moreover, cities in India are not planned and could not have been planned in many cases. Unbridled growth of such cities inevitably causes serious pressure on primary resources like clean water and clean air.

Whether for cities or rural areas, availability of primary resources is a key to sustaining livable conditions. Regenerating water resources seems to be a key development area that is tackled. Stream restoration, coupled with River Bank regeneration is an excellent way to march towards improved management of water resources. Once water resources are established, next steps are possible. A desirable side effect of such a policy is generation of employment opportunities in rural areas. The government in such cases can employ youth closer to the source regions of rivers and streams.

As a second key measure, understanding and documenting local biodiversity and resources which could be useful to human beings for sustainable consumption need to be established. These are the resources for developing local economic activity. Local economic activity is in a position to be largely sustainable over a long period of time at least in cluster of villages and towns and is a key to eliminating rural poverty and reducing migration to the cities. Local needs and wants satisfied using local resources, through local entrepreneurship could be an excellent way to generate wealth in a distributed fashion for the benefit of a large community base in poverty. Should such opportunities develop, many a migrant community will be very happy to return to their homes.

If we can look at this problem as a problem of balancing producers and consumers, we will easily see that it is very important to support and stabilize the producer community in the villages. At the same time we need to contain the consumption appetite in the cities. This is considering the fact that only certain amount of surplus food and resources created by the villages can sustain for a long time with minimal degradation of soil and surrounding resources. There could be models developed to get a city and a set of villages almost self-sustaining, to fulfill the minimum primary requirement of people with a focus on long term sustainability of supply and demand. If we can assure food security through this route, we might have found a model for scaling across more cities and villages.

Another critical challenge is energy. Urbanization inevitably leads to increasing use of energy. Either individual consumers ask for more energy for household use or industries demand more energy to sustain production of secondary goods and services. Let us remember that every act of energy consumption – where energy comes from fossil energy sources directly or indirectly, leads to pollution and to further deterioration of ecological support systems, and thus deterioration in the quality of human life. Access to energy is another serious issue faced by the poorer communities in India. On one hand, urban populations demand more energy and create more pollution, while on the other, poorer members of the community, especially in rural areas do not have access to energy. The fuel wood that they normally use also creates pressure on forests, which are an important sink of carbon.

Designing ways to reduce aggregate energy consumption in cities is a plausible way out. While this seems very tough to execute, it is probably the only way to ensure long term sustainability of cities. Such reduction in energy consumption in cities will allow better access to energy for the poor. This step will take us closer to our objective of alleviating poverty.

Conclusion and recommendations

To summarize, it seems that we need to assess and accept the current state of affairs realistically and take steps which would be in the right direction and can help in the nations' biggest social problem – that of poverty alleviation. Specifically, following recommendations could be considered.

1. Spend public money to create infrastructure and opportunity for masses; this means there is complete access and availability to such services for the poor. These services make poor live better in spite of relatively lower levels of income.
2. Education must be context sensitive. Education must focus on understanding local resources, local needs and local services at the highest priority. Education needs for people in different circumstances and environment are different and an attempt has to be made to meet these diverse needs. Students need to get the tools to learn most of the things on their own. Such learning tools will empower the poor to create better living for themselves in the villages.
3. Ecosystems preservation and judicious use of natural resources needs to be principles of a modern policy maker. This will ensure that livelihoods generated are sustainable and distributive justice is preserved, a key tenet in poverty alleviation. For that matter, new jobs must be directed towards restoring nature. The potential scale at which these jobs can be created without overburdening the resources is excellent. This will also help us gain much needed natural resilience.
4. A focus needs to be on developing 'real' producer areas, areas which provide for the entire primary requirement for us in villages and cities alike. Strong focus on distributed development will go a long way. This will enable the rural poor to taste the fruits of progress and at the same time ensure that such fruits of progress are available to the community in the longer run as well.
5. It is important to drive policies for sustainable well-being and not growth at all costs. If this principle is used to derive all the policies, we will be on a right path of 'development' that is required and essential. This path will also ensure distributive justice.

This essay attempts to link poverty, job creation, current state of education and the direction of current economic progress.

More detailed study must be undertaken to evolve policies which are based on this holistic understanding of the connections between tenets of ecology, economics, resource use, education, entrepreneurship, employment and poverty. The author believes that such policies could then help towards developing better livelihoods and drive towards reducing widespread poverty and its social implications.

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