Linked Social and Ecological Dynamics in a Managed Forest Ecosystem: Kendu leaf extraction in Baisipalli Sanctuary, Odisha

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree Master of Arts in the School of Human Ecology

By

Padmasai Lakshmi B

M.A.in Environment and Development

School of Human Ecology

Dr.B.R.Ambedkar University, Delhi

2013

School of Human Ecology
Ambedkar University, Delhi
New Delhi-110077 (INDIA)

Phone: 91-11-25074069,
Fax: 91-125074053

DECLARATION

This is to certify that the dissertation entitled "Linked Social and Ecological Dynamics in a Managed Forest Ecosystem" submitted by me is in partial fulfillment of the requirement for the award of the degree of Master of Arts in Environment and Development at the School of Human Ecology of Ambedkar University. This dissertation has not been submitted for the award of any other degree in this University or any other University and is my own work.

(Lakshmi B)

CERTIFICATE

We recommend that this dissertation be placed before the examiners for the evaluation.

Dr. Suresh Babu
(Supervisor)

Prof. Chandan Mukherjee
(Dean, SDS/SHE)

LIST OF FIGURES

Section I

Section II

Section III

LIST OF TABLES

Section II

Section III

LIST OF ACRONYMS

- PES – Payment for Ecosystem Service
- PEFESPA – Political Ecology For Forest Ecosystem Services
- ATREE – Ashoka Trust for Research in Ecology and the Environment
- SES – Social-Ecological Systems
- NTFP – Non-Timber Forest Products
- OFDC – Orissa Forest Development Corporation
- PCCF – Principal Chief Conservator of Forests
- WLS – Wildlife Sanctuary
- MVSP – Multi-variate Statistical Package
- CBNRM – Community Based Natural Resource Management
- PCA – Principal Component Analysis
- PESA – Panchayat (Extension to Scheduled Areas) Act
- FRA – Forest Rights Act

Preface

A rather long process involving several phases of research and ideas led to culminating this thesis. The concept of ecosystem services is being widely applied all over the world. Several "Payment for ecosystem services" (PES) projects were being initiated in India, as also the idea of economic valuation (TEEB India). Though coming from a background in Economics, I have been skeptical of these valuation exercises and their implications in the larger schema. And during my interdisciplinary MA, I felt that courses Social and Political Ecology, Environmental Policy and Governance, Ecological Economics offered a more nuanced perspective and allowed me to explore further into these themes and analyze environmental problems through multiple conflicting or complementing lenses, narratives and frameworks.

I undertook an internship (December 2011) with the Political Ecology of Forest Ecosystem Services and Poverty Alleviation (PEFESPA)[1] project at ATREE, Bangalore, India. My internship in 2011 aimed to study (as a team) the community forestry regime in Ranpur, Odisha and specifically the distribution of ecosystem 'services' and 'dis-services' across multiple user-groups segregated across caste, class and gender. I also contributed to co-draft a detailed survey questionnaire for the entire PEFESPA project.

My continued interest led me to undertake a second internship – a semi-independent project that would contribute to the PEFESPA project during the months of May-June, 2012. We agreed upon undertaking a value chain analysis of NTFP, as one of the objectives of this project is to examine how benefits from the ecosystem services are spread out across vast geographical space and among varied stakeholders beyond the community level.

Having been a part of a multi-disciplinary course, I was keen on empirically testing the practicalities of undertaking such research using multiplicity of approaches, methods and frameworks. And working for this project offered me the autonomy to undertake cross-boundary research. We agreed that my thesis would serve as an interdisciplinary NTFP case study for the PEFESPA team, which enabled me to work in a semi-independent way. The field period was for about 1 month, during the months of December, 2012 and March, 2013.

[1] See Annex I for details regarding the project.

Acknowledgements

For the completion of this thesis, a great number of people have contributed, supported and extended help. First of all, I would like to thank my supervisor at AUD, Dr. Suresh Babu, who helped me in conceiving this thesis. Dr. Babu provided useful feedback and his constant guidance in the form of regular brainstorming sessions was very instrumental. I would also like to thank my co-supervisor, Dr. Asmita Kabra who provided critical inputs when needed and also for being an immense source of support and encouragement, and especially for patiently listening to my numerous long field stories. Additionally, I would also like to thank Dr. Praveen Singh and Dr. Rohit Negi for brief discussions and inputs on some aspects of my research work.

I would extend my heartfelt gratitude to Dr. Sharachchandra Lélé for help in conceptualizing my thesis and for the invaluable critical inputs. Dr. Lélé has provided constant supervision through my entire research work with PEFESPA and discussions with him have only led to more conceptual clarity on multiple themes related to interdisciplinary forestry research.

I am grateful to the team of Vasundhara, Orissa, especially to the director Dr. Giri Rao, also Dr. Prasad Dash for helping with logistics to materialize the field part. Nilamani Mahapatra, staff member of Vasundhara, helped me immensely with logistics and planning for field visit. Sincere thanks to my team-mates on field – Biswarupa Sahu, Hemanta Sahoo and Madhab Jena, who were extremely cooperative, cordial and supportive throughout.

A special thanks goes to Roan Lakerveld, PEFESA coordinator, a fellow team-mate and a great friend who has played an important role in materializing this research work. Roan was quite supportive, not just in helping with gathering toposheets, census data and figuring out field site, but also for his patience with hearing out my field stories and for being there always.

Lastly, my sincere thanks to all the people at Gochhabari village who were inquisitive, helpful and took out time from their busy schedules to interact and engage with our questions on a regular basis. And thanks especially to my field assistant who joined me on my long walks into the forests to undertake vegetation sampling.

A last special word of thanks to my friends and family for their constant support and help in completing my thesis.

Table of Contents

1.1. General Background: Conceptualizing the thesis

This thesis makes a preliminary attempt to elucidate some of the linkages between the interdependent social and the ecological systems. Forest Ecosystems have been studied for the longest time using the lens of science - biodiversity conservation, carbon sequestration and primary productivity, soil analysis as well as through the disciplines of economics, sociology, anthropology – livelihoods, cultures and traditional knowledge. The larger structure of academic institutions, the nature and concept of disciplines, theories and methods, also worldviews serve as barriers to integrated and interdisciplinary approaches. In the context of environmental research, the field is distinctly divided between the social and the environmental; further, within these broader categories are bigger divides like in the social sphere with the ideas shaped by sociology/anthropology/political science/economics – sometimes complimentary but mostly contradictory. Even within the ecology sphere there are contradictory schools of thought. Integrating approaches and interdisciplinary research will help to understand environmental problems in a holistic sense and seek solutions by transgressing multiple discipline, theories, and viewpoints.

Changes in the social system have an immediate impact on the ecological system and changes in the ecological system also have an impact over the social system. The notions of ecological thresholds (biotic and abiotic) and barriers are used to define what is called a "degraded" state. However, the concept of "degradation" has witnessed much critique from various spheres – for being arbitrary, equating it with a more loose term of 'desertification' and more importantly for being 'value-laden'. However, conceptual models such as state transition model (Westoby et al 1989) and spiral degradation model (King and Hobbs, 2006) have attempted to 'model' degradation, the factors leading to it, the processes involved and contributed to our understanding of what is "degradation" of a ecosystem. The factors leading to disturbed ecosystems (the biotic component and/or abiotic component) are both natural and human-induced.

Both direct (land-use change, pollution, invasions) and indirect drivers (economic, demographic, socio-political and tenchnological) act upon to bring about changes in the ecological system (species, functions), this in turn affects the productivity of the ecosystem which shapes the well-

being of forest-dwellers. The communities dependent on forest ecosystem constantly make choices about the kind of system and components they want to prioritize and they have a general social disposition towards it. Ecosystem cannot function at its maximum at all times, there are bound to be trade-offs involved between species and that might imply between user groups as well (Lele et al. forthcoming). The actions of user groups are manipulated in a bandwidth in which they can operate. As Wiersum states that there are some kind of forests which may be defined as a mixed tree stands in which species composition has been adapted to suit human needs, but which are still 'nature analogous' (Wiersum et al. 2005). These have been identified under different terms – 'intermediate forests' or 'agroforests' or 'altered forests'. These are neither close to "undisturbed" forests, nor can be likened to heavily managed agricultural systems – but fall somewhere in between the two extreme categories where trees and their compositions are deliberately and consciously managed. Wiersum (1997b) therefore address them as being representative of anthropogenic forest system shaped by the interactions between ecological processes and human manipulations in the form of forest management activities. This thesis attempts to study the ecological processes and the human manipulations, their resource extraction patterns and how the former feeds back into the other and vice versa to truly understand a "system" through multiple inter-linkages.

This study tries to classify the habitats/sites across a gradient of disturbance based on the dependence over and management for Kendu leaf, the information for which is gathered by how local people perceive their landscape – whether highly managed, moderately managed or least managed. However, the differences across habitats will mostly be guided by the ecological forces - nature and severity of the disturbances, among other factors. The immediate question that arises is - how sustainable are these 'anthropogenic forests'? Also, does resource sustainability necessarily translate into livelihood sustainability as well? But does the optimum resource sustainability be able to fully satisfy livelihood requirements. On the other hand, if the system is managed in a techno-managerial way, then will it be capable of adapting to long-term changes caused by the process of socio-economic dynamics? (Wiersum, 1995)

It could be argued that this kind of system being arrested in intermediate successional stage is a more complex and dynamic system, and hence more stable. They might seem to offer a good balance between conservation and development. And they might be managed consciously with

the help of traditional and cultural practices, and therefore also marked as sites of "bio-cultural diversity"[2]. Often the idea of 'ecological sustainability' includes a heavy emphasis on an end point, "one-fit-for all framework" – 'equilibrium', either 'climax state' from ecological point of view or 'cultivated agro-ecosystem' from society point of view. The primary objective of this study would be to understand the "process" itself instead of a "state" and understanding what influences and shapes these processes and how can they be maintained at an optimum yield level and yet dynamic and resilient enough for the system to recover.

This thesis aims to undertake an analysis of the coupled social and ecological systems and contribute to our understanding of systems in a holistic sense in order to develop a comprehensive framework. The former is by using the lens of political ecology and through value chain analysis studying the institutional and market aspects, using PRA methods and questionnaires. The latter is through the lens of community ecology and standard ecological parameters, also accounting for the qualitative aspects. Using the theories of social-ecological systems and their sub-theories of political ecology, sustainability science and ecological economics, this thesis would attempt to develop a holistic and in-depth understanding of a context specific social-ecological system.

[2] See Luisa Maffi (2011) "Biocultural Diversity and Sustainability".

1.2. Theoretical Framework – SES (Conceptual Models)

Nature and society has been intricately interlinked in plural ways, yet have been treated in isolation under different disciplines and theories. In other words, the problem solving approaches for economic issues and environmental issues are shaped within respective academic disciplines. Most researchers and studies have pursued answers to fundamental questions on the ecological and human world from within the boundaries of one discipline, overlooking and neglecting the relationships and inter-linkages between ecological and social systems (Redman et al, 2004).

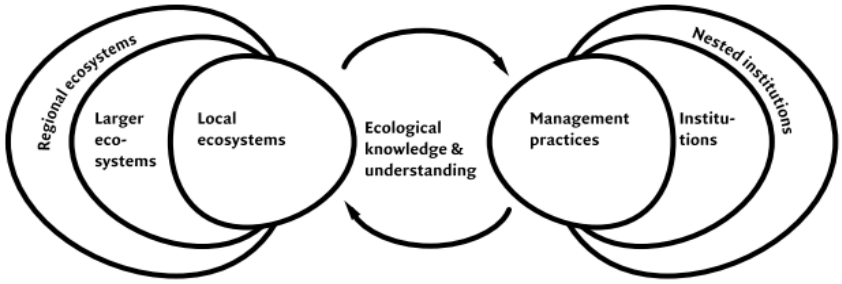
While the ecological system has been largely understood through succession theories, food webs, population and community dynamics; the socio-economic system has been understood through political economy, market models, institutional and governance mechanisms so on and so forth, while both addressing problems in linear mechanistic ways. As noted by Norgaard (1989), in both economics and ecology, theories shaped have largely proven to be logically inconsistent and hence lacked coherent problem solving abilities. The whole set of global, national and local economic and ecological problems are "manifestations of how we have thought about economic systems, natural science and the (non) role of ecological systems and culture in the development process" (Norgaard, 1989).

However, it is no longer tenable to study ecological and social systems in isolation from one another (Redman, 1999a; Gunderson and Holling, 2002).

Of late the socio-ecological systems, henceforth SES, have been understood as complex coupled human and natural systems that are supported by feedback loops and multiple interactions within themselves (Norgaard, 1994; Berkes and Folke, 1998). SES is an ecological system intricately linked with and affected by one or more social systems. As noted by Anderies et al (2004), both social and ecological systems contain units that interact interdependently and each may contain interlinked and interactive subsystems.

The Resilience Alliance (Stockholm Resilience Centre), through multiple projects analyzed varied facets of SES, has come up with interesting insights over the years through multiple projects focusing on different aspects of the social-ecological systems. Complex systems are now the basis of newer integrative and innovative approaches such as political ecology, ecological economics, common property – allowing for plurality and breadth of methodological base.

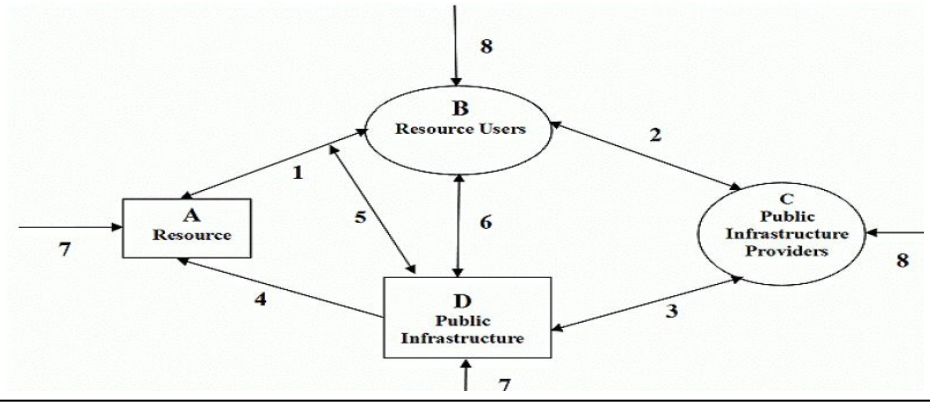
Fig. 1.2.1 A conceptual framework for the analysis of linked social-ecological systems (Berkes *et al.*, 2003)



Processes in both the ecological and the social systems are guided by non-linearity and uncertainty with dynamic steady states and multiple equilibria. Berkes et al. developed a conceptual framework (Fig. 1.2.1) to understand SES through the linkages between ecosystem, knowledge and institutions (Folke, Berkes and Colding, 98a).

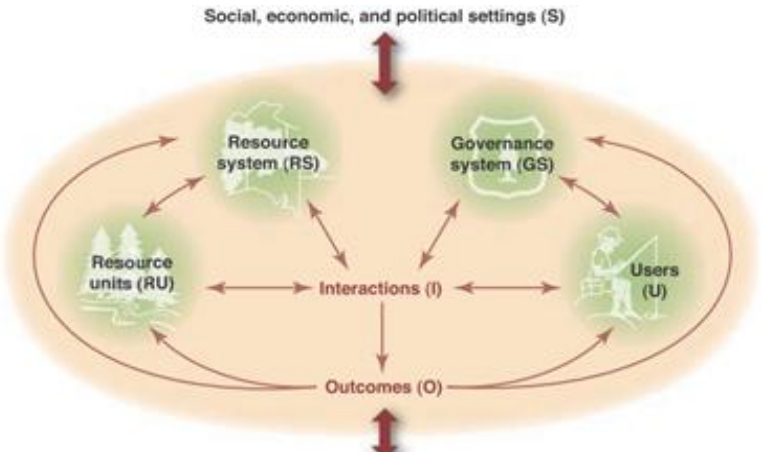
Berkes (2002) analyzed the lagoon system as a case of SES using common property theory and adaptive management. Berkes charted the management practices/interventions over about four decades/distinct periods/factors and the parallel changes that were witnessed in the local ecosystem and charted the feedback cycles by drawing from Holling's adaptive renewal cycle (1986) and the panarchy idea from Gunderson and Holling (2002). By studying the multiple inter-linkages within the systems, Berkes identified the key factors that strengthen socio-ecological resilience. However, the temporal scales that the case has dealt may not be sufficiently large enough to reflect underlying patterns which might conflict with the dynamics studied at shorter spatial and time scales.

Fig. 1.2.2 Conceptual model to analyze the robustness of social-ecological systems (Anderies et al., 2004)



Anderies et al. (2004) developed a framework as depicted in Fig. 1.3. Unlike previous studies focusing largely on the interactions of the resource users vis-à-vis the resource (Hardin), this paper attempts to shift the larger attention to other important linkages, especially between the resource users and the public infrastructure providers, which may have a significant impact on SES and its robustness over longer time scales. The paper, while defining robustness (referring to Carlson and Doyle, 2002) as "the maintenance of some desired system characteristics despite fluctuations in the behavior of its component parts or its environment", attempts to design SES with "robustness" using multiple cases. The concept of resilience however, does not however apply to consciously designed systems.

Fig. 1.2.3 The core sub-systems in a framework for analyzing social-ecological systems (Ostrom et al., 2009)



Elinor Ostrom et al (2009) developed a framework which identifies the core sub-systems as resource system (e.g., a coastal, fishery), resource units (lobsters), resource users (fishers) and governance systems (organizations and rules that govern fishing on that coast) which are relatively separable, however, are interdependent and interact to produce outcomes at the interface of the social and the ecological, which in turn feedback to affect the distinguished components within the larger SES. Additionally, researchers have analyzed supporting the view that large, highly valuable, open-access systems lack coherent organizational mechanisms when resource harvesters are diverse and community little (Berkes et al. 2006, Ostrom et al. 2009). "Dissect and harness complexity instead of eliminating". Coupled human-natural systems are not static but dynamic entities that change across time. Ostrom's framework helps to identify

multiple variables and relationships and their interactive processes under the identified sub-systems. However, perhaps this framework maybe more insightful for simpler models with clearly defined and demarcated responses among the resource users and units, which is not usually the case with forest ecosystem comprising of multiple overlapping users and interdependent units.

The importance of multiplicity of perspectives follows from complex systems thinking. There is no one "correct" perspective or form of understanding a system. History, management practices and institutional mechanisms overlap with resource extractions regimes and biodiversity conservation. "Preserving well-functioning small-scale SESs to manage ecological resources may be as important for the future as preserving biodiversity. The reason for this importance is that preserving institutional diversity maintains a rich set of solutions of social systems adapting to ecological contexts" (Janssen et al., 2007).

Liu et al (2007) in a review paper analyzed six case studies from five different continents studying socio-ecological or human-environmental systems in order to demonstrate the approaches used and results found. These studies integrate a wide range of research methods and tools borrowing from varied disciplines in the social sciences and natural sciences. Liu et.al.(2007) specifically focused on indentifying the common characteristics among the different and complex systems. The common linkages as noted are: reciprocal effects and feedback loops, non-linearity and thresholds, surprises, legacy effects and time lags, resilience and heterogeneity. Some of these have been also discussed in the context of this study in the following sections.

However, Liu et.al.(2007) note that even in cases where human-nature interactions have been studied, the complexity of coupled systems has not been well understood. And this is largely due to the separation between ecological and social sciences. The changes among the management system have repercussions in the ecological system that might affect resource sustainability and hence livelihood sustainability. It is thus critical to reconcile and synthesize to undertake interdisciplinary work and develop more comprehensive frameworks. It is in this context that this study aims to fill the gap by undertaking interdisciplinary research and will make a preliminary attempt to contribute to the emerging theories/framework on SES.

1.3. Forests-society as a "complex system"

Forests have been extensively used to meet the subsistence needs of communities. Biomass extraction in the form of grazing, fuelwood, NTFP and fodder extraction are the most common and widespread of pressures exerted on forests in order to sustain livelihood needs (Saberwal and Rangarajan, 2003). Mace et al (2005) in a comparison across different management regimes highlighted that highly managed areas for resource extraction exhibit varied patterns of species composition and community structure indicating the influence of human activity in determining patterns of biodiversity. However, forest degradation and loss of biodiversity may impair the functioning and sustainability of ecosystems. And this further has a negative feedback effect that can lead to vulnerability of the forest dependant communities'. Contested landscapes such as forests provide not just livelihood benefits but also are the sites for biodiversity conservation. However, very few studies have examined any direct linkages between resource extraction regimes and ecological dynamics, in particular the feedbacks between livelihood support and resource base.

The ecosystem services literature – Millenium Ecosystem Assessment (MA 2003) defined ecosystem services as "the benefits people obtain from nature". Additionally, MA (2003) points out that "ecosystems provide a variety of benefits to people including provisioning, regulating, cultural and supporting services". However, amongst these services, the most important and direct constitute the category of provisioning services. These are defined as "the products obtained from ecosystems" (Ecosystem and Human Well Being: Synthesis, 2005). These products include fuelwood, fodder, NTFPs, among other resources. The concept of "service" (term derived from the field of economics) has been severely criticized for being reductionist in nature i.e. reducing critical resources and multiple processes into a mere "service". The ecosystem services literature has gained much momentum in the last decade; however this study will not specifically engage with this literature, rather just highlight that NTFPs have been studied as "services".

NTFPs were long portrayed as fulfilling twin objectives of poverty alleviation as well as sustainable management of forests (Wollenberg et al 1998), which has been sufficiently challenged. The former is a problematic assumption because markets have been frequently known to be unstable (Padoch, 1992); trade often controlled by the elite both locally and

regionally (Ribot, 2000); and access to NTFPs is socially mediated and inequitable (Kumar, 2002). In case of the latter, highlighting the relationship between NTFP commercialization and forest ecology, a substantial number of studies have demonstrated the 'negative' ecological impacts of harvesting; also leading to use of concepts like "maximum sustainable yield" in forest management. However, some studies have pointed out 'neutral' and even 'positive' impacts of commercialization.

The impacts range from the level of individuals and populations, communities and ecosystems, all of which have important consequences (Hall and Bawa, 1993). In particular, extraction regimes may lead to significant changes in plant associations and community patterns. Belcher et al note (2004) using the cases, Anji in China and Cardamom in Western Ghats that intensively managed systems have completely displaced the natural vegetation within the management unit. However, very few studies have focused on the ecological effects of NTFP commercialization at the community level. And even those studies that raise questions about system-wide effects of commercial extraction do so based on extrapolating from the empirical results of one or few NTFP species, as noted by Neumann and Hirsch (CIFOR, 2000).

Particularly in the context of India, there is much dearth of comprehensive studies on NTFP commercialization. Rai et.al. (2004) undertook a socio-economic and ecological analysis of uppage (*Garcinia gummi-gutta*) harvest and compared the harvest methods across different tenurial regimes and the impacts on ecology (analyzing population structure of the NTFP species). They conclude that a complex interplay of factors such as regulation of forest access, social dynamics within the community, unstable trade due to fluctuating market demand and local and global economic scenarios influence NTFP use.

This paper makes a preliminary attempt to undertake a multi-disciplinary analysis to understand institutional mechanisms and ecological processes underlying NTFP commercialization and develop a holistic framwork using the case study of Kendu Leaf, a significant source of "income" supporting livelihoods in Odisha.

1.4. Research Objectives

The study aims to assess the impact of a cluster of human interventions related to KL in the landscape (fire, grazing, NTFP) on plant community dynamics along a gradient (from low Kendu harvesting region to high Kendu harvesting region).

The objectives of this study are three-fold:

- To assess the resource extraction patterns of a village community across caste, class and gender groupings.
- To analyze how biomass extraction modifies plant communities across different Kendu management regions and what kind of community patterns emerge as a result.
- To examine how might the ecological changes feedback into the livelihoods of forest-dependent tribals.

1.5. Research Design

"The function of a research design is to ensure that the evidence obtained enables us to answer the initial question as unambiguously as possible" (De Vaus, 2001). The broader strategy in order to address the specific objectives and research questions are two-fold – incorporating both case-study design and cross-sectional design structure. The case study design was used for one village focused quantitative/qualitative study and one NTFP study; whereas the cross-section design was used to analyze the ecological patterns over large areas.

Case study design is good at building in-depth description, a detailed study and understanding of a specific situation or example. Cross-sectional design is used to "draw inference about the characteristics of a large population and the patterns of variation within the population by collecting data from a cross-section of its members". The primary difference between cross-section study and case study is of scale.

Specific research methods under these have been discussed in the respective – social and ecology sections.

1.6. Limitations of the Study

The field research for this thesis was carried out in two different months i.e. December, 2012 and March, 2013. The process of obtaining official permission from PCCF to carry out vegetation sampling in the Wildlife Sanctury did not happen on time due to which the initiation of the field study was quite delayed. Planning for the field part, arranging logistics and finding a field assistant took a lot of time in the initial phase. This led to time constraints in carrying out the actual field work. Additionally, despite the rapport building with the villagers during the months of May-June, 2012, a continuous process of rapport building again had to be undertaken to eliminate suspicion from people's minds.

In the second phase (in March), I went to undertake more sampling and also to record oral histories. This field phase proved to be quite challenging. In the initial days of my stay period, massive fall out and clash between the Wildlife Department and the villagers led to a series of rallies and meetings in the consecutive days. This pre-occupied the villagers (including my field assistant) for a few days and I was also involved in this by my default position of being a researcher. This completely derailed my own study for that time period. To sample in the less managed sites which were far off and much interior into the sanctuary required me to relocate to another village. This in-turn was combined with more rapport building in the new village and adjusting to the newer kind of social dynamics. I attempted to take help from the local forest guard and watcher to accompany, however this also did not materialize. Mid-march onwards is the peak fire season and the entire department was busy preventing the fire from spreading. Being alone this time in the field, with a lack of bike, it was difficult to cover sites at long distances from the village, also with the temperature being almost 40 degree celsius. This phase involved difficulty in carrying out the field study, an important learning curve nonetheless.

1.7. Study Site – Baisipalli Wildlife Sanctuary (WLS)

"The whole of Baisipalli RF has been declared as Baisipalli Sanctuary by the Govt. of Orissa vide Notification No.8F (W)-116/81-25335 dt.6.5.1981 of FF & AH Department with an intention of protecting, propagating and developing the wildlife in the area, and conserving its genetic biodiversity". It covers an area of 168.35 sq. KMs.

Baisipalli WLScomprises of mixed deciduous sal dominated forests adjoining Satkosia Gorge Sanctuary. Biogeographically the sanctuary comes under the Garjhat hills Sub-division of Chhotanagpur Plateau biotic province (6D) of Deccan Peninsular zone (6) as per Rodger's and Panwar's (1988) Biogeographic classification of India. The sanctuary is of ecological importance with variety of flora and fauna like Tiger, Leopard, Bison, Sambar, Barking deer, Mouse deer, Pangolin, and Malabar giant squirrel, amongst others. The presence of endangered species like Elephants, Tiger, Mouse deer, Pangolin makes it more significant. The avifauna comprises varied resident birds like Hornbills, Falcon and Hill Myna etc.

Forest Types – Baisipalli WLS (as per Champion and Seth classification) (Baisipalli Management Plan)

a. Moist Peninsular Sal Forest – -- 3C/C2e\

b. Moist Mixed Deciduous Forests. --- 3C/C_3

c. Bamboo brakes - - 3C/2e, 5B/e9 and 2e3

d. Northern Dry Mixed Deciduous Forests - 5B/C_2

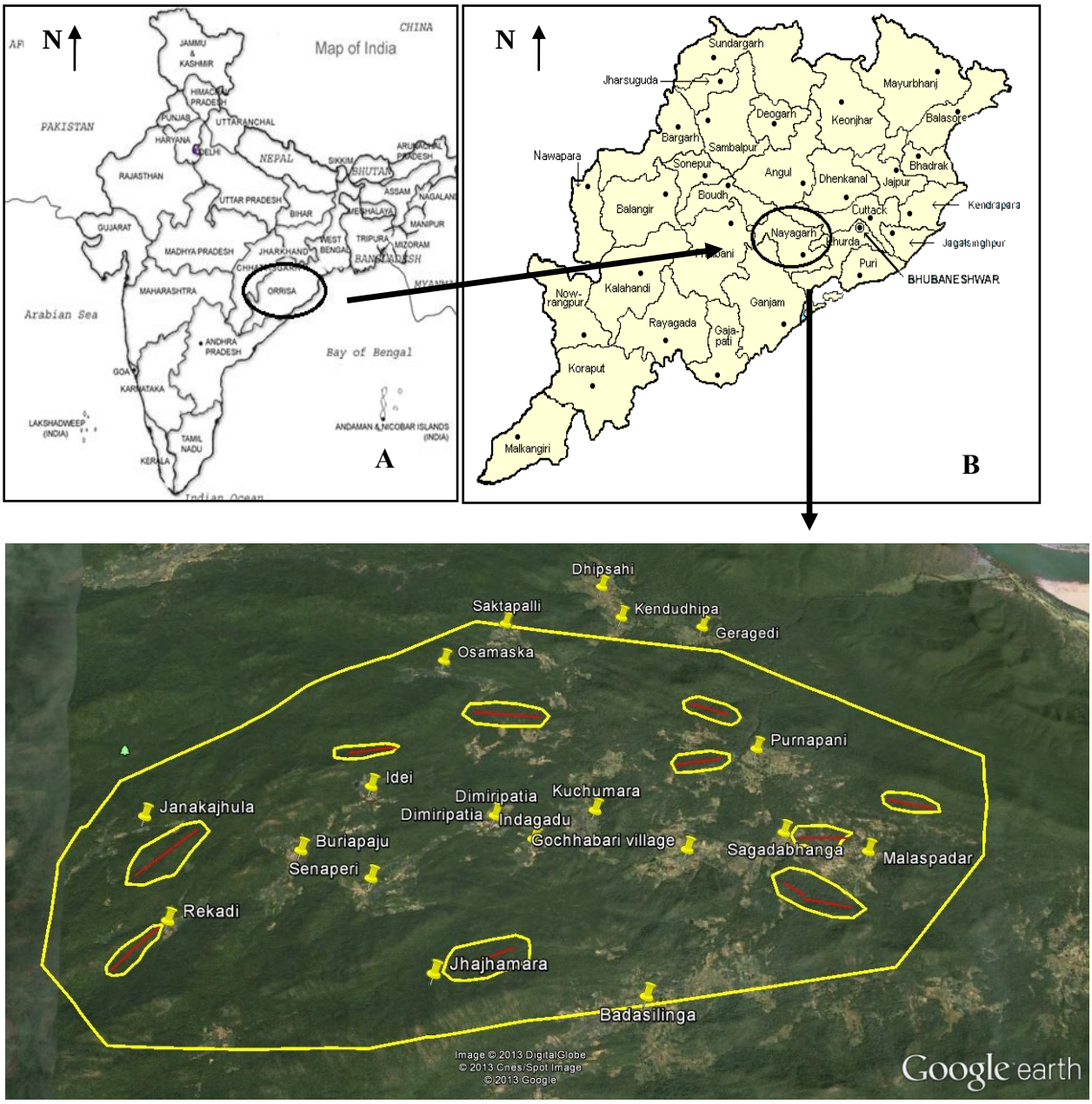
e. Riverine Riparian fringing Forest -- (4 RS_1)

The Sanctuary area displays a broken mountain system interspersed with numerous plains and valleys. Numerous seasonal streams, nalas and rivulets drain into Brutanga Nala from South Block and Khalakhala Nala from North Block of Baisipalli R.F. which finally drains into the river Mahanadi that cuts Baisipalli WLS from Satkosia TR. These however, do not carry any water during the dry period in May and June. Additionally, there are number of artificial (or man-made) water sources created in and around sanctuary area at specific locations.

The major precipitation occurs during rainy season by south-west monsoon. Usually rain breaks in the third week of June and continues up to middle or end of September. On the basis of rainfall data from past records, it is observed that the average no. of rainy days in a year is 80 out of which 55 are confined to the month of June to September. The annual average rainfall varies from 1000 mm to 1750 mm. Total rainfall was 1044 mm in 2002, 1641.4 mm in 2003, 1174.5 mm in 2004 and 1759 mm in 2005.

The advent of summer is noticed with beginning of March when temperature starts rising. Summer months are very hot. During these months, ground fires are a common occurrence mostly deliberate (for collecting Kendu leaves and Mahua flowers) (also a point of conflict between the villagers and the Forest Department). Maximum day temperature varies from 40°C to 45.5°C in the month of May and rarely goes beyond 47°C. After monsoon breaks, temperature drops appreciably. The coolest month is December when night temperature varies from 10°C to 13°C sometimes dropping up to 7°C also. The mean annual maximum humidity is approx 89% and the minimum is approx 50%.

Fig. 1.7.1 The Study Area



A – Political Map of India retrieved from mapsofindia.com

B – District Map of Odisha retrieved from indiamapsonline.com

C –Satellite image – Portrays the sampling sites within Baisipalli WLS – spread over about 60m²

1.8. Outline of the Thesis

Baisipalli WLS was chosen for the study of the dynamics of social-ecological systems where the tribal communities are significantly dependent on forests to support livelihoods and the ecology witnesses various forms of "active intervention".

The thesis will be divided into two main sections: socio-economic and ecological, followed by a synthesis section connecting the two and highlighting and discussing the inter-linkages.

In the social section, I provide a brief overview of the resource extraction regimes, historical usepatterns and discuss the current extraction patterns of a range of forest products by the community in one village. Following this, a specific NTFP, Kendu leaf (KL), being an important component for both livelihoods and ecology, will be discussed. The history of KL in the state, the production patterns, governance of KL trade, and actual benefits to the livelihoods will be elaborated in the light of the larger institutional arrangement and the dynamic policy scenario.

In the ecological section, I describe the forest ecosystem dynamics – by studying the ecological "processes" across a gradient of intervention/management. Standard vegetation sampling was undertaken to derive not just diversity patterns but also qualitative changes in the composition and structure. Qualitative aspects were noted to supplement the data and oral histories recorded to assess the changes over longer time scales, because of the absence of benchmark.

Third, I will explore the linkages and feedback loops between the socio-economic and ecological dimensions of the forest ecosystem.

II. SOCIAL SECTION

2.1. Introduction

The focus of interest here is the heavy dependence over one commercial NTFP species i.e. Kendu leaves. The sampled section of the landscape of Baisipalli Wildlife Sanctuary has been divided into three zones: heavily managed region for Kendu, moderately managed and least managed. These regions have been decided on the basis of the level of extraction of KL as per the local villagers' perspective and knowledge. Accordingly vegetation sampling has been undertaken across all the three regions (discussed at length in the next section).

Under the social section, the objectives will be two-fold:

- Based on one-village qualitative study undertaken in the highly Kendu managed region, resource extraction patterns will be traced and discussed.
- The ways of harvesting KL, the trade patterns and the impact on the livelihoods in the process will be analyzed

However, because of time constraints, only one village study has been undertaken of the highly KL managed region. A detailed village study in the less KL managed region would have been useful to compare across the landscape for both the social and ecological system. However, from my conversations with villagers in the less managed region, I will engage in broad comparisons in the social system across different regions.

The following section undertakes an analysis of the resource extraction patterns across caste/class/gender groupings, especially in the case of NTFPs in a particular village, which comes under the high Kendu harvesting region. The dependence over Kendu leaves is further connected with the governance of KL trade, the impact over livelihoods under the existing institutional arrangement and the share of the KL pluckers vis-à-vis the share of state.

2.2 Research Methods – Social Section

Fieldwork was carried out between June, 2012 and December, 2012 (intermittently through the period). Research methods for the first section included structured questionnaire survey, PRA methods (focus group discussions, resource mapping, group interviews and key informant interviews) to gauge the resource extraction patterns, inter and intra community differences and dynamics, and historical practices. In the initial period, several focus group discussions (including SC and ST hamlet, focused ones in separate hamlets, with groups of women from both hamlets etc.) were held to share the objectives of the study, build rapport and to start with basic conversations regarding different aspects.

Key informant interviews were conducted to gather specific information related to Kendu leaf extraction and trade. KL women pluckers, Srima and Jasomata Majhi[3], shared critical information about women's cooperative and issues related to NTFP trade. Additionally, a relatively influential ex-Sarpanch from the village and a middleman in the Kendu leaf trade, a village resident, were very cooperative and informative regarding quantities of KL sold and commission involved, also the nexus between the kendu leaf traders/agents, bidi manufacturers and lower level forest officials (guards), among other things.

Participatory resource mapping exercise was carried out by the ESPA team[4] of three with the help of 7-8 members of the village including both men and women. A basic village and resource map was drawn with the surrounding forest patches which the communities were dependent on. This exercise exposed us to how resources are distributed across different forest patches and which patches are accessed by the communities more often. For ex: salia bamboo is concentrated primarily in two patches (Jhajhamara hill patch and Bhalkumasani). A gathering of community members usually helps in immediate cross-verification. In one or two occasions, the members would clarify among themselves if a certain forest patch is accessed heavily by them or if the position of the hill is correct or not. This helps in gathering reliable information.

[3] Names of the villagers have been changed on purpose to ensure anonymity.

Transect walks were carried out during the months of June and December, 2012 to monitor the harvesting techniques, the time and effort involved, to account for seasonal patterns of resource availability. I have accompanied smaller women groups in collection of mushrooms, leafy vegetables, kendu, sal and siali leaves, and mahua flowers. This process also helped to understand the resource distributional patterns across the landscape and more importantly the effort required in collection of NTFPs and the techniques involved. There is some validity in the old adage, "The only way to learn how to do it is to do it,"

Participant Observation

Substantial time was devoted to participant observation. This is meant to provide a deeper, "insider" understanding of social relations, attitudes and behavior characterizing the local areas or community, as noted by Folke et al. (referring to Jorgensen 1989). Participatory observation was practiced in the field by interacting with the key informants, and by transects into the forest along with women to collect a range of tubers, leafy vegetables, mushrooms etc. Also, on different occasions, watched women collect Mahua flowers and Sal leaves, taking intermittent breaks, finding the particular place to dig for tubers and in specific ways that does no damage to the tuber itself etc.

Household Survey Questionnaire: The stratified household survey with a sample size of 40% was used to generate detailed quantitative information on socio-economic profile of the households and their dependence on ecosystem services and dis-services (quantities collected for use or for sale). This was carried out for the larger ESPA project as a team. The households were divided into two strata – relatively poor and relatively rich based on the data gathered through the wealth ranking exercise. As the village was segregated into caste groups, to avoid selection bias, a proportionate number had to be drawn from each stratum. Further, the team selected the households to be surveyed to include a diverse set of members (with and without jobs and so on) and those with dependence over forests. Additionally, to avoid researcher the list of sample households' bias was cross-verified with a key informant. (See Annex III)

The survey was divided into six units: household demography, occupation and assets; livestock grazing and fodder collection; cultural services; ecosystem dis-services; and a comprehensive fuelwood, timber and NTFP survey. Most of the questions are open-ended. This questionnaire

was undertaken only after the team had gathered general information on ecosystem services and some hands-on experience, which would help to probe and even approximately quantify some of the qualitative data provided by the respondent. For the section of the questionnaire on NTFPs (see Annex III).

2.3 Gochhabari Village: Profile

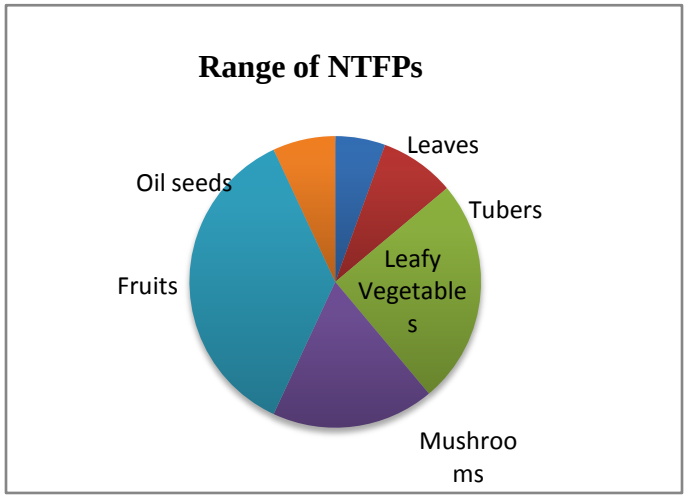
There are about 32 revenue villages inside Baisipalli WLS, with a total population of approximately 5874 (2001 census), most of them Scheduled Tribes with a heavy dependence over forests. Gochhabari village consists of 57 households with 35 ST households and 21 SC households and 1 GC household. The ST and SC hamlet is geographically separated by a few miles and the SC community claims a separate name for their hamlet as Nuasahi.

Almost all (ST and SC) households have BPL cards and get 25kgs rice, kerosene regularly and sugar occasionally. But there is hardly any work under NREGA. Under Indira Awas Yojana, only one household in the recent past has managed to receive tin sheets for the roof of the house and another got a room constructed. There is inadequacy of *pucca* roads, telephone networks, lack of electricity and access to market and medical facilities. The closest towns are Daspalla (about 25 kms away) and Gania (35 kms away). Most of the villagers complain that developmental activities have eluded this village because of the declaration of sanctuary. Additionally, crop damages by elephants and wild boars are a frequent phenomenon during agriculture season. No compensation has been received till date for crop damage.

The ST (Adivasi) community of Gochhabari is of the tribe – 'Zamindar Kondha'. The traditional language of Adivasis is 'Kui'. The SC community is further segregated into two sub-categories - Pana and Hadi. While the ST and Pana communities are primarily engaged in agriculture (rice, maize, millet,mustard etc.) and animal husbandry, Hadi community specializes in weaving baskets and other items (bujha, jhampi, kulei, binchana etc.) made from bamboo, for sale in the nearby villages and local markets both in cash and kind. As for forest dependency, both the communities collect fuelwood, diverse range of non-timber forest products (NTFPs), and green bamboo.The dependence over NTFPs is largely for subsistence sake; however few NTFPs are collected purely for commercial purpose. The resource catchment area of the study village, over 5000 acres (ESPA team) covered with forests overlaps with atleast 6 surrounding villages.

Hence, one village focused qualitative study might be sufficient to assess the extraction patterns especially when there are no clearly demarcated areas or customary boundaries for each village. Though there is a notion of specific areas of access, however even the overlapping spaces (for grazing especially) have witnessed little conflict among different villages, perhaps because of the vast stretch of forests available.

Fig. 2.3.1 Graphical representation of the diversity of NTFPs extracted



The villagers depend on at least about 75 NTFPs, of which most important are: Sal leaves, Kendu leaves, Mahua flowers, seeds and Siali leaves. Other NTFPs include: tubers (6 varieties), leafy vegetables (18 varieties), mushrooms (13 varieties), fruits (26 varieties) and oil (5 varieties) and a whole range of medicinal plants (for wounds, malaria, snake bites etc.).

2.4 Resource Extraction Patterns

The following discussion on the resource extraction patterns is derived from the household survey undertaken as a team. In case of NTFPs especially, it was difficult for the respondents to share even an estimate of the quantities collected over the last few months, as the collection is variable and seasonal patterns need to be accounted for. Moreover, most of the NTFPs are also collected together in bundles. For e.g. when a group of women go to collect kendu leaves, they also collect some sal leaves, pick some fruits and mushrooms on the way and dig some tubers and so on. Hence, relying entirely on the quantities will not necessarily reflect all the patterns and therefore the need for qualitative information which will also help to reveal nuances in thesocial dynamics. As already discussed in the research methods section, a range of PRA methods were used in order to understand community dynamics, level of participation, conflict resolution mechanisms, caste-based issues and NTFP trade-related problems. With the declaration of sanctuary, restrictions were imposed (in the form of trade tax and permits) for sale

of commercial NTFPs especially sal leaves and seeds which discouraged the traders from frequenting the study site, in turn reducing the potential to earn additional income by the villagers. This is also while being surrounded by sal dominated forests and the availability of leaves is almost throughout the year and hence could make for a stable source of income; however the low purchase price and trade permit issues have undermined this potential option. This has an interesting dynamics along gender lines. The activity of sal leaves collection and processing (stitching to form leaf plates and cups) is largely women's task and the revenue obtained is seen as 'women's income', though not in all cases. This also holds for Mahua flowers collection, which is again largely gathered by women and sold through the self-help group.

The dynamics can be understood by looking at particular socio-economic attributes and being a heterogeneous group, accounting for grouping and clustering across class, caste and gender will be discussed and how these in turn shape livelihood choices and opportunities.

Wealth, Caste and Gender Dynamics

The socio-economic status of ST community is slightly better than the SC households, but just in relativeterms. A wealth ranking exercise reflected that in ST community, 6 members have bikes, 9 have jobs and land titles have been issued to almost all except 5-6 households. Also a few of them own land in nearbyvillages and towns. Whereas in the SC community no one has jobs; no one owns bikes and only 1 household has received land title *(patta)* and mostly cultivate agriculture on occupied land.Perhaps in a qualitative sense, the SC hamlet is just relatively worse off and also relatively less 'connected'.

Table 2.4.1 Distribution of land across caste groups

Caste	Own Dry Land	Occupied Land
SC	0	34.5
ST	23.1	24.75

As depicted in the table above, and as per the interactions with the villagers, more than half of the ST households have received *pattas*(under FRA), however there are problems with the appropriation of the land titles. For e.g. Bhubaneswar Majhi has been cultivating agriculture in

about 10 acres, whereas he has received the title for only 2.3 acres. Some other households in the ST hamlet have not received any land title. In the SC section, according to the villagers no one has received land title and hence most of the cultivation is headed under the 'occupied land' category. This is also one of the reasons probably contributing to the hostility between the ST and SC households. However, it would be wrong to say 'hostility' in an absolute sense. And moreover, not having a *patta* doesn't lessen the economic well-being. The land title is just for legal recognition; however land has been occupied and cultivated for years.

In SC hamlet, water is a major issue. Few hand pumps are not functional and the wells dry up during the summer season. Occasionally water is provided by means of tankers but it is never sufficient for all the households and for all purposes, especially during the summer period. There was one occasion in the month of June, two ladies from the SC hamlet complained about some of the members in the village who are not cooperative and careful with usage of water. They had come to borrow water from the ST hamlet for bathing purpose. However, because untouchability is still strictly followed, the SC members could not directly access water from the wells or hand pumpsof the ST hamlet. This sometimes does createhassle for the households and womenespecially bear the brunt.In order to understand the socio-economic dynamics, different aspects are being discussed here, including caste, household size, migration patterns etc. Caste hierarchiesdo not strictly penetrate in the appropriation of or access to resources. As the figure below reflects, that collection of mahua flowers and tubers is nearly proportional to the ratio of households surveyed.

Table 2.4.2 Distribution of livestock, NTFPs and bamboo across caste groups

Caste	Livestock(nos.)	Sal leaves(kgs)	Mahua flowers(kgs)	Bamboo(poles)
SC	**32**	**727**	**245**	**1350**
ST	**94**	**1522**	**355**	**1250**

As mentioned previously, the SC community is divided into Pan and Hadi sub-groups. The Pano community (13 households) is generally dependent on agriculture and forests for sustenance, but also on wage labour. Very few members, however, have temporarily worked as contract workers/labourers in companies in the nearby towns during the times of distress, but none of the

members have a salaried job and the proportion is anyway negligible. The members of the Hadi community (8 households) have been 'traditionally' dependent on bamboo for weaving baskets (and various other items) to support livelihood. This might explain the relatively high collection of bamboo by the SC hamlet vis-à-vis ST hamlet, as depicted in the table.

Women stitch and weave using bamboo to produce a diverse range of items like different kinds of baskets etc. Men go around in cycles to nearby villages selling the final product. However, depending only on bamboo does not ensure a very high income to sustain throughout, making them more vulnerable, hence the need to diversify.

Some of the members from the ST hamlet expressed that the availability of green bamboo has relatively declined over the years and that the members from the SC hamlet apply some crude techniques to restrict or slower the growth of bamboo. And a particular site, Jhajhamara, a very good hill patch for bamboo has witnessed much extraction historically under the OFDC that had undertaken massive bamboo cutting program to cater to the needs of private industries till bamboo was nationalized in 1988. There were also instances of big timber mafias from Banpur making their way into these landscapes for extraction for years.

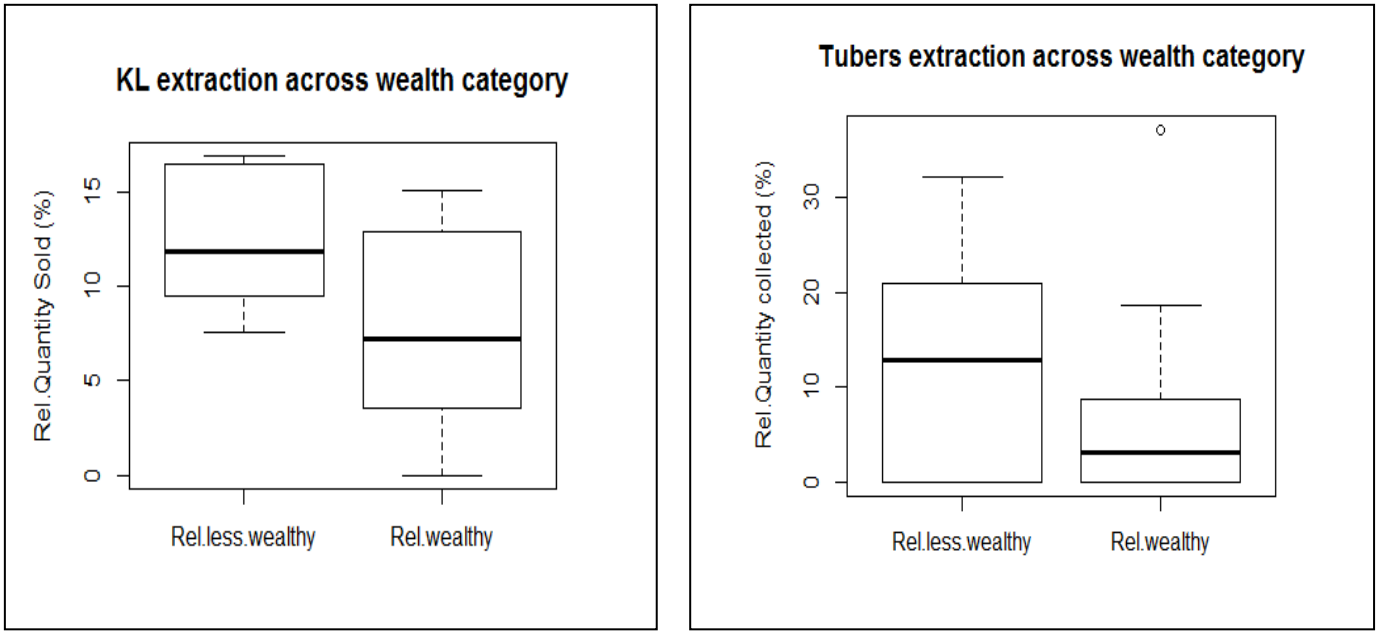
Further, the Hadi community, specializing in bamboo weaving, is restricted to sell their final products in the villages around at a relatively low price. Though they can get a relatively higher price in the local markets in the nearby towns but they faced competition with the merchants and were forced to have a relatively low market share catering to that particular area where the demand cannot go high beyond a point. Though alongside for years now, they cultivate agriculture, collect a host of NTFPs and have been depending on commercial NTFPs as well. However, Antara Nayak, 30, gives an example that some women (including herself) from the SC community are still not adept at stitching plates and cups out of sal and siali leaves as compared to the tribal women and hence their pace is much slower than the their tribal counterparts. This might explain for the relatively lower figure of quantity collected of sal leaves by the SC hamlet.

Further, migration patterns across ST and SC hamlet are very low. The aspirations for migrations across communities appeared to be almost non-existent. However, a large proportion of the villagers do believe in education and most of the young (including girls) are enrolled into govt. schools and colleges, a few even 12-14 kms away in higher secondary schools. There is a very

strong belief in higher education being the way ahead as the older generation did not see any future for the young ones in the forested areas.

The ST hamlet is relatively more connected with markets and trade – through village-based shops, undertaking government jobs and through acting as middlemen for trading in commercial NTFPs. This is however not the case with SC hamlet. Hardly anyone has jobs or act as middlemen and engage in trade relations. Both the communities in general had little to complain about their livelihood status, except for the issue of water and the lack of roads, electricity and telephone networks. They have expressed the need and want for these developmental works for the apparent betterment of livelihoods. On various occasions, during conversations with men and women with the SC hamlet, it seemed like they appeared less willing to earn 'additional income' or migrate to nearby towns or engage in some trade. The issue of caste and untouchability did not necessarily create hostile relations with the ST members and overall they had little to complain.

Fig. 2.4.1 Extraction patterns of KL and tubers across wealth



Box plots have been used to depict the relative basal area of species across management categories. The exploratory data analysis (EDA) makes use of five number summaries: Minimum, Lower quartile, median, upper quartile, maximum. This method is preferred as it

employs order based summaries, which are resistant and not affected by extreme values. The five-number summary of the boxplot enables a more nuanced analysis of the data, as it brings out several features of variability in a distribution – the level of the distribution, its spread, its symmetry or asymmetry, lengths of the tails and outlying data points (Mukherjee, 2007). One of the interesting features is outliers that bring in more detail into the analysis.

The most important element in the boxplot representation is the spread of the data or the variance. The standard deviation of the data set is a measure of how spread the data is. The definition for standard deviation is "the average distance from the mean of the data set to a point". Variance is almost the same as standard deviation; it is the square of standard deviation. The spread of the data suggests the distribution of the data or the range in which the data is lying

Here, the relative wealth categorization is made across the 40% (21 HH) members sampled in the proportion of 13:8 (ST: SC). A detailed wealth matrix was formed based on income and other assets. For income, the households were segregated into two categories - HH between 1.5 and 5 acres and HH between 5 – 10 acres. In addition to income, assets like jobs, bikes, livestock, pucca house, trade etc. were accounted for to form the wealth matrix of two categories.

Relatively less wealthy = Category 1, Relatively wealthy = Category 2

In relation to NTFPs, Neumann and Hirsch (2000:33) in their report written for CIFOR highlight (referring to e.g. Hecht et al. 1998, Jodha 1986) that "studies from all tropical regions indicate that it is often the poorest households in rural communities that are most directly dependent on NTFPs". In Gochhabari, this seems to be holding true. The dependence over Kendu and other NTFP species (especially tubers) reflect important variations. The relatively less wealthy households (as derived from the wealth ranking exercise) are relatively more dependent on forest resources than the relatively wealthy. However, the variations within each wealth strata are also an important aspect.

In case of KL, it was found that about 3-4 households in category 2 have a high dependence whereas the others have quite low dependence whereas in category 1, there is a consistently high dependence across all households. This is witnessed even in case of tubers, where 1 or 2 households are highly dependent in Category 2, and relatively greater consistency of dependence in maintained in Category 1. The category of tubers is a cumulative one including the set of

tubers (in kgs.) the households are dependent on. However, the overall dependence over tubers is relatively higher in the relatively less wealthy category. The outliers in case of sal leaves in both the categories are noticeable, which drive the boxplots. However, overall dependence is still relatively higher in case of category 1. This suggests that if in case at some point there emerges a trade-off between the productivity of KL vis-à-vis productivity of tubers, then the poorer households face a direct trade-off. Additionally, this trade-off will be between an additional income source and between resources for self sustenance, which might lead to vulnerability.

There are other subtle factors that might be shaping these patterns such as family size, number of female members, age etc. The richer households are also among the ones that are connected with the markets and trade linkages. For e.g., Bhramana Majhi, 60, has about 10 acres of ancestral land, livestock (2 bullocks, 11 cows, 14 goats) , 1 bike and a pucca house (unlike others) and an average family size – with 1 married son and a daughter-in-law, 2 daughters (18 and 25), 1 grandson (3 yrs old), husband and wife (7 adult members). His son, Surya Majhi, 35, is engaged with Kendu leaf trade acting as a middleman and working on a commission basis. This is a relatively well-off family and the agriculture work usually takes away a huge proportion of time as they also engage in double cropping in a small section of the field. But atleast 1 of the female members is stationed in the field till harvesting, to guard and prevent cattle from destroying the crops. Even though they have a high dependence on agriculture, they do depend on NTFPs especially commercial ones, however not so significantly.

On the other hand, Jashomata Majhi, 55, has a relatively small family size. Her husband, Jaydev Majhi, 60, works in the Forest Department's plantation scheme in Talcher (about 90kms away from Baisipalli) serving as a guard to look after the plantation plots. Her daughter works as an Anganwadi helper and her son is undergoing training for a job in Nayagarh. Both the male members of the household earn "incomes" and return to the village occasionally. Both the female members are engaged in the household work, managing agriculture work, collecting NTFPs and so on. Two members being income earners, a significant proportion of their wealth is channeled through "income transfers" and there is a relatively lesser dependence over forest resources.

The market linkages are still not very much in place and all households try to avoid "purchasing" anything from the market. So, even if both the households (the latter relatively much less) grow rice and a few vegetables – they still depend on a whole range of tubers, fruits, mushrooms, leafy

vegetables to diversify their food base, also with the continuing belief that these have significant nutritional and medicinal values.

Another case is of Sumitra Majhi, 30, unmarried, who lives with her old parents and a younger brother. Being the elder among the two, she takes charge of the family responsibilities, in addition to gathering NTFPs and carrying out a large part of the agriculture work. Though they are relatively poor, the small family size keeps them from depending significantly on NTFPs and most of the time attempts are just to make ends meet.

Though a significant section of relatively wealthy households also depend on NTFP's – but factors like family size, age, market linkages might also be influential to an extent. The opportunity costs involved in engaging with different activities are constantly negotiated.

There are 3 families who do not collect many NTFPs and not even Kendu leaves, which are supposed to be high income products because most of the members are very old, though they are extremely poor. However, collection of Kendu leaves is during the peak summer season when the temperatures usually go up to a maximum of 47 degrees Celsius as well. And the undulating terrain along with the temperatures usually makes for a very harsh condition.

Gender plays a significant role in shaping certain kinds of livelihood patterns. Most of the NTFP collection is attributed to women, in addition to managing all the household work, and helping with the agriculture work. Collection of Kendu leaves is undertaken by both males and females; however the proportion of collection by females will be relatively higher. Whereas the collection of sal and siali leaves is majorly a women's task, also most tubers. Though young boys help with collection of mushrooms, leafy vegetables, mahua flowers, sal leaves, however the percentage of women collecting these NTFPs and especially sal and siali leaves is significantly higher. Moreover, the processes post-collection for most of these NTFPs are also largely managed by women. For e.g. sal and siali leaves are stitched to convert into a marketable form i.e. leaf plates and cups, mostly for commercial purpose. This processing stage is entirely managed by the female labour.

This section discusses the community dynamics in the resource extraction patterns across caste, class and gender groupings and how certain patterns might may specific social groups more vulnerable to changes over others.

The above section involved discussion of extraction patterns of a village in the highly Kendu managed region. Because detailed quantitative study was not undertaken in the less Kendu managed region, the following section will engage with the qualitative aspects of this region.

Why are people in some regions not highly dependent on Kendu extraction?

This section will highlight the differences between different regions both in terms of socio-economics of livelihoods as well as the ecological aspect. Kendu leaf is of a very high economic value and serves as an additional income source for households. In such a context, why are not people across the entire landscape dependent uniformly on KL extraction?

The relatively less managed areas in WLS coincide with the unofficial categorization of a 'core zone' of the wildlife sanctuary. They overlap with wildlife compartments which are under relatively stricter enforcement as compared to the buffer area or the fringes. The road connectivity (pucca) and electricity (few solar panels in a village) exists only in the highly managed regions. However, this is not to say that there is a correlation between Kendu regions and developmental activity. It's a combination of factors – from the sheer location of these regions, undulating terrain, narrow jungle paths marked by steep slopes, greater distance from the nearby tows, lack of kuchcha roads and hencelack of linkages with markets and traders that has led to the these areas extracting less KL if there are little ways to sell or trade KL. Moreover, these regions also are quite far away from the Kendu collection centres (or Phadis).A middleman or two from the neighboring villages would occasionally visit to purchase KL, however because of topography, lack of roads and distance from Phadi makes it difficult for them to sell Kendu leaves. These households practice subsistence agriculture and depend on forests for subsistence purpose.

The following section will focus on understanding the impacts of harvesting KL on livelihoods and whether or not it has contributed in poverty reduction. Additionally, this will also highlight trade patterns and the larger debates of KL governance and policy.

2.5 Kendu Leaf: Case Study

Brief History

From overall observations, conversations and discussions throughout my field period it has been assessed that Kendu leaf (KL) is among the most important NTFPs ('provisioning services') which is of high economic value and contributes to the "income" of the household during the lean period when there is little agriculture income or stocks left and hence serves as a significant resource for two above mentioned purposes. Collection of KL in this area dates back to atleast over 60-70 years or so. However, Kendu leaf collection is hardly for own consumption purpose and is of not much use if there are little opportunities for sale. Bhubaneswar Majhi and Bubei Majhi, both in their sixties, recall that as young children they used to collect Kendu leaves and some obscure trader would visit once or twice in a year or sometimes once in two years.

To trace back the history at the State level, until 1960s, private traders dominated the trade of KL from purchase of leaves to distribution of beedis. However, partial nationalization took place in 1961, regulated by the Orissa Kendu Leaves (Control of Trade Act) 1961 and the Orissa Kendu Leaves (Control of Trade) Rule, 1962. Post-1961, the Government entrusted collection and processing through a commission agent and also through approved tenders. Prior to 60s as well, government had attempted to bring in some control over KL trade because for a long time it "was monopolized by a few merchants against payment of nominal royalty to the state exchequer" (KL Trade in Orissa, OFDC Report). The stakes have always been quite high in KL trade because of the profit margins involved. And under Chief Minister Nandini Satpathy (1972-76), state government's monopoly was strengthened and Kendu was declared as a fully nationalized product in 1973. Additionally, because of the 'constraints of operational efficiency' of the prior schema, a 'Joint Scheme Operation' was also initiated in 1973.

The Forest Department (FD) (and later Kendu Leaf Department wing under the FD) was given the responsibility to handle the collection, processing, baggage and storage of Kendu Leaves whereas the Orissa Forest Development Corporation Ltd. (semi-government organization) (OFDC) was to take charge of marketing and selling KL on behalf of the State government. In structural terms, a massive public infrastructure was created i.e. villagers/pluckers would have to deposit leaves at Phadis (or government leaf collection centres) in the month of May, these

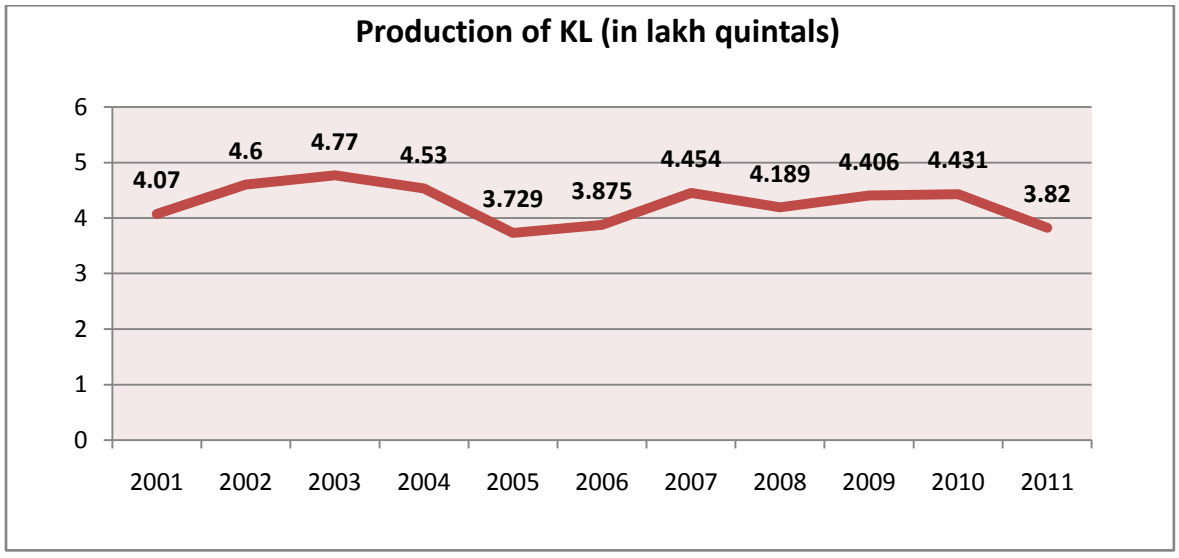
leaves would be sorted, graded and bagged by specialized skilled labourers in the month of June, the KL bags were to be transported to central godowns soon after, and then auctioned off by OFDC in the months of October-December.

Nationalization meant that KL trade was under the direct control of State government, aiming to protect the interests of KL pluckers and also to raise revenues for the state. However, as Lele et al suggest, perhaps retaining a major proportion of the profits from KL may not have been a popular policy. And hence, under the Kendu Leaf Act, state government passed orders in 1986 to share 50% of the profits with the local government bodies. In practice however, KL grants have not been implemented properly till date. However, there has been massive investment and huge government establishment in managing KL trade from registered pluckers (850000) casual labourers (239000), seasonal salaried staff (about 19350) to senior level officials and maintaining physical infrastructure from Government Collection Centres or Phadis (about 7434) to Central Godowns (Task Force Report, GOO).

Production Figures

Odisha comes third after Madhya Pradesh and Chattisgarh in the production of Kendu leaves in India. And it is the only state that produces 'Processed' KL based on strict sorting and grading into different quality standards.

Fig.2.5.1 Production of KL in Odisha during the period 2001-11



From the mid-1990s to the early 2000s, state earnings from the sale of KL generally ranged from Rs. 400-700 million per year. KL is estimated to have contributed around 74% of the state's total earnings from forests during this period. (GOO, 2005 as in Lele et al) The state had an annual production of about 20 lakh quintals between 2005 and 2009 (OFDC report).

Having traced back the history of KL trade in a state context, the following sections will elucidate the patterns of KL trade witnessed in the local context i.e. Baisipalli and how domarket and state forces interact to shape livelihoods and choices communities make with regard to incomes, with regard to ecological trade-offs and so on.

Kendu Leaf - A coveted resource

The leaves of *Diospyros melanoxylon* (family Ebaneceae), known as "Kendu" in Odisha and "Tendu" in Madhya Pradesh and other parts of Central India, are used as wrappers for bidis (indigenous cigarettes). They are one of the most important NTFPs in India because of their high economic value.

Kendu leaves are elliptical in shape, rounded at the base and vary from 10-30cm in length. Leaves from coppicing bushes are larger, thinner and more pliable and hence preferable for making bidis than the leaves of mature trees which are shorter, thicker and coriaceous[5]. The leaves possess unique flavor and texture, and upon processing acquire flexibility which makes them amenable for rolling into a bidi (Lele et al forthcoming). In the processed form, KL is segregated according to the quality standards from Q-I to Q-IV as per the specifications of color, texture, size and body condition of the leaf.

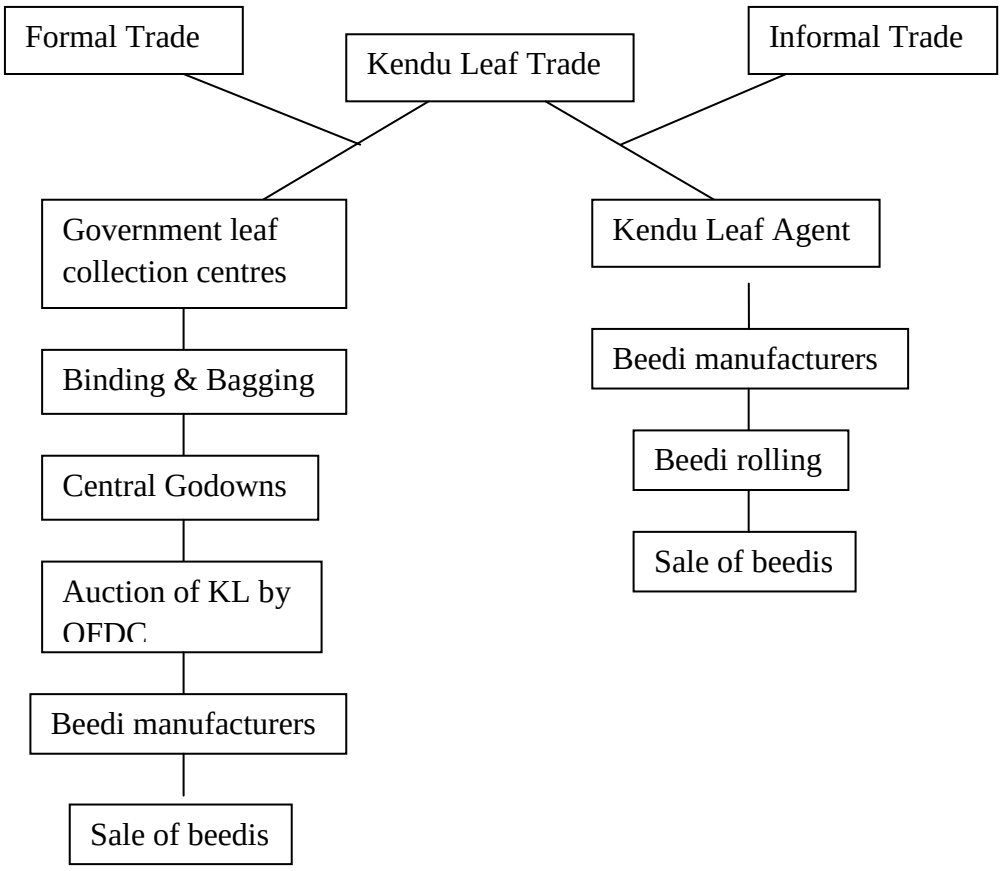
State of KL Trade in Gochhabari village – Sagadabhanga Phadi

With the declaration of Sanctuary and imposition of stricter norms during the 90s's, several Phadis got closed by the late 90s inside the Baisipalli WLS. Because of the lack of Phadis, the influx of private traders (illegally) drastically increased to fill the gap and directly collect leaves from the local communities. The process and steps of trade in both the forms are illustrated below through graphical representation. The formal trade involves the channels through

[5] In this context, coriaceous suggest at a tough, leathery texture of leaves of mature kendu trees and not pliable, hence not preferred for making bidis.

government establishment as opposed to the informal trade which bypasses the stages of formal collection and auction process. The parallel economy of villagers selling directly to private traders continues along with the government process.

Fig. 2.5.2 Process of KL trade in Basipalli WLS



The informal channel is preferred as it provides multiple incentives to both villagers and the traders. To the villagers, the set of incentives include higher prices on leaves, prompt payments and even advance payments, exchange of credit, and also scope for agent and middleman negotiations and commissions. To the traders, the incentives include much lower purchase price of KL than the price at which they are auctioned by the government. However, there are also transportation costs and the risk of getting caught by the authorities. But the nexus between the traders/agents and the lower level forest officials (guards) reduces this risk.

In the context of Baisipalli, with repeated requests, a Kendu Phadi was set-up about 4 years ago in Sagadabhanga, a village that is 1 km away from Gochhabari to allow leaves to be deposited from 4 nearby villages (Gochhabari, Sagadabhanga, Malaspadar and Purnapani). KL is to be deposited in Phadi in the form of kerries. One kerry contains 20 leaves and 2 cover leaves. The two cover leaves on either side is to prevent excessive sunlight. The Kerries are tied with siali fibre or a rope and deposited at the Phadi.

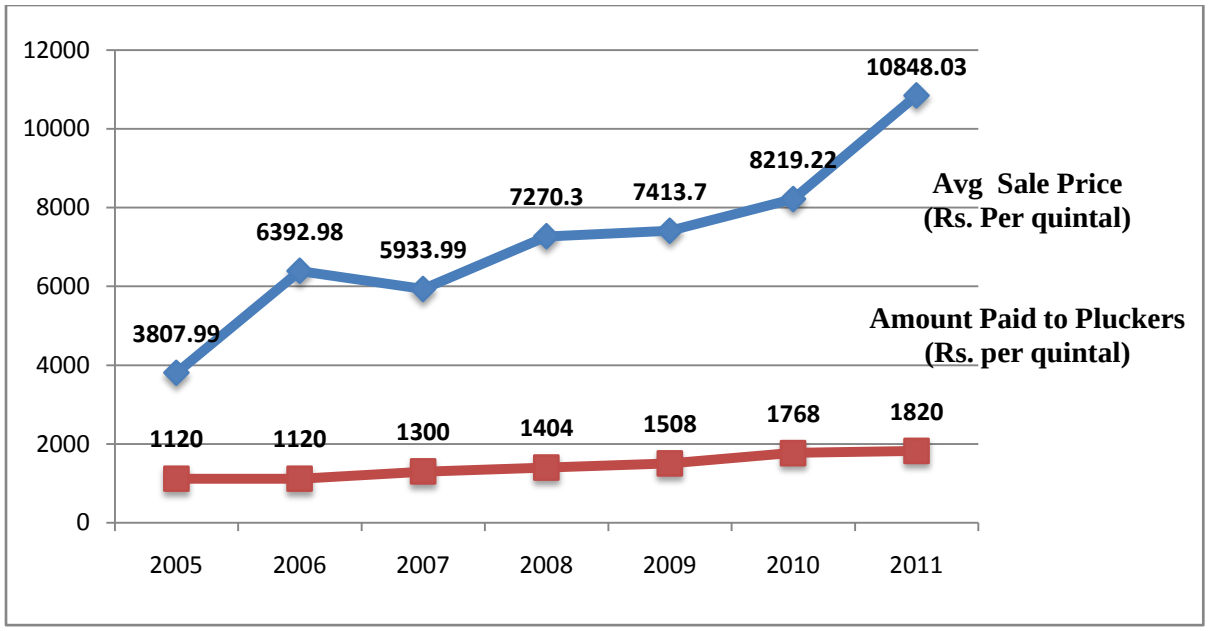
Table 2.5.1 Production of Kendu leaf and wages earned by the pluckers in the past three years in Sagadabhaga Phadi (includes KL pluckers from four villages)

Year	**Total kerry**	**Cost per Kerry (22 leaves) (in Rs.)**	**Total wage labour paid (in Rs.)**
2010	**190000**	**0.34**	**64,600**
2011	**74680**	**0.35**	**26,138**
2012	**136520**	**0.40**	**54,608**

(Source - Phadi Munshi, Field level information)

For 2012 KL, 1 kerry fetched 0.40 paisa, a .05 paisa hike from last year. In the past 12 years, the rate of Kerry has increased only 8 times, from 5 paisa in 1990 to 40 paisa in 2012. KL collection is not a very remunerative activity for pluckers. The collection price is fixed by the government. A day's hard labour fetches on an average about Rs. 80. The average monthly income of a household from KL collection came to around Rs. 1300. Further, gathering official government data at the State level, projections were made to depict the stark difference between the purchase price and the sale price. This suggests the poor sharing of returns from KL of pluckers vis-à-vis the gross earnings by the State.

Fig. 2.5.3 Comparing production price of KL offered to the KL pluckers with average sale price at which KL is auctioned by OFDC Ltd. For the period 2005-11



(Source - OFDC & RTI Odisha)

Table 2.5.2 Comparing share of pluckers share vs government's in % terms

Year	2005	2006	2007	2008	2009	2010	2011
Avg sale price (per quintal)	3807.99	6392.98	5933.99	7270.3	7413.7	8219.92	10848.03
Pluckers Share	29%	18%	22%	19%	20%	21%	17%
Govt.'s Share	36%	49%	38%	39%	34%	33%	61%

Over a 7 year period (2005-11), the average share of final auction price received by the collectors was only 20%, whereas that of the govt. was about 40%. Moreover, over a 10 year period (1984-94), the average share of final auction price received by the collectors was only 16% (whereas the State received about 56% of the final auction price over the same period) (Vasundhara, as in Lele et al). This suggests that the share of pluckers has been always small and has hardly risen over the past two decades. Moreover, it shows that if the government took a decision to return the 'profits' back to the collectors as the legitimate return on their labour, the pluckers' income would increase three-fold. However, over a three year period (2006-08), it was witnessed that KL grant passed on to panchayat bodies was just 10 crore as opposed to the

royalty paid to the government worth 120-150 crores. This is a remarkable opportunity for poverty alleviation that is being squandered by the Odisha government in a short-sighted pursuit of state revenues (or a failed KL grants programme).

2.6. Discussion

This section on the socio-economic and institutional aspects of KL trade indicates that the current system of KL is not fair to the collectors. Further, their wages are never paid on time and the facilities/benefits not delivered. Moreover, the pluckers have little say even in the light of recent decentralized policies. PESA (1996) introduced a radical provision of granting "ownership of minor forest produce" to the Gram Sabha (village general body). However, as Lele et al (2010) point out, the provision has been rendered ineffective due to persisting ambiguities about which forests the rights are to be exercised in. Likewise, FRA (2006) makes provisions to confer NTFP rights to the forest-dwelling communities, yet fails to address the larger issues encompassing NTFPs. On the other hand, the ecological aspect of KL commercialization has been little researched, especially the vegetation compositional changes and ecological trade-offs or understanding the behavior of natural resources. A large number of studies have focused on population models and growth rates, instead of large-scale analysis. For most research studies on the ecological impacts of NTFP, the central question has been to assess how much of the resource can be harvested without diminishing its capacity to regenerate or degrading the environment.Neumann and Hirsch (2000) describe that in case of Ngamiland, mbare palms (Hyphaene ventricosa), the source of fibre, became scarce within a few years of the start-up of basket making (referring to Terry, 1984). A group of specialized collectors emerged to bring palm leaves from ever distant areas and an estimated 40% of these basket-makers engaged in harmful harvesting techniques that involved wholesale cutting of trees rather than selective leaf harvesting. In case of KL, though pruning or bush-cutting is a better method for plant growth, however fire is used instead for the growth of newer stems and better quality leaves.

Rising market demand, unsustainable harvesting techniques, mis-assigned property rights (or weakness of institutions) and biological characteristics of particular NTFP species have together contributed to the ecological impacts (Neumann and Hirsch, 2000). In the context of this case study, the ecological impacts will be analyzed in the following section.

III - ECOLOGY SECTION

3.1. Introduction

In the last few decades, research studies have focused on understanding and analyzing the ecological effects of NTFP commercialization. Alongside, studies on disturbance regimes, on community ecology patterns have been used to analyze some of the large scale ecosystem changes. Compound disturbances, whether of a physical or biological nature, may yield ecological "surprises" (Paine et al. 1988), such as novel species combinations or functional attributes. While on one hand the commercialization of NTFPs has varying ecological impacts, the commercial potential is also affected by ecological factors (Neumann and Hirsch, 2000).

However, several gaps exist still in the realm of ecological knowledge. Research on commercial NTFP extraction in tropical forests has attracted little attention. Moreover, most NTFP studies are focused on one species/population based that fail to trace the large-scale changes. This thesis makes a preliminary attempt to undertake analysis at plant community level while focusing on a commercial NTFP using the lens of community ecology.

Krebs (1985) defines a community as a 'group of populations of plants and animals in a given place".The magnitude, scale and intensity of 'disturbance', in addition to a range of abiotic factors (climate, topography, soil) contribute to the community composition.

Simberloff (2004) believes that most of the societal problems ecologists are called on to help solve are fundamentally about communities, and once cannot solve them without engaging with multiple scales. With detailed synthesis and ordination, community ecological research can help in reducing redundancy and identifying small groups of species that are crucial to community structure and function. Mueller-Dombois et.al. (1974), referring to Whittaker (1967) defines "ecological groups" as species with closely similar distribution modes. In the following section, species associations and clusters will be studied in order to ascertain ecological groups or specific species functional traits.

3.2. Research Methods – Ecology Section

The fieldwork for ecological section was carried out during the months of December, 2012 and March 2013. This section included undertaking detailed research mapping exercise, vegetation sampling exercise using standard methods and recording local ecological knowledge, oral history narratives etc.

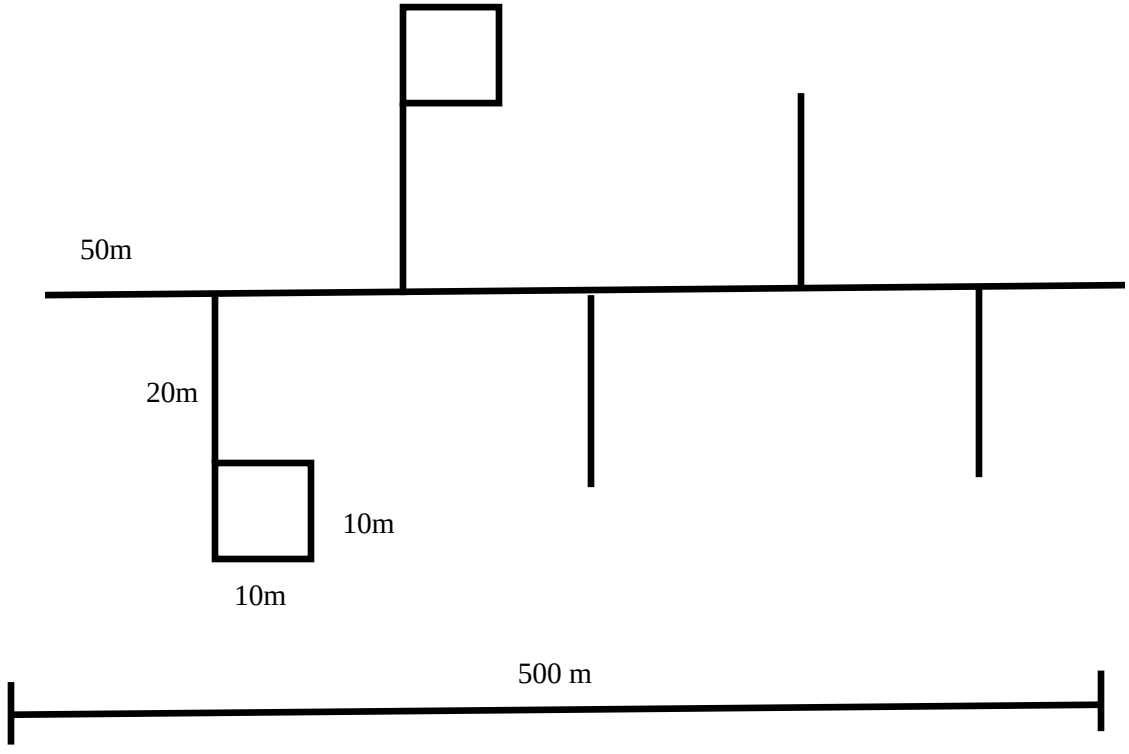
Resource Mapping – In addition to the resource mapping exercise undertaken for the social section to locate the natural resource access map for the resource catchment area, I had specifically undertaken another mapping exercise with women pluckers to trace the Kendu areas. In an informal group interview session, a map was drawn with help from women, noting down the direction of the specific patches, the distance of the sites from the village and general preferences for sites by the pluckers, also noting down some moderations within the highly managed sites for Kendu. This exercise was undertaken to identify the most preferred or highly managed sites for Kendu collection according to the leaf pluckers or even to understand why some sites are preferred over the others.

Key Informant Interviews

A total of 6 interviews (4 female pluckers and 2 male pluckers) with key informants were performed. Qualitative interviews with open-ended semi-structured questions (Kvale, 1996) were used to detect the highly managed, moderately managed and less managed sites for Kendu collection and to understand their perspectives and views on forest fire and its possible impacts on the ecology. The interviews were done through conversations at the homes of the respondents. One of the male pluckers, Surya Majhi, also acts as a middleman in the KL trade, works on a commission basis in exchange for selling leaves directly to the private trader. He was quite informative regarding some of the moderations within distant KL collection sites as well, as to which are the specific sites which are heavily accessed and which are the ones relatively less accessed, with some reasons around it. Women pluckers were quite helpful in strengthening the resource map and for stating their preferences for sites. In addition, qualitative changes in the ecology, tree composition in the particular sampled sites were enquired and recorded to as long as their memory and recollection dates back.

Vegetation Sampling

For this section, systemic stratified sampling was carried out. With the help of resource mapping and in-depth interviews with key informants the sites were identified and marked for sampling. The basic criteria were to capture the local ecological knowledge and perception regarding the various sites across the landscape and also to ensure adequate representation of sites across different gradations of slope. Moreover, each site was accessed by multiple villages. So, though a focused resource mapping exercise was carried out with one village, conversations of villagers from neighboring areas helped to ascertain the actual resource dependency over these sites. What was also found that the Kendu managed areas are also extremely important sites for also grazing, fuelwood, and some other NTFPs like sal and siali leaves etc.Vegetation survey was carried ut across 12 different sites during December 2012 and March 2013 using the transect plot method.



In these sites, along a 500m transect line; alternatively 10 quadrats at 50m distance were plotted. In each quadrat, circumference at the breast height (CBH) at 1.37m above the ground of all woody/tree species was measured and recorded individually using a measurement tape. Also, % age canopy cover using a spherical densiometer was recorded. Four readings facing different

directions in every quadrat were noted and averaged out. Additionally, abundance of Kendu bushes (with height <1.37m) was recorded separately in each quadrat.Such a transect plot method was used in order to ensure a broad representation of the site and gather a larger database of quantitative and qualitative information in a limited time frame.

In addition to the quantitative data, qualitative data for each quadrat and for each site in general were noted. These would include: cut stumps, signs of lopping, grazing, litter, wild animal sightings, slope, kind of terrain, trails/paths passing through and some qualitative assessment of the kind of understory species. This data will supplement the quantitative data gathered and help to substantiate the findings.

The areas accessed the most for Kendu leaf collection in the present context were identified. Among these, different strata (valley, steep slope, gradual slope) were sampled. In case of highly managed areas for KL collection, 6 sites were sampled. And in case of moderately managed areas of KL collection 2 sites were sampled (steep slope and gentle slope), whereas in case of least managed 4 sites (very steep slope) were sampled. These highly, moderately and least managed sites were identified with the help of local villagers and local traders engaged in Kendu leaf trade. Sites relatively under stricter enforcement by FD (Jhajhamara) or far away from the village and with bad road/market access (Rekadi) are marked by moderate amount of Kendu leaf collection and hence selected. Further, sites with little Kendu leaf collection (or the least amount) were also sampled with the objective of understanding successional dynamics and community composition. The following section comprises of a detailed discussion on this.

Oral History: This method is commonly defined as, "the recorded reminiscences of a person who has firsthand knowledge of any number of experiences" (as in Janesick, V.J., 2007).Historical use patterns of forest products and changes in the past few decades were recorded with the help of open-ended questions with a few old members of the village based on their memory and recollection. The discussion ranged from general topics – societal changes, rural/urban spaces, erosion of cultural forms and local language and the knowledge on medicinal plants being not passed on to more specific topics like broad patterns of population changes of Kendu and Sal trees and other vegetation composition changes, if any. However, this exercise required a lot of time and in-depth engagement which was difficult with time constraints and people's busy schedules.

3.3. Sampled Sites Description

This is a cross-sectional study and undertook over a short period of time. Instead of the control plot method which would require a long period of time, this study undertook transect plot method across an environmental gradient in order to represent the landscape and the ecological processes across wide management practices.

Instead of the typical mode of classification into 'disturbed' and 'undisturbed', this study undertook three categories as per three levels of intervention and resource dependence in order to account for changes across gradations. These categories are: highly managed (HM), moderately managed (MM) and relatively less managed (RLM). The most important sites for Kendu leaf collection, as identified by the villagers (or pluckers) heavily dependent on KL, are categorized as the heavily managed areas. However, these areas are also being managed for usage of fuelwood, grazing, fire and collection of other NTFPs, amongst others. Therefore, a cluster of interventions overlap and shape the landscape and this study will not try to isolate their impacts but treat them as a result of the cluster.

However, fire and Kendu leaves have an even more important role, re-enforcing each other. Fire is a common phenomenon in Baisipalli Sanctuary and is mostly deliberately lit because of a few reasons: for enhancement of quality of KL leaves, for facilitating the collection of Mahua flowers and other minor reasons include keeping snakes away from the settlement etc. Co-incidentally, beginning of the KL season (during Mar-April) when pruning is initiated overlaps with the collection period of Mahua flowers (during March). Both of these NTFPs are extremely crucial as "additional income" to the households and neither is for self-consumption or self-sustenance.

Overall, KL was selected as a critical NTFP both from the point of view of livelihoods (additional income source) as well as forest ecology (fire dynamics).

Table 3.3.1 Total sites and plots sampled across different categories and different slope types

Categories	**Sites Sampled**	**Total Plots**	**Slope**
HM	6	55	Valley and Slope
MM	2	20	Slope
RLM	4	40	Slope

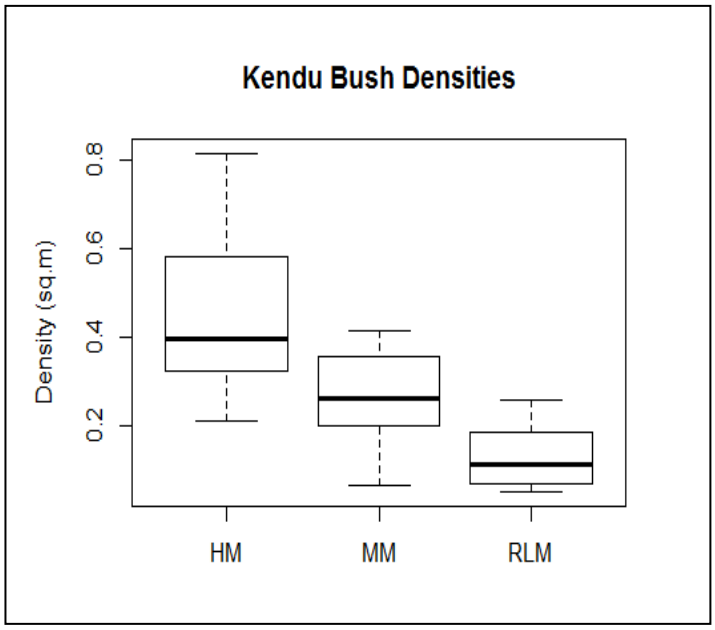
Heavily Managed Areas (HM): These are referred to as HM. These areas are surrounded by several villages and with an increase in population and trade linkages; the dependence over KL has only increased over the years. Leaves are collected when Kendu is at a bush stage because theygo brittle as the plant grows. The leaves at a bush stage are soft and pliable and hence appropriate for rolling purpose. Hence, for better quality leaves, Kendu bushes have to be pruned and maintained. The pruning period begins by mid-March every year for about two weeks and the collection season begins from the first week of May for a month. However, villagers and traders across believe that using fire leads to good quality of leaves because new shoots emerge and that this method is even better than pruning. Moreover, the pruning process, as per the villagers, is never undertaken properly by the KL department of the government and hence in order to cover large areas, fire serves as a convenient method. The reproduction of *Diospyrosmelanoxylon*occurs both by sexual methods and by vegetative means via root-suckers and can hence proliferate widely. In two of the sites sampled in the heavy managed areas, women have reported an overall increase in KL bushes, however there has an increase in the population, therefore reducing the share of each family. Some newer areas have also emerged for KL collection which didn't exist previously. Since the history of KL collection only dates back to about 50-60 years and also the market linkages have been established in the recent decades (which are still not strongly connected), these heavy managed areas are among the ones that would have witnessed a proliferation of KL bushes with increased dependence and constantly managing with fire. Under the heavily managed areas, about 6 sites were sampled with a mix of both valley and slope areas.

Moderately Managed (MM): Moderately managed sites are those with relatively less resource dependency than the heavily managed sites. However, it was difficult to explain "moderate" to the villagers. They identified sites where there is high population and heavy dependence but they could not really imagine a site where collection is relatively less. And even in cases where the population is relatively low, but the overall dependence might still be high due to perhaps "extra hands" - more young girls or boys in the family or for sites which is surrounded by multiple villages and hence dependence remains high even though the individual village household number might be relatively low. However, after a series of questioning and several discussions with the villagers on multiple occasions, 2 sites were identified as moderate. The first site was near Idei village which comprises of just 7 households (2001 census) and very small family size in each household with a total of 20 people. Though they do collect KL on a yearly basis, however the dependence is less just because of the sheer population involved and also sometimes it gets difficult to transport heavy loads of KL leaves as the village is not connected by a *pucca* road. Moreover, by cross-checking with the villagers in Idei and in the neighboring villages, it was assessed that no other village has any dependency on that site. Hence, they considered it as moderate in comparison to the heavy managed sites and yet more than the least managed sites. The other site, was also being managed for KL collection but the location is such that it is relatively further away from two villages and only one of them do access that patch but not heavily rely on it as much.

Relatively Less Managed (RLM): The relatively less managed were identified by the villagers as sites which are far interior into the sanctuary, falling into the core zone, with very little population and no road facilities or hardly any market linkages and also sections where KL is not being collected at all because of the difficulty in transporting them through the undulating hilly terrain. These sites are not "undisturbed", however are relatively less managed. It was fairly difficult to access areas where there is no KL collection at all because of the distance and time constraints, among others. In total, four sites were sampled, out of which 1 is nearly not being managed for KL. 2 of the other sites are not too far away from the villages, however the fairly small household size and hardly any road access respectively discourages collection. The latter village collects in alternative years or once in two years, also these sites are very rocky with steep slopes and hence difficult to access. The fourth site has witnessed occasional collection of KL and is at a distant from the surrounding villages and apparently fire is not lit in and around

these patches annually. These categories have been decided purely based on villagers dependence over a resource and via undertaking resource mapping exercises. Given that it is a short-term study, it was impossible to assess the output of KL collection quantitatively in all these villages especially as there is no past record or any baseline data at all. Hence, it was based on people's perception of heavy, moderate and less collection of KL in relative terms. Additionally, this information was cross-checked and supported by a resident villager, Santosh Majhi of Gochhabari, who serves as a middleman to the KL traders and collects/transports KL leaves from all areas especially which are far away from the government collection centres (Phadis). Hence, he has a very good knowledge of the average output from each village and also the specific areas from where KL is collected. This served as being very useful in the absence of quantitative data of KL of every village in the Sanctuary. Moreover, these also correlated with the villagers perceptions in general.

Fig 3.3.1 Densities of Kendu bushes across categories



The boxplot depicts the relative densities of KL bush across the three different categories. Boxplot serves as an important graphical representation of the five-point summaries, along with highlighting the outliers. The median of HM lies close to 0.4, whereas the median of MM is less than 0.3 and greater than 0.2, and the median of RLM is about 0.1. The raw bush numbers reflect

a range of about 80 bushes per 1000 sq.m to above 500 bushes per 1000 sq. m. This suggests that a wide range is being covered and hence serves as a representative sample accounting for the differences across the landscape. The mid-spread is relatively higher in HM, as compared to MM and RLM. Also, the outliers also exist at almost double the density than the actual median, which means that the variance is high in HM.

In the following section, the important ecological characteristics of a forest ecosystem are discussed and how different indices contribute to our understanding of these attributes.

Vegetation Structure, Composition and Function

Ecological characteristics are examined largely in terms of compositional, structural and functional features. The attributes with regard to each is very different across different types of forest for e.g. managed open forests vis-à-vis old growth dense forests.

Structure – Most of the distinctive and unique compositional and functional characteristics of forests are a direct consequence of their structural features(Franklin et.al.1991). Structural manipulations can be undertaken to suit the objectives of the forest managers/stakeholders. This primarily involves with silviculture practice i.e. controlling the establishment, growth and composition of the forests to suit certain needs and values.

Composition – Alpha (species) diversity of both plants and animals is often highest early in succession (also with the invasion of weeds – generalist species) before tree-canopy closure occurs, after which the shade-intolerant species will be eliminated and diversity reduces in the heavily shaded young forest. Some of these species however, become sufficiently specialized to survive and thrive in the old-growth forest conditions(Franklin et.al.1991).

Function – Function refers to the productivity and efficiency of an ecosystem. Examples of forest ecosystem functions include production, capture of sun's energy through photosynthesis, regulation of nutrient cycling and hydrological cycles and provision of habitat for organisms.

In the following results section, these ecological characteristics will be discussed in the context of tropical mixed deciduous forests in the study site. A large part of the ecological study is focused on understanding the vegetation compositional patterns and the structural features in this forest ecosystem.

3.4. RESULTS – Ecology Section

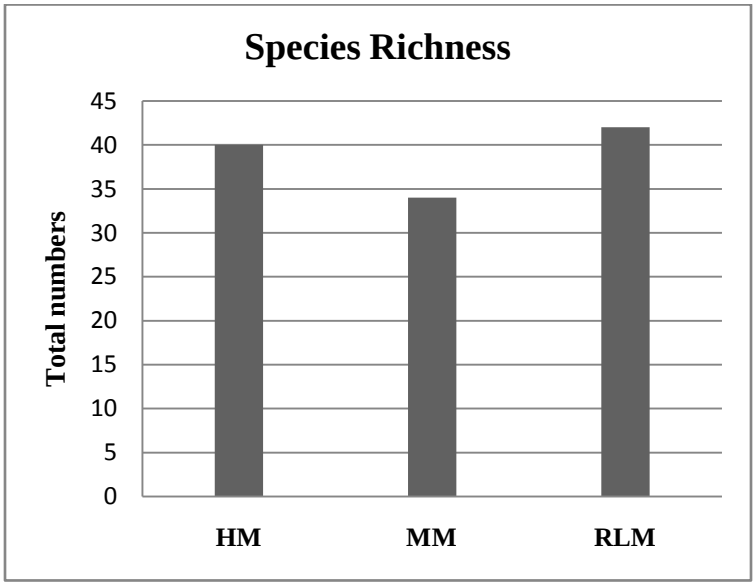
Species Diversity

A diverse range of indices have been shaped over the years to capture different variations and patterns with little scope for biases and errors. Species diversity measures can be divided into three main categories. These are: species richness, species abundance models and indices based on the proportional abundance of species. Each of these categories are discussed in the following section.

Species Richness

This index is essentially a measure of the number of species in a defined sampling unit (Magurran, 1988).

Fig. 3.4.1 Species Richness across categories

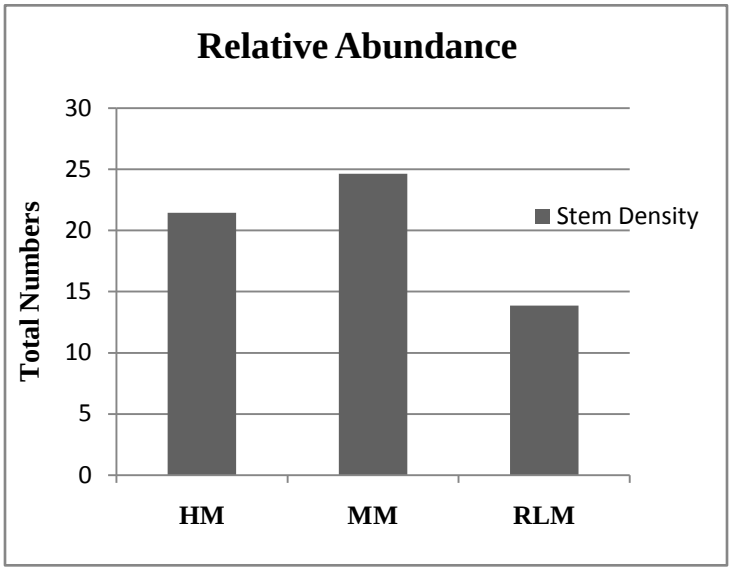


In this study, the total number of species is found to be much higher in RLM than in HM and further less in MM. Accounting for the differences in the sample size, the patterns in relative terms do not seem to be serving to the 'intermediate disturbance hypotheses'. Species richness in itself may not be a strong indicator of diversity across different habitats. Species richness, a quantity, does not necessarily translate into species diversity but one of the components, the other being species evenness.

Relative Abundance

This index refers to the total abundance of species numbers across the categories adding all the sites under each category and dividing the total by the number of plots. It refers to the overall stem density across each category.

Fig. 3.4.2 Relative abundance of species across categories

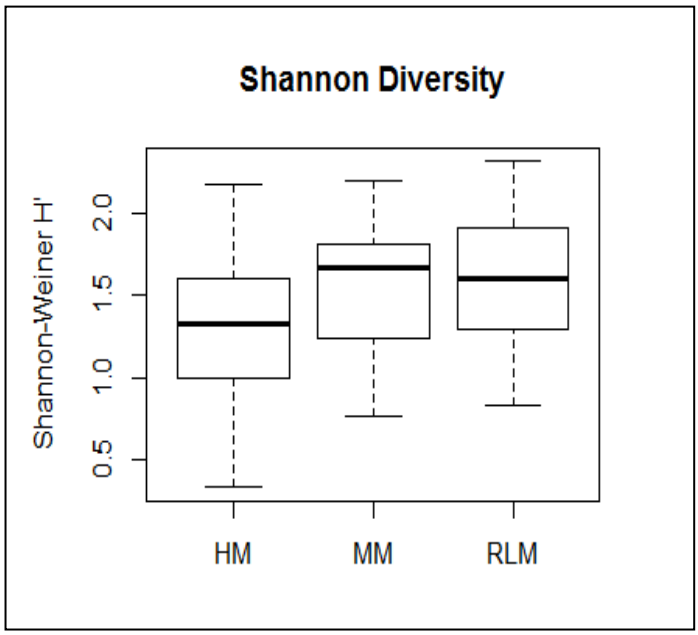


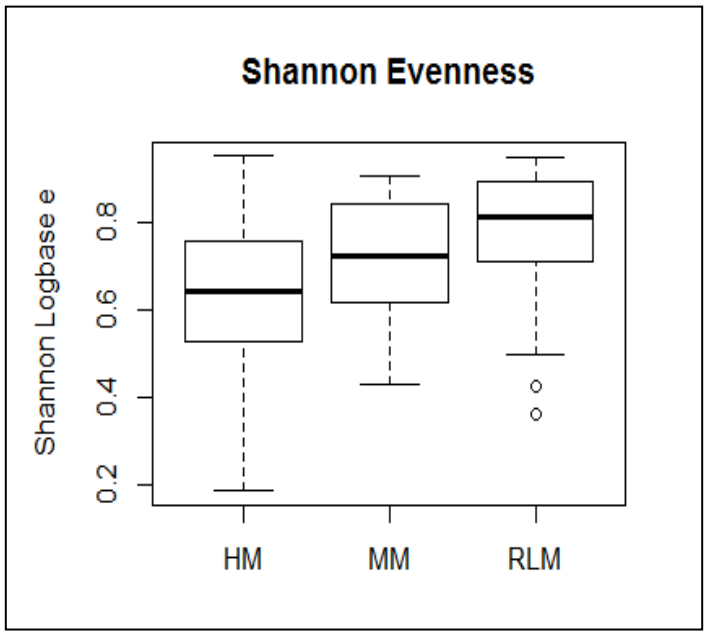
Fisher et al, (1943) note that a characteristic pattern of species abundance occurs – that a few species being very abundant, some would have medium abundance, while most would be represented by only a few individuals. This is the premise for species abundance model. A general relative abundance graph is depicted here. The relative abundance is found to be highest in MM, followed by HM and least in RLM. This does match with my observations on field. The sites under MM had particularly very high number of thin stems which could mean high amount of regeneration with moderate amount of disturbance. And in case of RLM, the stem density is much lower as there were relatively few stems or trees and more were old growth trees. One could clearly see the difference in the total number of trees in a 10m by 10m plot in RLM vis-à-vis MM or HM.

Diversity Indices

Indices based on the proportional abundances of species provide an alternative approach to the measurement of diversity. Peet (1974) terms these indices heterogeneity indices because they take both evenness and species richness into account. Diversity is a measure of the number of species (richness) and how evenly spread out are the individuals among species (evenness).

Fig.3.4.3 Shannon Diversity (H') and Shannon Evenness across categories





Shannon-Weiner Index (H')

Shannon index is weighted towards the less abundant species and is preferable to track changes due to rare species. The Shannon index is affected by both species richness and evenness. A greater number of species and a more even distribution both increase diversity as measured by H'.

However, the Shannon index assumes that individuals are randomly sampled from an indefinitely large population (Pielou, 1975). The index also assumes that all species are represented in the sample. In this study, the H' for RLM category is relatively

Shannon-Weiner Inde (H'):

$$H' = -\sum_{i=1}^{s} \frac{n_i}{N} \ln\left(\frac{n_i}{N}\right)$$

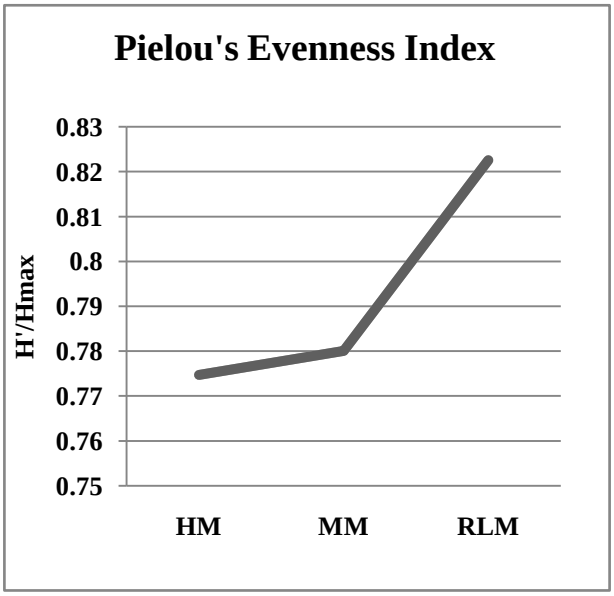
- where s is the number of classes observed, ni is the number observed from the ith class and N is the total number of individuals observed in the sample – in the natural log form

lower than MM but higher thanHM. However, the differences across sites in case of diversity are not too much. They occur in a similar range and hence could suggest at some overlaps between sites.

However, Shannon evenness reflects that RLM has a relatively higher evenness than both HM and MM. This suggests that species are evenly distributed in RLM as opposed to the other sites. The same has been re-represented through another evenness index – Pielou's index.

Species Evenness – Pielou's Index

Fig. 3.4.4 Pielou's Evenness Index

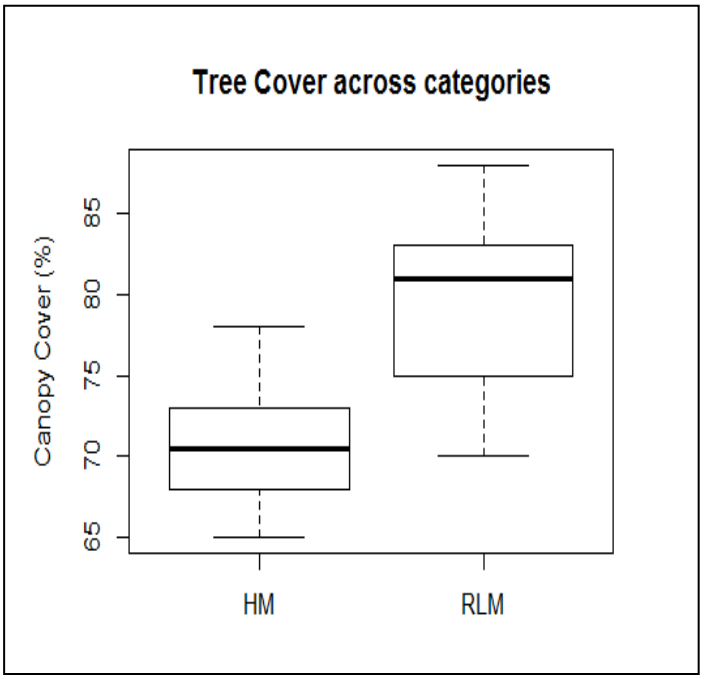


Evenness refers to how similar each species in a community are in terms of the number of individuals of species (C. J. Krebs, 1998) was calculated using the measure of Pielou's evenness index.

The index, J', is derived from the Shannon diversity index and is the maximum equal to Hmax (put in the equation). J' is constrained between the values 0 and 1. The value of J' close to 1 and a higher value suggest a relatively less variation in communities between the species. In this case, RLM reflects a relatively higher J' value, as depicted in the graph, in comparison to both MM and HM.

Canopy Cover

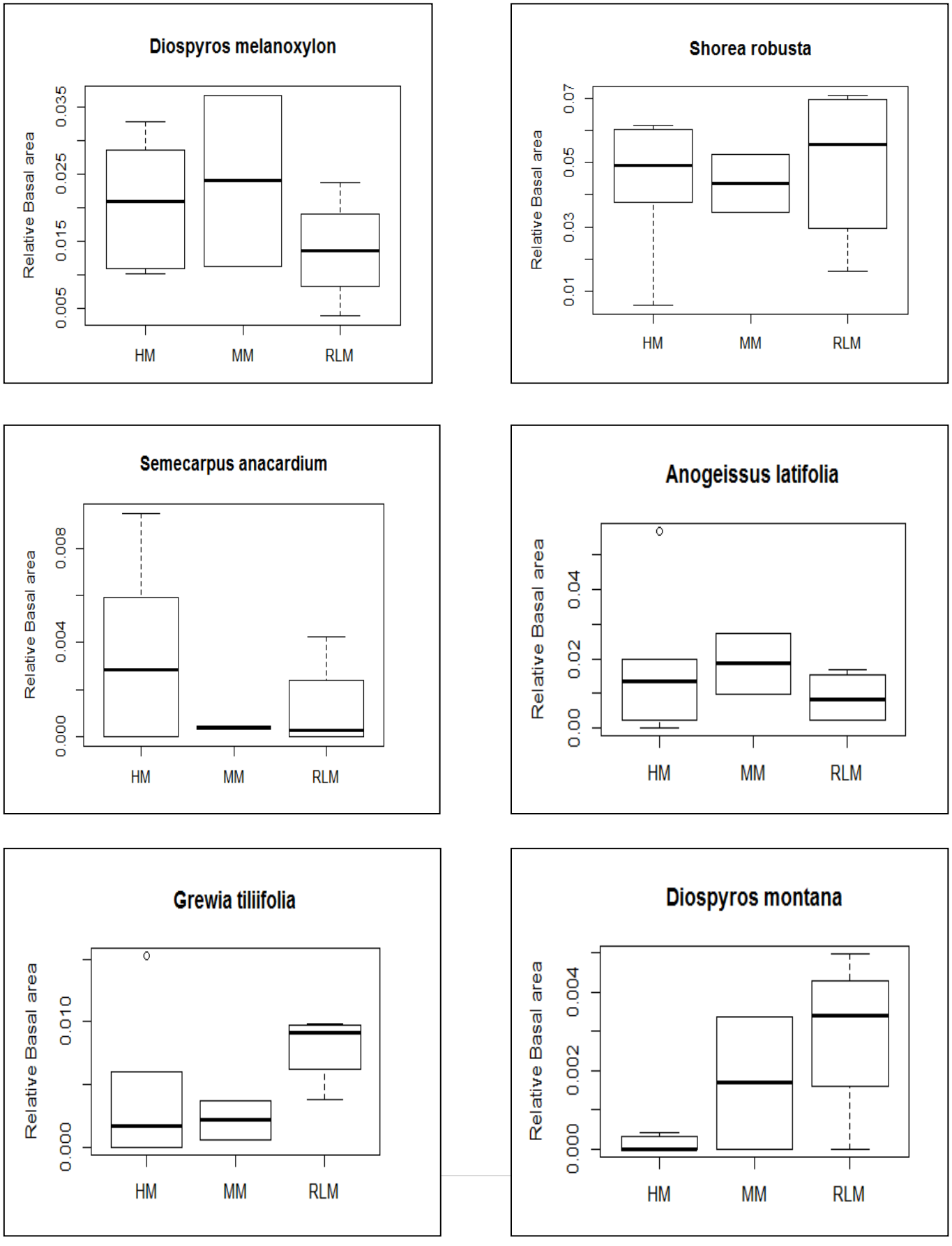
Fig. 3.4.5 Canopy Cover (in %) for woody species across different categories



The boxplot depicts the canopy cover (in %) across the categories of HM and RLM. The cover is much less in case of HM, the median being close to 70, while that in case of RLM being above 80. However, the mid-spread is higher in case of RLM suggesting that there is a higher variation in the distribution of cover across plots under RLM. This does generally cater to the idea of relatively more old growth trees in RLM as compared to HM. The cover measurement has been derived in relative terms from about 6 sites in HM and about 3 sites in RLM during the winter months. Though the cover measurements for MM were noted, however, during fall when most of the trees had shed their leaves being deciduous in nature. Hence, these measurements were excluded from this graph as they would have led to under-reporting.

However, the difference between two sites is not stark. The highly managed sites also have a fairly good canopy cover in comparison to the relatively less managed sites. And canopy cover also serves as a proxy for primary productivity. This could to some extent suggest that there aren't huge variations even in primary productivity or in functional aspects across sites. However, this index is also used to highlight a point that macro indicators cover based may not necessarily reveal the functional associations, the compositional and structural aspects.

Fig. 3.4.6 Relative Basal Area (RBA) of species across different categories



Relative Basal Area

Diameter at base height (DBH) was manually recorded for individuals of all species. The calculation for r involved girth/2π. The formula for Basal Area is (πr^2). Relative Basal area has been calculated for each species divided the total basal area of all the species in that particular patch. The cumulative relative basal area of all the patches across different sites within each management category has been plotted.

Relative Basal area refers to the area occupied by a particular species in relative to the area occupied by all species. RBA also serves as a proxy for dominance.

All the species box plots reflect multiple patterns. *D.melanoxylon* is high across HM and MM categories, but relatively lower in RLM. However, the variations within HM and MM are quite high and outliers also seem to be shaping some of the patterns. In case of Shorea robusta, though the RBA is relatively high in case of RLM, however the variation among the species is also quite high, making it ineffective for absolute comparisons.

Semecarpus anacardium has a much higher basal area than in HM and very low dominance in case of RLM. This can be traced to the characteristics of this species itself. *Semecarpus* is a light demanding species and common in understories. This could be correlated to the relatively greater canopy cover in RLM and the low dominance of *Semecarpus* because of relatively less sunlight percolating through to reach the understory.

Topographic variations seem to have been captured by the patterns of *Diospyros montana*and *Grewia tillifolia*. Both these species are dominant in RLM as opposed to HM and MM. There is also a significant difference in medians of the species across different categories. Both these species also prefer very undulating rocky terrain and steep slopes. This is a feature of the sites in RLM. Hence, it could be deduced that perhaps some of these patterns seem to be because of the topographical variations.

Frequency Distributions

Frequency refers to how frequently do individuals of a species occur in a particular site. These were based on the presence and absence of individuals in each plot, divided by the total number of plots. The cumulative frequency distributions for the all the sites under each category have been represented (See Annex II). The patterns reflected are as follows:

Common species across all categories:

Diospyros melanoxylon, Shorea Robusta, Madhuca indica, Terminalia tomentosa, Anogeissus latifolia, Buchanania lanzan, Caeseria elliptica, Cleisthanthus collinus, Lagerstroemia parviflora, Ougenia oojeinensis. Schleichera oleosa, Lannea coromandelica

Rarer species across all categories:

Cassine glauca, Woodfordia fruticosa, Syzgium cumini, Diospyros montana, Cassia fistula, Nyctanthes arbor-tristis, Pterocarpus marsupium

Rarer species in the RLM category:

Albizia odoratissima, Cipadessa baccifera, Antidesma ghaesembilla, Dalbergia sissoo, Mitragyna parviflora, Aegle marmelo, Terminalia bellerica, Morinda pubescens, Semecarpus analcardium, Pterocarpus marsupium, Holarrhena antidysenterica, Dalbergia paniculata, Cassine glauca,

Rare species in HM category

Flacourtia indica, Diospyros montana, Limonia acidissima, Bridelia retusa, Cassine glauca, Grewia hirsuta, Sterculia urens, Cassia fistula, Woodfordia, Phyllanthus, Pterocarpus, Dalbergia paniculata, Limonia, Naringi crenulata, Ixora, Chloroxylon

The frequency distributions were carried out to identify the most common species and the rarest species across all categories – also known as generalists and specialists. The generalist species being highly abundant across the landscape, might not adequately reflect the qualitative changes taking place across habitats. The patterns and dynamics of the specialist species will be important to analyze.

The rarer species in the HM category do not completely overlap with the rarer species in the RLM category. This could also suggest that the rarer species in the HM category are relatively abundant in the RLM category. This discussion will be taken up in the following pages in conjunction with correlations and cluster analysis.

Presence and absence of species

Species absent in HM but present in RLM

Morinda (early), *Protium serratum, Careya arborea, Dalbergia sissoo*(mid to late), *Mitragyna parviflora (*mid to late), *Terminalia bellerica*(mid to late), *Aegle marmelo, Cipadessa baccifera, Albizia odoratissima*(mid to late), *Mallotus phillippensis, Strychnos potatorum(*early)

Species absent in RLM but present in HM

Woodfordiafruticosa(early), *Helecteres isora* (understory – early), *Nyctanthes, Limonia, Flacourtia indica*(early), *Ixora pavetta*(early), *Grewia hirsuta, Chloroxylon.* (early).

The categories (early – mid – late) are referring to successional stages. For e.g. *Dalbergia sissoo* is usually known to be occurring in the mid to late successional stages of an ecosystem. These have been highlighted to portray that many of the species absent in HM, but which are present in RLM are of the range of mid-late successional species. On the other hand, those species absent in RLM are mostly early successional species. This can be used to deduce that the patches in RLM are arrested in mid to late successional stage, unlike the patches in HM.

Species absent in HM but present in MM

Morinda, Protium serratum, Terminalia bellerica

Species absent in MM but present in RLM

Miliusa tomentosa, Naringi, Cassia fistula, Careya, Mitragyna, Dalbergia sissoo, Aegle, Cipadessa, Albizia, Mallotus, Strychnos

Correlations

Correlations summarize the strength of the association or relationship between two variables. There are two most commonly used methods: Pearson product-moment correlation and Spearman rank correlation. Pearson correlation is used when there is an underlying assumption of normal distribution unlike Spearman in which no such assumption of 'symmetric' distribution is made and is carried out by ranks of the data.

The Pearson Product-Moment Correlation Coefficient(r), is a measure of the degree of linear relationship between two variables, usually labeled X and Y. Correlations can be either positive or negative. A positive correlation coefficient means that as the value of one variable increases, the value of the other variable increases and vice versa.

In this study, bi-variate pearson correlation method was calculated using SPSS and the most significant r values along with corresponding significant p-values at 95% and 100% significance levels were highlighted and extracted from the large pool of data base across 56 variables. This method was followed across categories and the most significant associations were recorded. For convenience sake, these are graphically represented through scatter plots and through general shapes to highlight the significant associations across all categories.

R software was used to plot correlations.

CORRELATION COEFFICIENT (Pearson's r)

Pearson's r is also referred to as the "bivariate correlation coefficient"

$$r_x = \frac{\text{cov}(y,x)}{\sqrt{\text{var}(y)*\text{var}(x)}} = \frac{\sum(X_i-\bar{X})(Y_i-\bar{Y})/N}{\sqrt{\sum(X_i-\bar{X})^2\sum(Y_i-\bar{Y})^2/N*N}} = \frac{\sum(X_i-\bar{X})(Y_i-\bar{Y})}{\sqrt{\sum(X_i-\bar{X})^2\sum(Y_i-\bar{Y})^2}}$$

Where

Cov(y,x) = the covariance of y and x
Var(x) = the variance of x
Var(y) = the variance of y

OR

$$r_{yx} = \frac{\sum Z_{xi} * Z_{yi}}{N}$$

Where

$$Z_{xi} = \frac{X_i - \overline{X}}{SD_x}$$

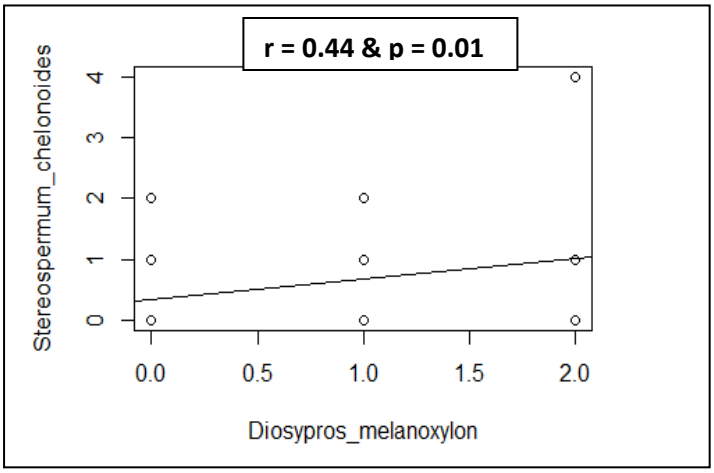
$$Z_{yi} = \frac{Y_i - \overline{Y}}{SD_y}$$

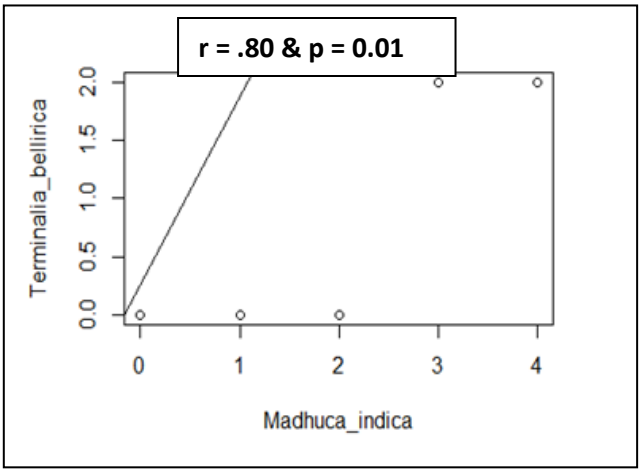
(Z_xi= is the standard score for Xi. It tells you how many standard deviation units (SD_x) the score Xi is from its mean.)

Pearson's r is symmetric. Pearson's r is always between -1 and +1, where -1 means a perfect negative, +1 a perfect positive relationship and 0 means the perfect absence of a relationship.

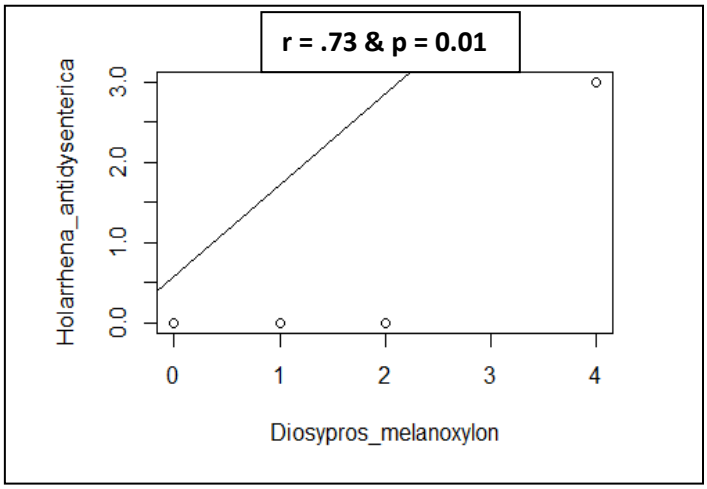
Fig. 3.4.7 Significant correlations among species across categories

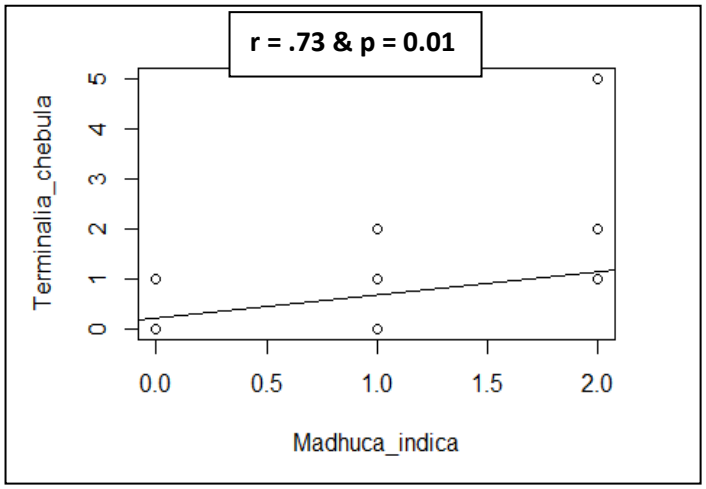
Relatively Less Managed



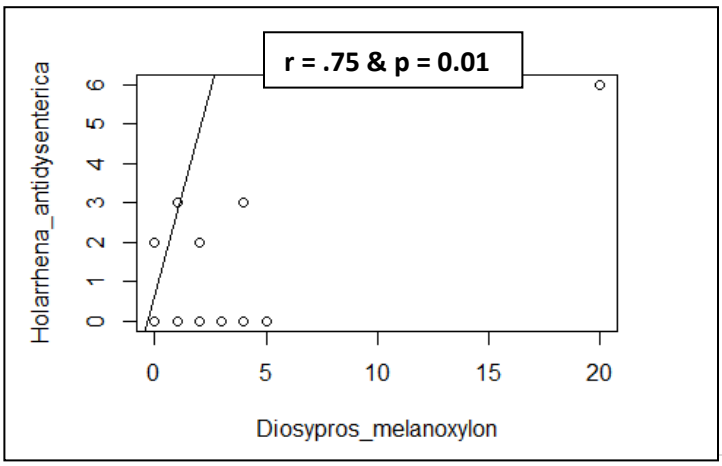


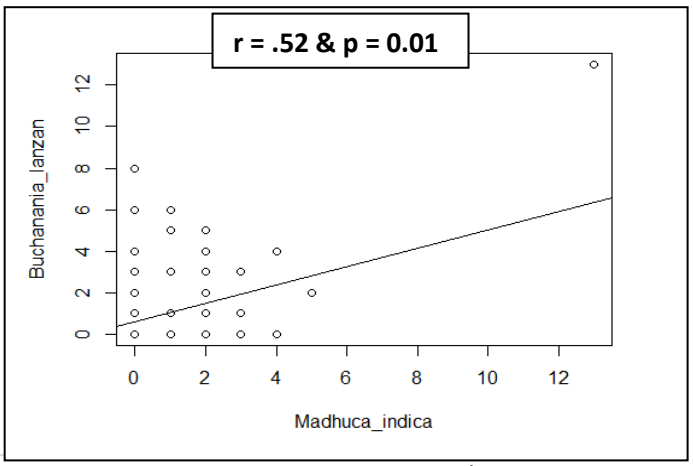
Moderately Managed





Highly Managed





Analysis of the Graphical Representations (Species correlations/associations)

The scatter plots above represent the degree of association between the two variables. And in a more simplified form the correlations have been represented below.

For scatter plot, examples of association change in two species have been represented.

First plot in the RLM category depicts a very strong association of Madhuca with T.bellerica However, this association breaks down and Madhuca forms strong associations with T.chebula, along with Caeseria and Buchanania in the MM category. Some of these associations break down, but Madhuca retains its association with Buchanania in the same form even in the HM category.

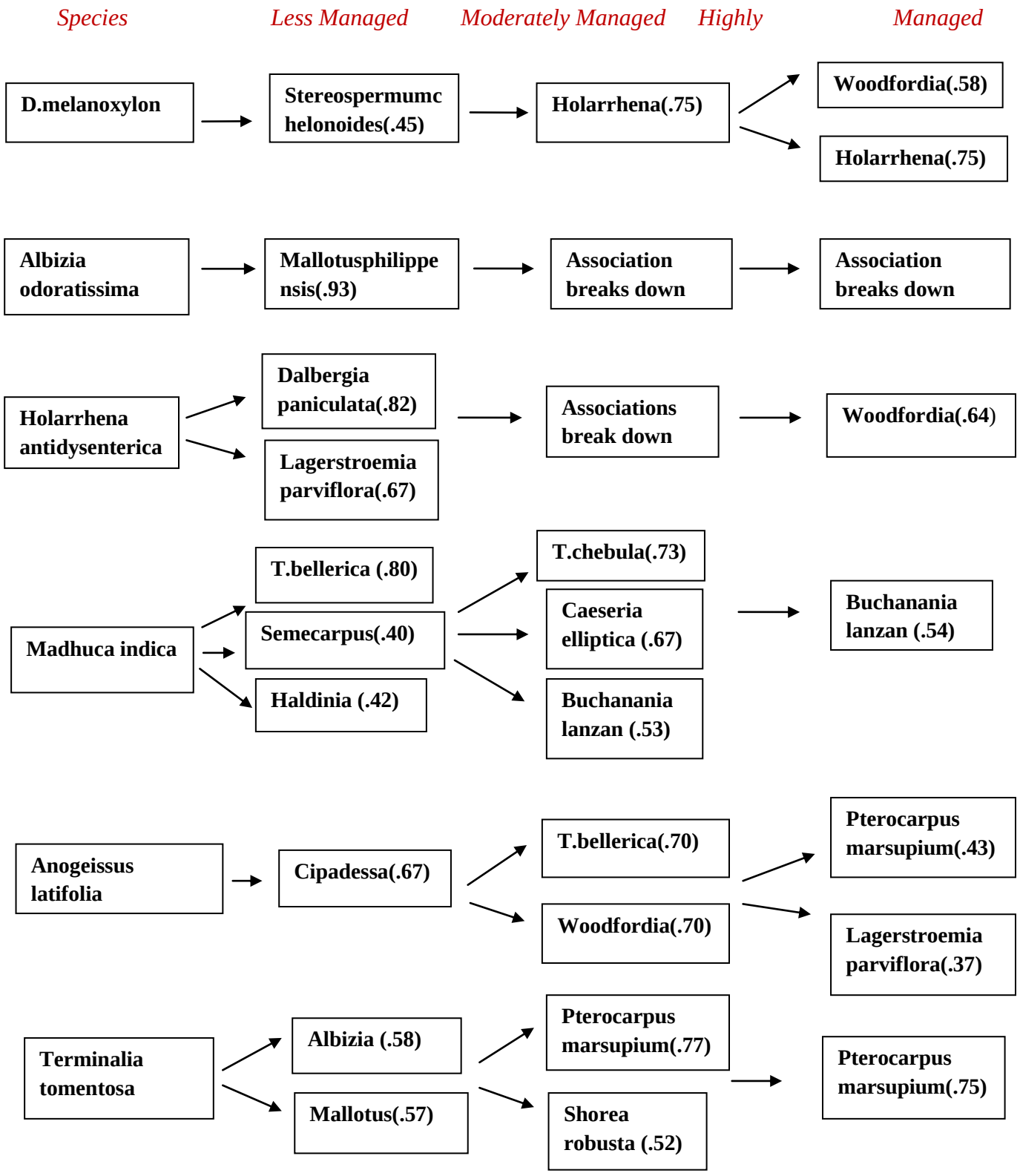
Second plot in RLM category, D.melanoxylon depicts a weak association with Stereospermum Chelonoides. This association however breaks down and further gives rise to a newer strong associations with Holarrhena and remains intact for both the MM and HM categories.

In addition to the above two cases, four more have been graphically represented (below). These showcase how associations have witnessed qualitatively changes. In some cases, associations completely break down in the habitats from RLM to HM, while in some newer associations are formed and in others associations remain intact across categories. Albizia odoratissima and Mallotus philippensis form a very strong association in the RLM category. However, the association has have broken down completely in HM and MM category.

Stereospermum has a fairly strong association with D. montana at r=.70 with a p= 0.01 in the RLM category. However this association breaks down and Stereospermum forms very strong associations with Dalbergia paniculata (.75), Helectris isora (.95) and Cassine glauca (.95) in the MM category, however all associations of Stereospermum break down in the HM category.

Anogeissus latifolia forms a relatively strong association with Cipadessa baccifera in the RLM category, which breaks down and leads to associations with T.bellerica and Woodfordia in MM, which further breaks down to form weaker associations with Pterocarpus marsupium and Lagerstroemia parviflora. Hollarhena forms a very strong association with Dalbergia and Lagerstroemia in RLM, no association in the MM category, and a strong association with Woodfordia (.64).

Species Associations



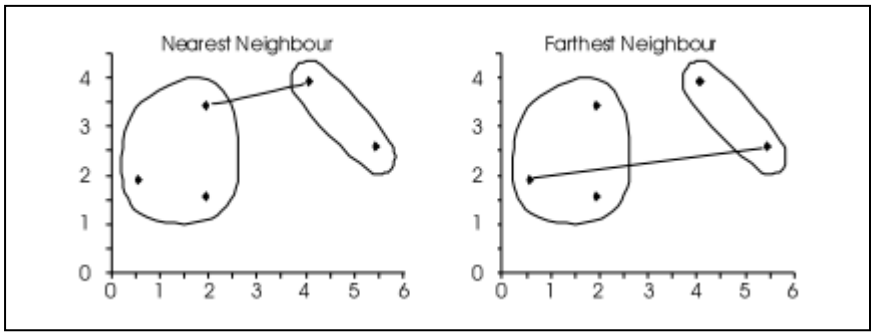
All the above mentioned r values have a p-value of 0.01. Only highly significant correlations have been used. In conjunction with the correlations section, the following sections – cluster analysis and PCA will be discussed.

Cluster Analysis

Cluster analysis is described as a set of numerical techniques in which the main purpose is to divide the objects of study into discrete groups. The most commonly used ones are the agglomerative hierarchical methods. The results are presented in a dendrogram format.

There are different clustering methods – nearest and farthest neighbor (among others)depicted across a similarity/dissimilarity measurement index.

Fig. 3.4.8 Difference between the two clustering methods



In this study, nearest neighbor clustering method is used in which the distance between one group and another is taken as the distance between their two closest points. Nearest neighbor clustering is also susceptible to a phenomenon called ‘chaining’ in which there is a tendency to repeatedly add new individuals onto a single cluster rather than making several separate clusters. This gives the dendrogram a staircase-like appearance.

JACCARD(x,y)=$a/a+b+c$

For this, either a similarity or dissimilarity measure is used to discern patterns. Binary coefficients (presence/absence) are based on a table of frequency matches and mismatches of the presence or absence of a single variable. The binary data should be entered into the data matrix as 0 (absence) and 1(presence). Any number that is not zero is treated as 1. In this study we use

the binary Jaccard's coefficient, a similarity measure widely used to classify ecological species. The measure reflects the shared attributes among multiple variables.

The most important aspects for interpreting the dendrogram are to analyze the branching order and the length of the branches. The precise order of the variables does not matter. Higher the value, higher is the degree of similarity.

Principal Component Analysis (PCA)

PCA is among the best known and one of the earliest ordination methods, first described by Karl Pearson (1901). PCA consists of an eigen analysis of a covariance or correlation matrix calculated ordination methods, first described by Karl Pearson (1901). Mathematically, PCA consists of an eigenanalysis of a covariance or correlation matrix calculated on the original measurement data.

PCA helps in data summarizing and reduction. Like most ordination techniques, PCA is most effective at separating objects that are different, representing their distances more faithfully than those among more similar objects. The goal of PCA is to summarize as much of the information (variation) in the data set as possible in the fewest number of dimensions. This is done by finding a new set of mutually-orthogonal axes that successively explain the greatest amounts of variation remaining (MVSP).

Graphically, it can be described as a rotation of a swarm of data points in multidimensional space so that the longest axis (the axis with the greatest variance) is the first axis and the second longest is the second axis. The first two PCA axes represent the greatest amount of variation in the data set and also contain some patterns of significance. (MVSP)

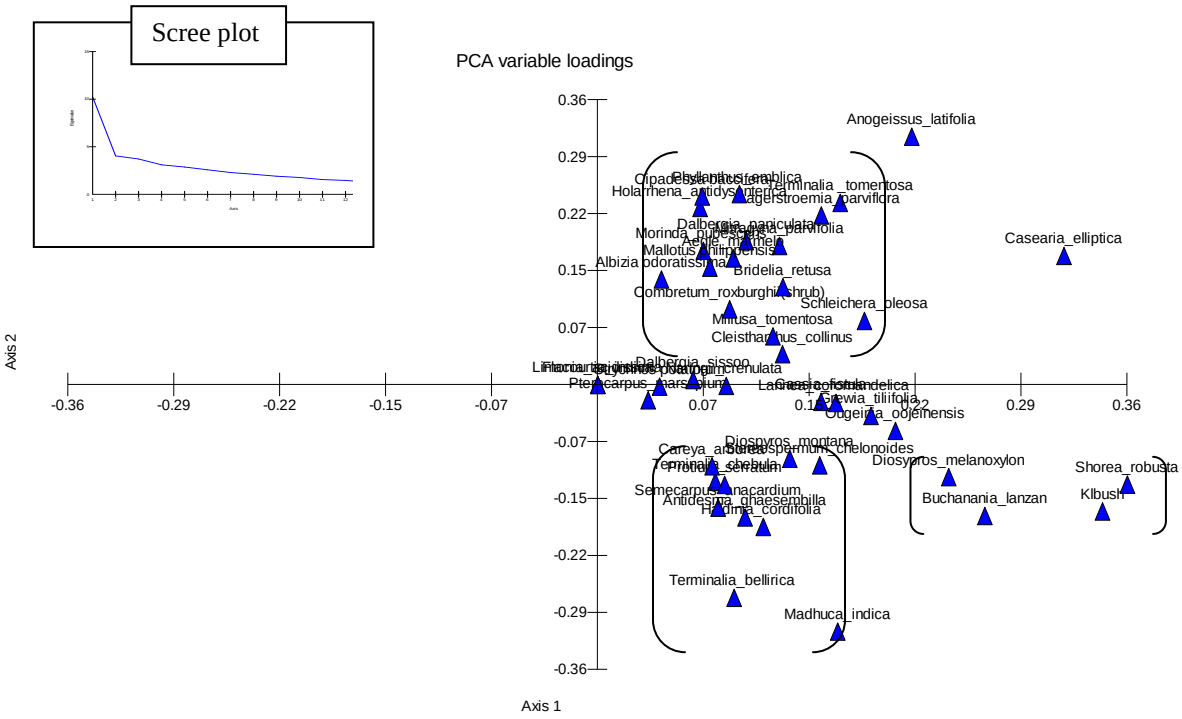
There are two methods used: center data or standardized data.

The correlation matrix is used if standardization is desired; this is useful if the variables have been measured on different scales or are of different orders of magnitude. Standardization is desired in ecological studies to reduce the effects of dominant species, so that rarer species play a greater role in the resulting configuration.

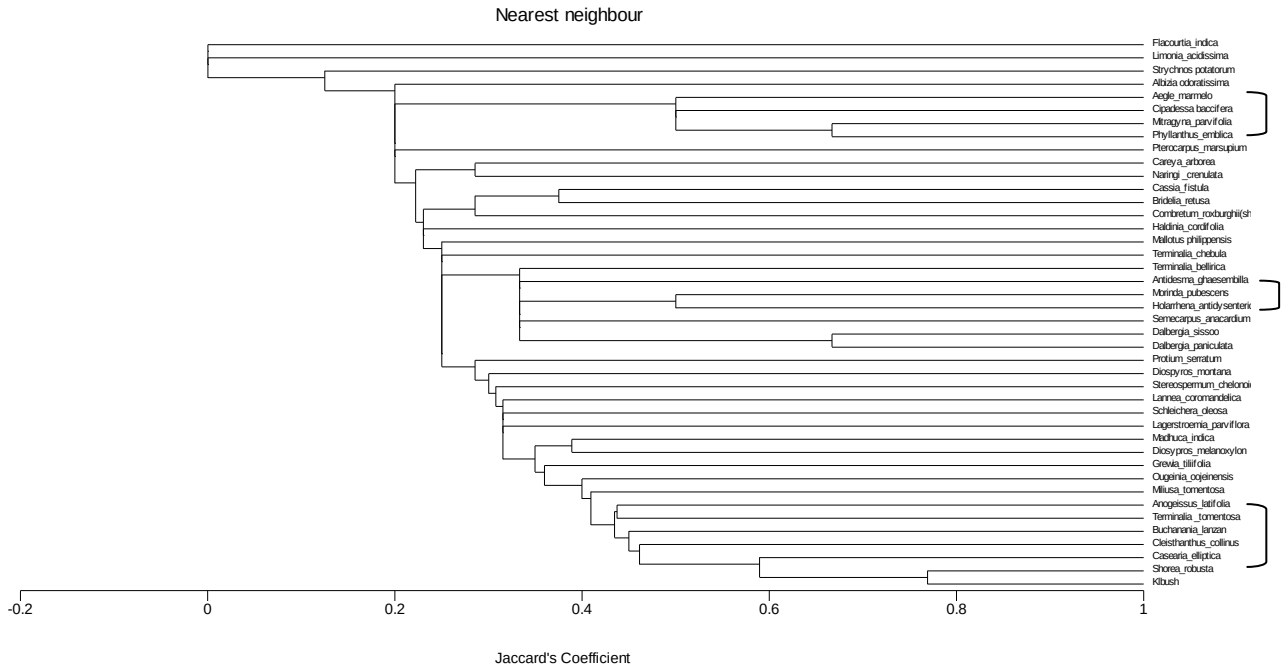
Both PCA and cluster analysis were calculated using MVSP 3.21 software.

RESULTS - Relatively Less Managed

Principal Component Analysis – Fig. 3.4.9



Cluster Analysis – Fig. 3.4.10



Analysis – RLM

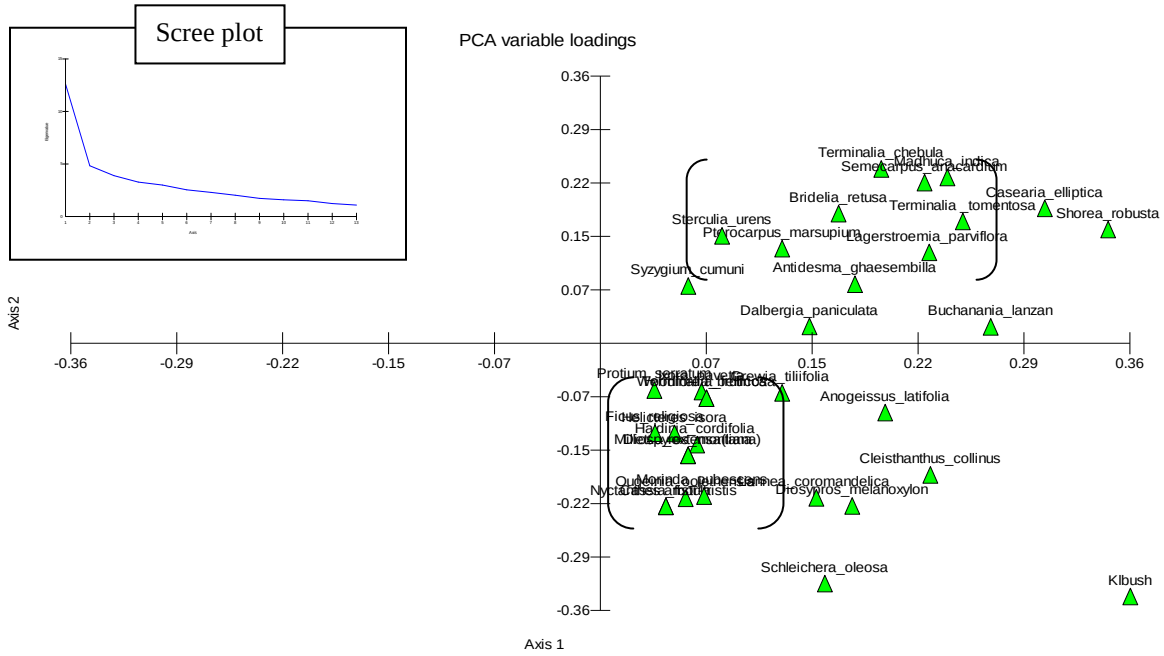
The scree plot depicts the eigen values on the Y-axis and the axis on the X-axis. This reflects the variance that is captured across axis. In the case of RLM, the scree plot is quite spread out and hence just the Axis1 and Axis2 or PC1 and PC2 cannot capture for all the variance in the data and hence it's difficult to get clear patterns. Perhaps the sampling effort required should be greater in order to find clusters. With the existing data, the points look relatively scattered. Hence, PCA analysis in this case may not be extremely useful. However, there are still some variables that are closer which also leads to some sense of clustering among them. This will be correlated with the findings from the cluster analysis and that in turn with the findings of the species correlations. In order to reduce the redundancy in the data, the focus will be less on the generalist species which abundantly occur in all the categories across the landscape rather more on the patterns of the specialists or the rarer species.

PCA reflects some clustering below the axes line, around the line and above it and with some smaller clusters spread out and a few outliers. The group below the line has ***Antidesma, Semecarpus, Careya, Haldinia cordifolia, T.chebula, T.bellerica, Madhuca indica***. Some of these have been already charted through the correlations graphs. ***Madhuca indica*** forms fair associations with ***T.bellerica, Semecarpus*** **and** ***Haldinia.***

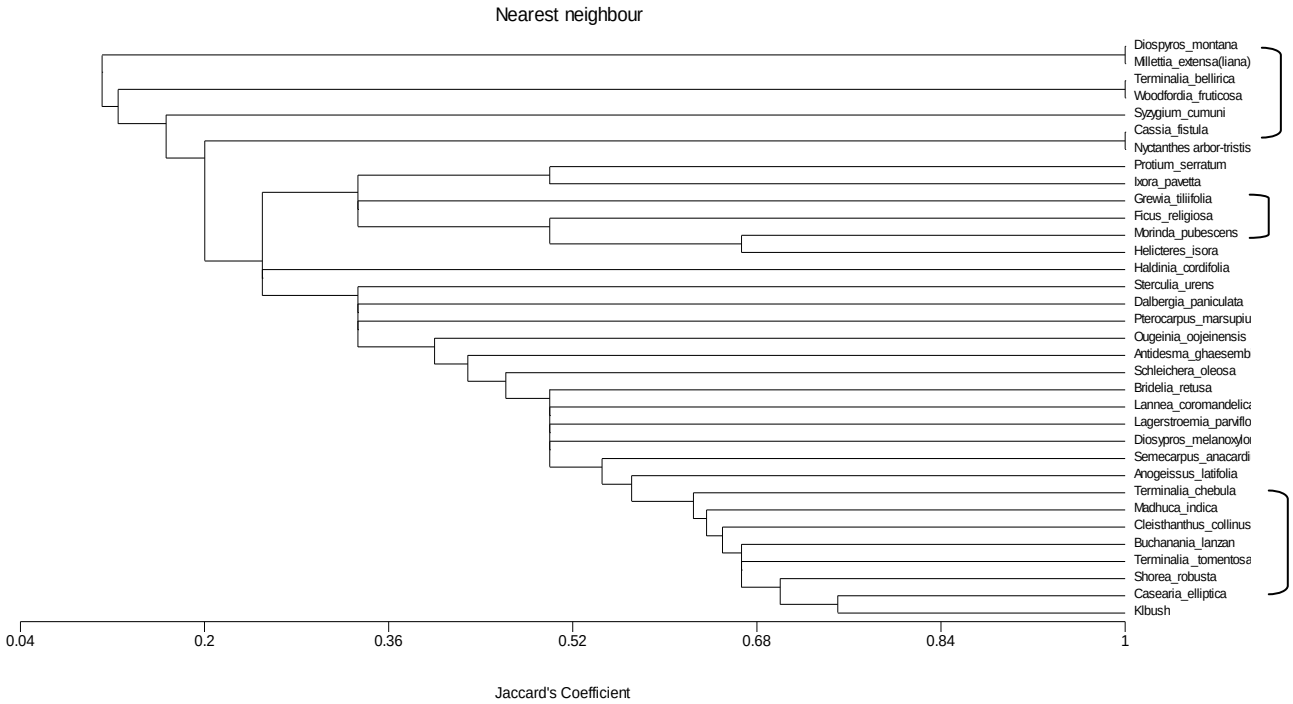
The group far above has a cluster formation with some specialist species - ***Holarrhena, Morinda, Albizia, Mallotus., Phyllanthus, Mitragyna, Cipadessa, T.tomentosa, Dalbergia Paniculata, Lagerstroemia***. Cluster analysis reflects relatively higher similarity between *Holarrhena and Morinda* (50%), also *Phyllanthus and Mitragyna* (70%), followed by Aegle, *Cipadessa and Mitragyna* (50%). Correlations reflect that the strong correlation between two specialist species in RLM category has broken down in both MM and HM categories. *Holarrhena* has a strong correlation with *D.paniculata and Lagerstroemia* in RLM which breaks down and forms association with *Woodfordia* in HM.

Moderately Managed

Principal Component Analysis – Fig. 3.4.11



Cluster Analysis – Fig. 3.4.12



Analysis MM

In this case, the scree plot is quite spread across and the first two components only capture about 50% variation which is not significant. Synthesis of PCA will be undertaken along with cluster analysis and correlations. The variables are quite scattered and this might be attributed to the relatively low sampling effort.

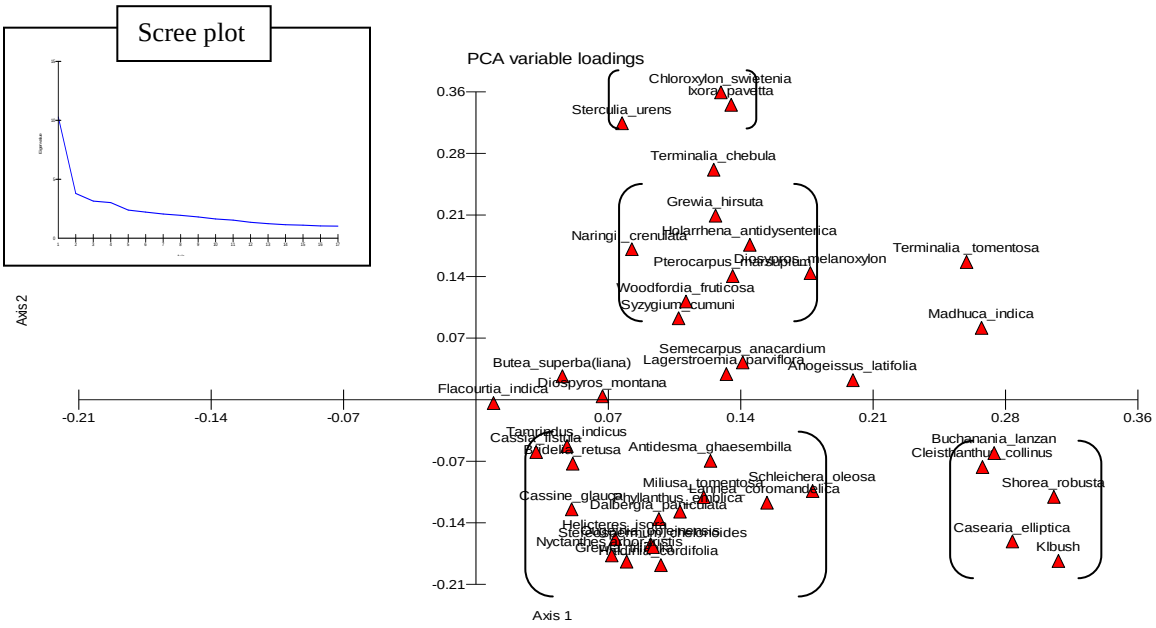
In PCA, there is some clustering of variables occurring, these are: ***Ougeinia, D.montana, Haldinia, Morinda, Woodfordia, Helicteres isora, Ixora pavetta, Protium serratum, T.bellerica, Grewia tillifolia, Cassia fistula, Nyctanthes***. Cluster analysis reflects 100% similarity between ***T.bellerica and Woodfordia*** and also between ***Cassia fistula and Nyctanthes*****.** Further, there is a great degree of similarity between ***Helicteres and Morinda*** **(70%), also** ***Ixora and Protium*** **(50%).**

There is some clustering around *T.tomentosa, Madhuca, Shorea, Buchanania, Caeseria, Clesithanthus, T.chebula* (65%-70%) as reflected in the cluster analysis. In PCA variables grouping in this section are ***T.chebula, Madhuca, T.tomentosa, Caeseria, Shorea***. Moreover, in species associations grouping, in the MM category we observed that *Madhuca* forms good correlation with *T.chebula, Caeseria and Buchanania*, however some of these associations gradually break down. *T.tomentosa* forms correlations with *Pterocarpus and Shorea*, which is reflected in both PCA and cluster analysis.

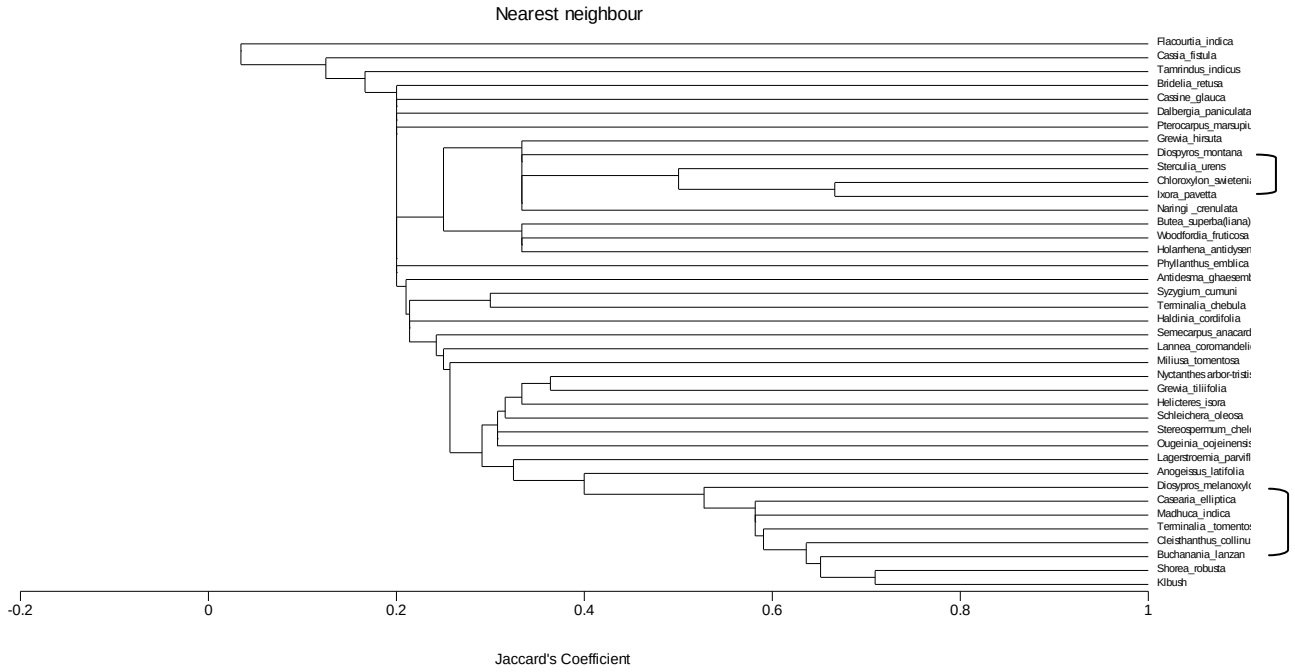
In PCA in MM, the variables are quite scattered and there are very few correlated variables as compared to both HM and RLM. One of the primary reasons could be the low sampling effort (as discussed in ecology section). Hence, there seems to be a high degree of variation among the variables and therefore it is difficult to deduce the patterns.

Highly Managed

Principal Component Analysis – Fig. 3.4.13



Cluster Analysis – Fig. 3.4.14



Analysis - HM

In this case, the scree plot is relatively better than in case of MM and HM. However, this also accounts for about 70% variance in Axis1 and Axis2. However, just below the axis line in PCA, the variables show fair amount of clustering towards the left, scattered set of variables clustering above the line and a small cluster forming below the line, towards the right.

Below the axis line on the left, the species include - ***Nyctanthes, Grewia tillifolia, Haldinia, Helicteres, Stereospermum, Ougeinia, Dalbergia paniculata, Phyllanthus, Miliusa tomentosa*.** Another cluster towards the right include: ***Kl bush, Shorea, Buchanania, Casearia and Cleisthanthus.*** As depicted also in the dendrogram, Kl bush, Shorea, Buchanania and Cleisthanthus form about 60% - 70% clustering.

In PCA, Ixora pavetta and chloroxylon form a strong association, as reflected in the cluster analysis (70%) and at about 60% with sterculia.

Another cluster above the axis line comprise: ***Holarrhena, D.melanoxylon, Naringi, Pterocarpus, Grewia hirsuta, Woodfordia and Syzygium.*** There is a strong correlation between *D.melanoxylon and Holarrhena* as already described in the above section. However, in case of RLM, this association did not exist and *D.melanoxylon* only had a weak correlation with *Stereospermum.*

Overall the PCA correlated variables are quite different in case of HM as compared to RLM. Additionally, there seem to be fewer clusters in this case as depicted in the dendrogram, most of the clustering is of weak nature unlike the case of MM and RLM. In particular, the most common species across categories form very strong clusters; however the weak species seems to have lost some of the clustering with species perhaps with the changing dependency patterns. Additionally, as also discussed above, in the HM areas several associations do not exist as they do in RLM and in turn many new associations have been formed.

3.5. QUALITATIVE ASPECTS – DISCUSSION

In additional to the quantitative methods, qualitative aspects of the ecosystem sampled were also recorded. These include: cut stumps, amount of leaf litter, dung count, signs of lopping and terrain, among others. The counts and presence/absence were noted for all plots across categories. Overall, they serve as visualization tools validating the quantitative data.

Fig.3.5.1 Counts of stumps, litter, dung, lopping and trails in all plots across categories

Categories	Cut stumps	Leaf Litter	Dung	Lopping	Trails
HM	2.3	0.2	0.56	0.5	0.5
MM	2	0.3	0.4	0.4	0.05
RLM	1.5	0.43	0.2	0.17	0.13

Cut Stumps	**Leaf litter**	**Dung**	**Lopping**	**Trails**
1 – for 1 cut stump	1 – Layer of leaf litter 0 – scanty/no leaf litter	1 – Presence 0 – Absence	1 – Heavy signs of lopping	1 – for 1 trail

Scores 1 and 0 have been allotted to each category as per the specifications given in the boxes above. The contingency table showcases the counts for the above categories. The counts for cut stumpsin the plot were noted (1 point for 1 cut stump) and divided across plots for each category to compare the relative count. The cut stumps found in the RLM category is almost half to that of the HM category. In case of leaf litter, as noted in the box, 1 point each was allotted for plots with a layer of litter, as observed, vis-à-vis scantly or no leaf liter at all. The amount of litter found in the RLM category is again quite high in relative terms followed by the MM category and the least being the HM category. Several patches observed in the HM category had almost no litter and soil was in an eroded state due to grazing, lopping and fire. However, some of the RLM sites with steep slopes were also highly eroded because of run-offs and gullies and in some of those plots very scanty little litter was present. In case of dung/scat (cows & goats), only presence/absence was noted, however the actual number of dung clusters were not noted. The

presence of dung in HM category is almost the double of that found in the RLM category. The number of cattle and grazing pressure is significant. The effects of grazing is however a matter of contestation and depends on the type and more importantly the 'intensity' over a short or long period of time. Intense grazing also leads to erosion on slopes. Further, lopping reflects a general dependency patterns. Signs of lopping were assessed based on cut stems or fallen stems etc. Only two scores are allocated, 1 for heavy signs of lopping and 0 – moderate or no signs of lopping. Trails were much higher in the HM category relatively than in the MM and RLM category. Some of them were grazing trails and some walking paths, though they overlapped as well. So, the distinction between these two was not made. And the count of trails is just informative of the relative level of intervention, but is not indicative of any generalizations per se. Overall broad reasons for these patterns or factors influencing and answering the 'why' questions will be taken up in the discussion session.

Fig. 3.5.2 Qualitative aspects – soil, terrain and burnt patches in all plots across categories

Slope	Soil Form	Terrain	Burnt patches
HM	**38**	**6**	**15**
Gentle	**26**	**4**	**8**
Valley	**12**	**2**	**7**
MM	**15**	**7**	
Gentle	**5**	**2**	
Steep	**10**	**5**	
RLM	**22**	**18**	**1**
Steep	**22**	**18**	**1**

Slope
Steep
Gentle/Gradual
Valley

Soil Form
1 – Eroded

Terrain
1 - Rocky

Burnt Patches
1 – Presence
0 – Absence

Scores 1 and 0 have been allocated as per the specifications. For e.g. in case of soil, only scores have been allocated for those plots where some degree of erosion was noted. So, if the score is less under one category, it suggests relatively less erosion.

In addition to the above features, some other aspects were noted. These include: trails, soil, slope, topography and presence of fire. Slope is a crucial aspect in determining vegetation patterns, fire intensity patterns, levels of erosion and so on. The sampling sites were undertaken across different slopes in order to represent strata adequately. Based on visual observations, slope in the landscape was divided into three broad categories: valley, gentle or gradual slope and steep slope. The contingency table reflects some interesting patterns, which would not have been captured just by quantitative sampling methods. Though soil NPK analysis would have been extremely important for such a study and could have highlighted interesting patterns, but because of time constraints, I had to rely on visual observations. And the categories allocated for soil form are eroded (1 point) and not eroded (0 point) based on the thickness of the topsoil. It was found out that erosion is much higher in case of HM and specifically in gentle slopes, and in steep slopes in RLM. The reasons for high erosion particularly in HM sites could be because of three reasons: water run-off, grazing and fire. It is difficult to demarcate and isolate their impacts. In addition to noting down the elevation or altitude of the sampled sites, observations were made regarding the terrain being too rocky. This information is important because, as Whittaker (1975) suggests that altitude defined climatic and soil factors are serve to be the primary determinants of change in species composition and community structure in undisturbed mountains. As shown in the box, for rocky sites 1 point each was allotted. The RLM sites comprise of very rocky, undulating terrain with steep slopes ranging from 1250 ft. to about 1500 ft. and beyond. One of the RLM sites was very difficult to navigate because of the presence of huge boulders unlike in case of HM sites which had relatively gradual slopes or mostly valley areas. This is reflective in the figures as per the table. Those sites with steep slopes are the ones with rocky terrain. And also erosion is also quite high in RLM for which water run-off forming gullies across steep slopes is possibly a more important factor. Soil chemistry affects plant species composition through levels of salinity, pH, calcium and organic carbon (Shankar et al. 1991; Abbadi et al. 2002). In the context of rangelands, Jafari et al. note that topography, climate and soil are three important environmental abiotic factors controlling vegetation composition. Additionally, small burnt patches/stems (1 point) were noted commonly in the HM sites. These are not necessarily annual ground fires but fire lit in smaller specific areas. Both burnt patches and trails are not strictly indicative of anything, but a certain level of intervention and

management. The emphasis on qualitative aspect has been to complement and supplement the quantitative data.

3.6. DISCUSSION

The ecology section has summarized the broad patterns emerging out of both quantitative and qualitative aspects. The quantitative aspects involved analysis of vegetation structure and function and the qualitative compositional changes in species associations across different categories. However, all regions have not been sampled equally. Moreover, strata of topography have not been adequately represented. The HM sites had relatively lower altitude and were gentle slopes and valley areas, whereas most of the RLM sites only comprised of very steep slopes with a significant altitudinal difference. This was not known prior to selecting the study area. To an extent, topography also influences some of the ecological patterns and changes witnessed. However, landscape heterogeneity cannot be the only factor for these changes because these are generally 'managed forests'. Landscape heterogeneity also reflects that the spread of disturbance or the intensity will not be uniform.

In order to understand the differences in altitude and slope, the following section involves a discussion on this, also to examine if KL bush densities are influenced by slope.

Topography – Altitude and Slope

Topography plays a significant role in shaping the landscape and the multiple processes – hydrological, ecological and biological. In particular, slope, altitude and aspect are the three most important factors in the undulating hilly terrain. Topography contributes to the vegetation patterns and compositional dynamics. This is especially through sunlight, rainfall and wind patterns.

There is a substantial literature that describes vegetation responses to local topographic variation (e.g. Armesto & Martinez, 1978; Davis & Goetz 1990). Carmel et al. (1999) evaluated the combined effects of grazing regime and topography on vegetation dynamics, and using regressions, illustrated that slope and aspect, along with grazing intensities significantly affecting the vegetation pattern.

Altitude

As we can see in the table, there is a significant difference in the altitude across the three categories. The altitude within each site is almost comparable; however the variation is quite high especially of HM vis-à-vis RLM. These differences are highlighted and hence taken up in the discussion section because for such a short-term study; it was difficult to account for all the topographic variations.

Table 3.6.1 Altitudinal levels across categories

ELEVATION ACROSS CATEGORIES			
Sites	**HM (in ft.)**	**MM (in ft.)**	**RLM (in ft.)**
1	400	520	1400
2	530	880	1275
3	520		1225
4	610		950
5	415		
6	460		

All the four sites under the RLM category had relatively steeper slopes, were at a greater altitudeand comprised of an extremely rocky terrain. This could also be concluded from the relatively high presence of *Diospyros montana, Grewia tilifolia, Semecarpus anacardium* species which are known to thrive in rocky, undulating slopes.

Slope

Table 3.6.2 Densities of KL bushes across different slope categories

Bush Density	Steep Slope (>35°)	Gentle Slope (>5° and <35°)	Valley (0° - 5°)	Total
0-2	3.32	0	0	3.32
2-4	5.31	4.97	6.66	16.94
4-6	0	**14.33**	0	14.33
Total	8.63	19.30	6.66	34.59

Slope is another critical factor determinant of vegetation composition, intensity of disturbance, levels of erosion, and densities of plant communities. In order to understand whether slope influences KL bush densities, the table above has been plotted.

There is a high concentration of bush densities in gentle slopes in comparison to both valley areas and steep slopes. Additionally, almost 75% of the KL bushes within the gentle slope itself seem to be occurring in very high densities, whereas almost 100% and about 60% of the bushes seem to be occurring in moderate densities in the valleys and steep slopes respectively. The total number of sampled sites is also higher in gentle slopes followed by steep slopes and least being valley areas. The topography is such that there are very few valley areas; however the proportion of KL bush density is relatively higher than even the steep slopes. There is also an overlap of these figures with the different regions sampled.

Table 3.6.3 Differences of bush densities across sites and slope categories

Sites	Steep Slope	Gentle Slope	Valley
HM	0	**17.24**	6.66
MM	3.12	2.06	0
RLM	5.51	0	0

From the above table, it is evident that most of the high bush densities of the gentle slopes and valleys also overlap with highly KL managed regions whereas a high proportion of bush densities in the steep slopes only occur in the relatively less managed sites.

The next was to check if slope influenced bush densities. This was carried out through a chi-square test plotting the observed and expected numbers. The null hypothesis was that there is no relationship between slope and bush densities. It was found that the p-value was significantly low and hence the null hypothesis was rejected. Therefore, bush densities were to some extent influenced by slope and because there is a significant difference in the slope categories across different regions, to some extent this may have affected the vegetation patterns. However, as already notes, landscape heterogeneity can act as one of the factors but not the only factor influencing vegetation dynamics because these are all actively managed systems.

In addition to the topographical factors, there are a range of changes occurring across different management regions which might affect the resource extraction patterns.

Greater connectedness, increased dependence over commercial NTFPs and population pressure, among others has been the points of difference across different regions. Additionally, general population pressure is much higher in the HM sites. Cluster of villages have concentrated in a limited space, whereas the villages in RLM sites are scattered across a much larger landscape.

- **Connectedness - Market/Trade linkages**

Villages surrounding the HM sites have been the beneficiaries of kacha roads and trader-linkages in the recent decades. There are two small shops in Gochhabari village itself which become the

contact point for influx of goods from markets – ranging from rice/potatoes to salt/soaps/shampoos to gutkas/beedis. Interestingly, these shops also become the convergence point for traders.

In case of HM, there is a greater connectedness with markets and traders, an increased emphasis over trade-based products, and also greater interest because of the profit margins involved. This could also suggest that more people are also prioritizing their time and resources into specific products with higher economic value or with higher returns, like Kendu leaves. This is not witnessed in case of some of the LM sites because of their location, lack of roads and distance from markets leading to their 'disconnect' as well.

Additionally, the linkage with market also has led to a greater integration with the cash economy in relative terms. Villagers have started to prefer "buying" commodities from the market.

- **Subsistence/Commercial agriculture**

In the HM sites, there has been a gradual shift from an entirely subsistence based agriculture to include some cash crops as well like sunflower, in addition to paddy, wheat and some vegetables. About 6-7 years ago, farmers started growing this crop and continued to because of the higher returns involved. A kilogram of sunflower oil is sold at prices ranging from Rs. 80 to 100. A greater number of farmers are now taking up sunflower cultivation as a follow up crop after paddy harvesting.

- **Eroding 'traditional' ways**

There is an on-going shift to involve "modern amenities" into everyday life in the HM area. Historically, the tribal communities only believed in traditional ways of healing diseases, with the help of local ecological knowledge and traditional healers. However, in the past decade, higher proportions of people have started visiting government dispensaries to avail medical facilities. This dependency alongside also suggests that there is lesser emphasis on acquiring and practicing the 'local medicinal knowledge'. However, this is not the case in some of the relatively less managed sites located in interior hilly areas, which are still fairly disconnected from the market economy and direct trade linkages.

Most of the tribal communities have also undergone the process of ‘sanskritization’, which refers to low tribe communities taking over the customs and practices of a higher caste. In explicit forms, some of the practices of the communities reflected the ‘brahmanical’ ways. Additionally, the traditional language of tribals, ‘kui’ is not spoken anymore and almost forgotten, not passed on to the new generation. These changes in the social system may not have a direct and immediate impact on the ecology, but they may still have in subtle ways.

The above section discusses the changes related to the ecological base in the social system. In addition to changing ways of life, value-systems play a critical role in shaping both the social-ecological systems.

IV Synthesis: Coupled social-ecological dynamics

4.1. Introduction

The thesis attempted to assess the impacts of a cluster of interventions related to KL extraction over a landscape and to identify and analyze the linkages and feedback loops between the user groups, institutional structures and the ecological changes across a gradient from a low Kendu harvesting region to a high Kendu harvesting region. Having analyzed the socio-economic and the ecological aspects, this section will focus on inter-linkages and synthesis of the entire thesis using the existing theoretical frameworks (which has been highlighted in the initial section). This section will examine which theoretical propositions are approved or disapproved when applied in the context of this specific case study. Hence, the following frameworks will be analyzed:

1) NTFP Commercialization Literature
2) SES –Resilience/Adaptive Cycle
3) SES – Institutional Perspective

4.2. NTFP commercialization

NTFPs have been portrayed as fulfilling the twin objectives of poverty alleviation as well as sustainable management of forests (Wollenberg et al, 1998, Neumann et al, 2000). However, these are problematic assumptions which have been challenged in the recent years. There are very few extensive studies dealing with the commercial performance, developmental linkages and the ecological impacts of NTFPs (Belcher et al, 2004). On the one hand, the growing commercialization led to greater volumes of trade has resulted in increasing pressures and overexploitation of resources. (in Schreckenberg et al. 2006) On the other hand, livelihood of the forest dependent communities hasn't significantly improved with increased integration with the cash economy. Lately, theorists like Jesse Ribot have pointed out the need to question who really benefits from the processes and how the decision-making authority and the dynamics of control and access is spread out across actors.

In this case, through a focused analysis of the livelihoods and institutional structure from KL collection/sale/trade, it has been concluded that the primary KL pluckers have not benefitted much over the years. Moreover, the decision power has solely rested with the Government and a significant proportion of the net profits have been 'squandered' by the State government and OFDC in the royalty payments and commission respectively. The case of one Sagadabhanga Phadi (discussed under the social section) where pluckers from four villagers deposit their leaves highlights that the purchase price of KL is so low that the daily earnings of a plucker is even below the minimum wage level, and the payments are invariably delayed by a month or so after the leaves have been deposited. Atleast 50% of the net profits are supposed to be passed on to the primary pluckers under the KL grants system, however not even 10% is passed, which also gets scattered and remains either in the Panchayat fund or in the village fund. Therefore, under the existing nationalization system of KL trade/sale, returns to primary collectors have not been significant.

On the other hand, with this level of optimization of resources and pruning and collection of KL leaves, there have been some compositional changes in the ecosystem as described in the ecology section. The following section undertakes a more detailed analysis of the ecological patterns. However, the present data is sufficient to conclude that there are negative ecological impacts. This case more or less approves the larger scenario, where a host of research studies from across the world have suggested negative ecological impacts; however most of these were population biology related studies.

4.3. Social-Ecological Systems Framework

In the theoretical framework section, multiple conceptual models of social-ecological systems framework were discussed. In the results section, socio-economic aspects as well as ecological aspect of a forest ecosystem were discussed. Here, I will showcase the linkages in the case study and how it proves or disapproves the conceptual frameworks.

The coupled impacts of a cluster of human interventions related to KL on a landscape were discussed by highlighting the subtle qualitative changes in the vegetation composition in the highly managed areas.

How are these ecological changes felt in the social sphere? What is the response of the social system?

In this case study, the notion of 'scarcity' among the villagers in the highly managed region is yet not established. In explicit terms 'scarcity' is yet to be felt. These could be because of certain reasons. A direct observational point being that the proportion of forests vis-à-vis the proportion of people is quite less. Hence, for the communities, there is a vast stretch of forests to depend on. The other two points are – the spatial and temporal variations of the forest resources. This implies that even though there might be periods of scarcity felt – in case of delayed monsoons or extended summers or failed crop year – the diversity of resources spread across seasons and across spatial scales acts as a cushion against any event.

The management choices in this case study (Gochhabari village) (also, qualitative experiences and conversations from the villagers in Sagadabhanga, Malaspadar, Purunapani, Kuchumara, Sanasilinga) is to fulfill diverse wants and hence the dependency patterns range from fuelwood, a range of NTFPs, medicinal plants and so on. Among these, there are subtle priorities for some species over the others. Consciously or unconsciously, the user groups would maximize the priority species or those that are most important from the point of view of subsistence or for earning additional income. In case of wood, some 2-3 species (*Anogeissus latifolia, Terminalia tomentosa*) are highly preferred for fuel purpose, whereas some are preferred for house building purpose, especially *Shorea robusta*. Bamboo (*Dendrocalamus strictus*) is also required for building sheds for cattle, for creating boundary around the cultivation area to prevent cattle and boars from destroying. However, these management choices and preferences for species are not always planned or consciously made.

Within NTFPs, there is not just a diversity of types and usage but also variations across seasonal patterns. Most of the tubers, mushrooms and leafy vegetables are found with the onset of monsoons. Within tubers, there is a particular variety Masia kanda which is extremely sour in taste and hence undergoes several processes of boiling to reduce bitterness; but it is supposed to be very nutritious and beneficial for health. However, because of the effort involved, the preference for Masia has reduced over the years. Older men also point out that the young people do not consider 'sour' as being one of the tastes. Oil seeds like Mahua, Karanja are collected across time periods. Mahua seeds are collected during April to July and Karanj seeds collected

during Februrary to May. Mahua flowers are collected during the month of March-April and Kendu leaves are collected during the month of May-June. Fire is lit in the month of March, overlapping with the collection of Mahua flowers. Even if the nearby hilly areas haven't been lit by fire, the areas around the cultivation areas or home gardens comprising of Mahua trees are as it eases the process of collection. Both Mahua and Kendu are collected for 'additional income' purpose. Sal leaves are available almost throughout the year and serve as a stable source of low-income. The above description reflects the diverse set of choice and availability/collection periods spaced out across seasonal/temporal variations, hence leading to a continuous source of sustenance and additional income.

Additionally, a critical point emerged from the participatory resource mapping exercise (discussed in the social section) that the distribution of the resources is spread out all across the landscape (spatial variations). Though these areas are a host to multiple forest products, yet there are moderations of abundances among the sites. For ex: bamboo is found especially in Jhajhamara and Bhalkumasani hills whereas Dondapahada and Churokhulo are the best sites for Siali leaves. For Kendu leaves, Limandi and Dondapahada are among the most important sites for sal leaves Chitkabari and patches around these villages comprise old-growth sal forests. For tubers, Kali boli taela, Gadang is preferable, for mushrooms patches around the villages which has sal-dominated forests and for a particular kind of leafy vegetables are found at the onset of monsoons in a swampy area near Sanasilinga. This diversified distribution of resources across the landscape suggests that there are little direct or immediate trade-offs to be faced by the communities. There is not too much variation among the user groups (except for Hadi community being heavily dependent on bamboo). However, even if there was, the diversified distribution of resources also channelizes the user groups and their priorities accordingly unlike facing overlapping conflicting resource areas.

Though the user groups have witnessed and reported minor changes – with Kendu bushes expanding into newer areas and sal forests reducing in relative terms, the older generation people also immediately linked some of this phenomenon to the increase in population pressure over the decades. One of the villagers, Swayam Majhi, 60, also identified that there are many species which are not fire-resistant including sal and that their numbers have gradually decreased over the years. Few old women mentioned that there has been a change with regard to medicinal

plants. The knowledge base of the tribals of the medicinal plants is being eroded and not being passed on to the generations, and the loss of memory and reduction in the utilization of plants for medicinal used has somewhere also led to their decline in the abundance numbers in the forest. They identified fire as being a primary cause of that. When I interviewed some middle-aged women, young girls and old men in the village, there was a considerable difference in the host of medicinal plants and uses they could recollect and narrate. Most of the young children in the highly managed areas go to schools, unlike the case with the interior least managed areas. Some children in case of latter also study in higher secondary schools about 12 kms away, whereas a few of them have managed to attend colleges in towns and cities in about 50-100kms distance. There is a greater awareness of education and most of the people in different villages across the landscape have expressed the need for education and being the only path as they don't envisage a future in forested landscapes.

Overall, the discussion on the ecosystem changes and the dependency patterns of the social system in this particular context suggests a few things. First, there seems to be a phase difference in changes in the ecological sphere vis-à-vis social sphere. Perhaps these changes are not occurring simultaneously. And that for changes to be more apparent in the social system takes a longer time. But this is also further restricted by the fact that the overall 'degree of connectedness' with markets and trade linkages with the villages even in the HM areas is still not very high. The lack of roads, electricity and telephone networks especially serve as a barrier to the 'integration' with the cash economy, on the other hand the vast resource base is also contributing to the general satisfaction of the livelihoods in the study site. Additionally, this could also mean that because of the lack of the notion of 'scarcity', lack of strict boundaries/limits and lack of proper resource use arrangements; the early warning signals may not be seen or may be overlooked. This might in-turn lead to 'surprises' and 'shocks' in the ecological context. Till now, I have discussed the change in the ecological 'processes' which might or might not lead into 'state' changes. There is a, however, vast existing literature that deals with state changes and regime shifts. Liu et.al.(2007) states that when complexity is not understood, people may be surprised at the outcomes of human-nature couplings.

Ecosystem Resilience

Resilience theory has especially attempted to understand this phenomenon. Folke et. al. (2004) describe (referring to the seminal paper of Holling, 1973) that ecosystem resilience is defined as the magnitude of disturbance or perturbations that a system can experience before it shifts into a different state (stability domain) with different controls on structure and function and distinguished ecosystem resilience from engineering resilience. Folke et al. (2004) review a large body of evidence for regime shifts in both terrestrial and aquatic ecosystems in relation to resilience and discuss its implications for the generation of ecosystem services and societal development. Using examples from lakes, coral reefs, grassland, kelp forests and pine forest, among others, they discuss the alternate states and the causes and triggers behind loss of resilience and regime shifts.

Further, in the field of ecosystem dynamic and adaptive management, the model of an adaptive renewal cycle and the use of the idea of resilience have provided management insights (Holling 1986 as in Berkes *et.al*.2000). The adaptive renewal cycle encompasses four stages: exploitation, conservation, release and renewal. The model attempts to predict the reality of the responses of management practices to ecosystem changes in the context of natural resources. Through the case of a lagoon system, Berkes illustrates the different phases of the cycle. In the stage of exploitation and conservation, the water level is increasing and so is the biomass, in the stage of release brackish water, mature fish and shrimp leave the lagoon and in the last renewal phase, salt water, fish and larvae enter the lagoon.

The regime shifts, adaptive cycle models, the concept of 'ecological thresholds' have been theorized and also illustrated through case studies. The ecosystem witnesses these shifts and phases across multiple spatial and time scales depending on the magnitude and intensity of external perturbations. Some of these patterns and phases have been witnessed in both terrestrial and aquatic ecosystems; however they still cannot be generalized across different cases.

Systemic responses in forest ecosystem – case study

How is this ecological system likely to respond to a cluster of interventions – extraction of Kendu leaves, usage of fire, pruning operations and grazing? What might be the subtle factors

that might lead to state changes? And will it be a gradual process or will it be a non-linear one marked with ‘surprises’?

A system undergoes multiple layers of processes, simultaneous or not. In this particular case study, the ecosystem perhaps is still in the first stage of ‘exploitation’ (Berkes, 2002) and the direction it may take is unpredictable. However, discussion on the type of intervention and perturbations might help to gain some insights regarding the systemic changes and responses both at short time scales and at larger time scales.

In several instances, fires have been used as a disturbance to arrest the ecosystem at a mid-successional stage desirable by the human subsystem or even to favor the performance of a few species over others. Howe et al (2006) note that the existence of fire in tropical systems is a matter of contestation. Because repeated fires set by humans might degrade the plant communities, reduce diversity and increase the dominance of few tree species and admitting exotics (Howe et al 2006). Thus, the impacts of forest fires may be variable on different species impacting community composition and structure.

In this particular study site, fire has been historically occurring almost annually. Some of these maybe natural/wild fires (common phenomenon in tropical dry deciduous forests across Central and India) (which sometimes is also restricted by humans to prevent massive devastation in case of high intensity fires), whereas mostly fires are deliberately caused/managed by humans to serve various livelihood based needs. Several key components of natural disturbance regimes, including frequency, intensity and size of disturbance, act in a distinctive way on communities and populations, states Hobbs et. al.1992 (referring to White & Pickett, 1985).

One of the most important aspects is that fire has been discussed as a factor that can increase the likelihood of invasions (Christen & Burrows, 1986 as in Hobbs, 1992). Because species vary in their response to fires, fire may favor one set of species over another. In this case study, there has been a reported increase in weeds and invasive species (also fire-loving species). In one of the sites, the presence of a fire-loving invasive *Phoenix acaulis* was almost 35% of the total number of species encountered in the 1000m². plot and it occupies a large proportion of land. The local communities have also reported an increase in their numbers, while recognizing that it is a fire-loving species. However, for communities it is a boon as they make good use of *Phoenix*for

roofing annually during summer period prior to the onset of monsoons and also for making mats etc. This particular valley site with a high presence of *Phoenix* is also among the most degraded of all sampled sites. The entire patch is marked alternately by open barren patches with pebbles and with hardly any top soil. Overall the topography of the landscape is such that there are very few valley sites. Therefore, this is also a heavily grazed site. Some of the erosion can be attributed to run-off from the nearby hills and a stream, however, fire/invasion and heavy grazing also has a role to play. Additionally, an introduced weed *Chromolaena odorata* has massively spread over the years, as from the versions of the older men, but also contains useful medicinal value – to apply on wounds etc. The presence of this weed has been widely observed in the highly managed region as opposed to the less KL managed region. Fire can serve as being conducive for the spread such non-native weeds. Further, Hobbs et al.(1992) drawing from different case studies note that when these fire-tolerant species contribute to increased fuel loads, the disturbance regime can be shifted toward more frequent and intense fires; these fires further enhance the dominance of non-native over native species. In the long-run, these may result in the changes in the abiotic factors which may have critical consequences.

These are some of the changes that the ecological system is already undergoing, however which is not apparent in the social system. Additionally, both these species have been put to use in the social system and any increase/spread in their numbers will only be received positively and not necessarily as a trade-off vis-à-vis other species, as mentioned by some of the village members.

Role of Trade-offs

The compositional changes hint at emerging ecological trade-offs. An ecosystem does not function at its maximum potential at all times. At an ecosystem level, there are clear trade-offs involved across different types of forests and grasslands. Some of the recent studies have suggested that coffee plantations have potential for high carbon sequestration, but less for fodder, minor produce and diversity. Lele et. al. (1994), chart a detailed map of trade-offs among different benefits of an ecosystem at different stages.

The trade-off table (below) shows that every ecosystem state or land-use type provides a specific set of benefits for human well-being and there are hardly any scenarios which provide only synergies, and that every set of ecosystem benefits includes trade-offs (Lele et al. forthcoming).

The management choices of the user groups also highlight the probably trade-offs that the community is likely to face. For e.g. if a community decides to prioritize and optimize fuel wood, leaf manure and minor forest produce, benefits such as fodder and timber will be compromised in the process, shifting the system more towards 'dense lopped forest'.

Fig. 4.3.1 Illustrating trade-offs in an ecosystem (Lele et.al., 1994)

LAND USE TYPE			FOREST PRODUCT, SERVICE or BENEFIT								
			Timber	Fuel-wood	Leaf manure	Fodder	"Minor" Produce	Hydro-logical regulation	Soil Conser-vation	Bio-diversity	Carbon seques-tered
	"Forest"	Dense "natural" forest	0	++	++	0	+++	+++	+++	+++	+++
		Dense lopped forest	+	+++	+++	+	++	++?	++	++	++
		Open tree savanna	0	++	++	++	+	+?	++	+	+
		Pure grassland	0	0	0	+++	0	+++?	++	+	+
		Timber plantation	+++	+	+	0	0	+/-?	+	+	+++
	"Non-forest"	*Coffee plantation*	+	+	+	0	0	++?	++?	+	++
		Terraced paddy	0	0	0	++	0	+?	+?	?	0
		Slope cultivation	0	0	0	+	0	0?	-	?	0
		Barren land	0	0	0	0	0	-	-	0	0

Notes: 1. Source: Lélé (1994).
2. Plus signs indicate extent of positive benefits, minus signs indicate negative impacts. The signs represent physical impacts, and so are comparable only within a column, not across columns
3. Colours indicate different groups of beneficiaries: red=local, blue=regional, green=global.
4. Question marks indicate significant uncertainty about nature of impact

At the community level, these trade-offs exist even among species. For ex: if a particular patch is being optimized for one or two resources and accordingly the patch is groomed with certain interventions over the years, these might result in compositional changes, as already witnessed in the ecology section. Prioritizing and optimizing the sites for some species might not be conducive for all species to thrive. Perhaps a more detailed study would be required to investigate some of these patterns. Suppose a few leguminous species witness a reduction in abundance or were gradually eliminated; the reduction in the nutrient levels might eventually reduce the tolerance levels of adaptation of some species which require high nitrogen levels to survive and thrive. The vegetation compositional changes in the short time period might result in the changes in the abiotic factors in the long-run.

Swallow et al. (2009) state that "tradeoffs between ecosystem services arise from management choices made by humans, which can change the type, magnitude and relative mix of services provided by the ecosystem". Certain social groups within the community itself have specific resource dependency patterns. For instance, households dependent largely on NTFP species have interests that can be antagonistic to people who primarily depend on grazing. However, in this case study, though some of the patterns have been witnessed, however an even more confounding pattern has been found. Within NTFP species, the dependence over tubers (self-consumption) is higher for the relatively less wealthy members, those also of lower-caste in comparison to the wealthier members. The same poorer group is also highly dependent over Kendu leaves (commercial purpose). Kendu being a fire-loving species, and also that spreads through vegetative propagation in patches may not be equally conducive for tubers as well. In which case, the same community could face a direct trade-off between a resource for commercial purpose and one for sustenance purpose. Sustenance can be threatened in the face of commercialization and vulnerability of these specific social groups may increase beyond those of the others. Further, the dependence of the community over both Kendu and sal is significant. Both the NTFPs are largely for commercial purpose, while the former fetches a high economic value but the latter doesn't. However, sal leaves are abundantly available as a resource throughout the year, serving as a stable source, KL is only available for about a month during the lean season. Sal leaves are mostly collected and stitched/processed by women, unlike KL which is collected by both men and women. However, KL is a fire-resistant species and sal is a non-fire resistant species and even the villagers note that sal abundance has been affected over the years. The income contributing to the women's task and being of a stable source is being negatively impacted because the overall management priority of the villagers is to ensure high collection of KL. So, there are a clear set of trade-offs in a range of spheres. These patterns might lead to vulnerability in both the ecological and the social system.Such patterns have been recognized by Liu et.al. (in the review of seven case studies) in the context of Wisconsin where the socio-economic differences among people led to different choices and behaviors and in turn resulted in different ecological outcomes than if all had similar preferences, which is hardly ever witnessed in reality.

4.4. Institutional Perspective

For the longest time it was believed that national bureaucratic legislation was the only way to govern resources and communities were considered as a hindrance to social change (Agrawal et.al.2001). Hardin's "tragedy of commons" was a proposition to analyze the 'community' as a self-governing entity in the negative light as most of the outcomes is in the form of chaos, mis-management and degradation of resource base. However, this proposition has been criticized and identified as being conceptually flawed – as it addresses open-access systems rather than common property system. Further, failure in the outcomes of the former management system led to reconsidering the role of communities to better manage the forests, and ensure a decentralized process with increased local participation. Much of the analysis concentrated on the need to adequately define the property rights arrangement and sharing mechanisms. Community-based natural resource management gained a lot of momentum especially in the last decade. However, early CBNRM projects have also been criticized for relying on simplistic notions of a 'community' as a'homogenous' entity and with little scope for mediating agencies in political and economic means of negotiation. Over the years, this notion has shifted to view 'community' as a rather 'heterogeneous' group with multiple actors, interests, points of conflicts and contestations through the means of power and political linkages. However, an insight into institutions may be more useful than focusing only on community in the context of management of natural resources, as noted by Agrawal (1999).

Ostrom et.al. (2009) attempted to analyze social-ecological systems (as discussed in the introduction section) through an institutional perspective. They identified four sub-systems and highlighted the importance of 10 key variables that determine the social and the ecological performance which can be used for an overall synthesis of interactions and assess outcomes. Ostrom et. al. (2009) has always emphasized the need for 'self governance' and 'collective action', believing that locally managed forests thrive better than government protected forests. However, Ostrom herself admits that for land-related resource systems (like forests), very large territories are unlikely to be self-organized given the high costs of defining boundaries, monitoring use patterns and gaining ecological knowledge. Further, the prescription of analysis involves breaking down of the critical parts of the governance system and focusing on each one

of them such as social capital/norms/rules, leadership, monitoring and enforcement, among others.

Such a focus on formal structures with clear boundaries, transparency and codification of rules through written bye-laws and specification of property rights is common to the literature on 'design principles' for institutional development, notes Cleaver et. al. (2002) (referring to Ostrom, 1992, Agarwal, 1997). Strict definitions and neat categories of institutions as either 'weak' or 'robust' and also 'bureaucratic' or 'socially embedded' are favored in institutional analysis. Weak property rights are supposed to lead to contested outcomes.

However, in this evolutionary process of crafting and designing the institutional framework, social capital just becomes a raw material. However, the notion of social capital in itself is arbitrary, as Ostrom herself admits that there is a general lack of understanding about how to 'create, maintain, and use social capital' (Ostrom, 1992). Cleaver et.al.(2002), on the other hand[6], suggests to look beyond the dichotomies and rather recognize the inherent plurality of institutions and of actors. Institutions cannot be 'designed' consciously; rather they are outcomes of multiple layers of interactions, negotiations, articulations, conflict mechanisms mediated through the agency of varied actors forming complex networks and inter-linkages. Plurality of institutions and a dynamic political space (as also identified by Berkes, 2002) creates opportunity, processes of 'bricolage', of institutional improvisation which may also create spaces for negotiation, contestation and for different voices to be heard (Cleaver et.al.2002). These dynamic interactions might lead to complementing forces between both the bureaucratic form and the locally embedded form.

In this particular case study, to some extent, these dynamic interactions were witnessed. Though it is a protected forest, however there is no strict imposition of rules and norms as per the wildlife sanctuary. However, from time to time, the FD officials do impose or at least attempt to assert their authority over the local communities. The communities have witnessed a transition from reserve forest (equated to open-access) to a protected forest (some amount of enforcement). They feel that because of the sanctuary status, developmental activities (such as roads, electricity, telephone networks) have all evaded them. Multiple layers of responses, negotiations and

[6] Drawing from Levi-Strauss's concept of "intellectual bricolage"

contestations have been articulated by the community members. There is a constant expression of adjustment and compromise on part of local forest officials (such as forest guards and watchers) as well as local communities. There are instances when villagers express fear of being 'caught', of being 'imposed fines' for gathering fuelwood or for illegally engaging in KL trade or in domesticating wild boars or lighting fire in the forests deliberately. There are also instances when guards and watchers have expressed the fear of being 'beaten up' by the community as an act of rebellion or protest – expressing disregard to their authority. The local bureaucracy has known it the harsh way that the only way this can work is through 'adjustment', 'compromise' and 'negotiation'. There have been instances of both the parties coming together on one cause – to prevent fire from spreading into the forests. A fire committee was set-up consisting of about 12 members with monetary support from the Wildlife Department (WD). However, after two years (2010-12) it fell apart because of the meagre amount provided by WD and also because of a range of issues at inter and intra community level. However, the space for dialogue is yet to open up further. In some situations, multiple nuanced responses of the community members to the WD have been witnessed. Domestication of wild boards is a 'ritual' in the livelihoods of traditional Kondh tribals. However, this is in direct conflict with the department's objectives of 'protecting wildlife'. Though there is a fear among the villagers of being caught and some of them already have responded to the fear, while others resist and protest explicitly in the name of 'tradition' and 'ritual'. Very few articulate the scenario as *"I understand that the Department officials also have to perform their duty and in a way they are right, we should not domesticate a wild animal and be stubborn about our rituals. At the same time, we also need to put up a brave front or else they will think of us as complacent beings and impose their authority in other arenas too, so we must stay united and protest and fight"*.

In this way dynamic interactions and scope for dialogue and negotiations are mediated through the agency of multiple actors across both the parties. However, where does this take us? How can these nuances and plurality of forms be synthesized and analyzed as a complex whole? How can we comment on 'ecological sustainability' through this institutional framework? How does one assess the performance of the particular case study in the light of theoretical constructs and improvisations? One can highlight and discuss certain aspects of institutions that may or may not conform to the existing frameworks, however, drawing broader conclusions on SES and commenting on the 'robustness' or 'strength' of institutional mechanism is sufficiently difficult.

Another important aspect of the governance system (which may not be analyzed under a particular framework or theory) is 'decision-making' which in some contexts is taken at state level or national level instead of local level. In case of Kendu leaves, large-scale pruning operations of Kendu bushes are undertaken across the State. These tropical forests are multi-use forests that contribute to human well-being. Such a landscape level one species focused operations in itself will involve trade-offs because of the very nature of it. This mechanism has been functional from atleast late 70s onwards and this practice has trickled down at the village level as well. Hardly any agency or any interest of 'decision-making' and 'self-organizing' at the local scale has been expressed to manage and optimize the resource base.

In this section, I attempted to screen the frameworks discussed (in the introduction section) in the context of this specific case study, some sections approve of the frameworks and some other sections disapprove. However, for a holistic analysis of SES as a whole, more detailed analysis and comprehensive framework needs to be constructed. Some other theories like actor-network theory[7]can be explored and perhaps, context specific models need to be experimented.

[7] See Bruno Latour (1996, 2005) on this theory

Section V Conclusion

From the detailed synthesis of the above discussion section, four broad points have emerged. These have been synthesized to respond to the research objectives of this study.

- Certain social groups with overlapping caste/class grouping and specific resource dependency patterns may be more vulnerable to a change in the ecological dynamics. Hardly any institutional arrangements have been shaped that put limits on KL extraction, or assign no-fire or no-go areas. The history of KL hardly dates back to about 60 years. A general notion of ´resource scarcity ´ is yet to develop – vast spatial and temporal variations in resource distribution and also because of less proportion of people vs forests.

- Use of large-scale fire, grazing, KL collection will result in preference for some species (fire-loving) over others and lead to homogenization of the landscape, changes in abiotic factors in the long-run and entry of invasions in the short-run.

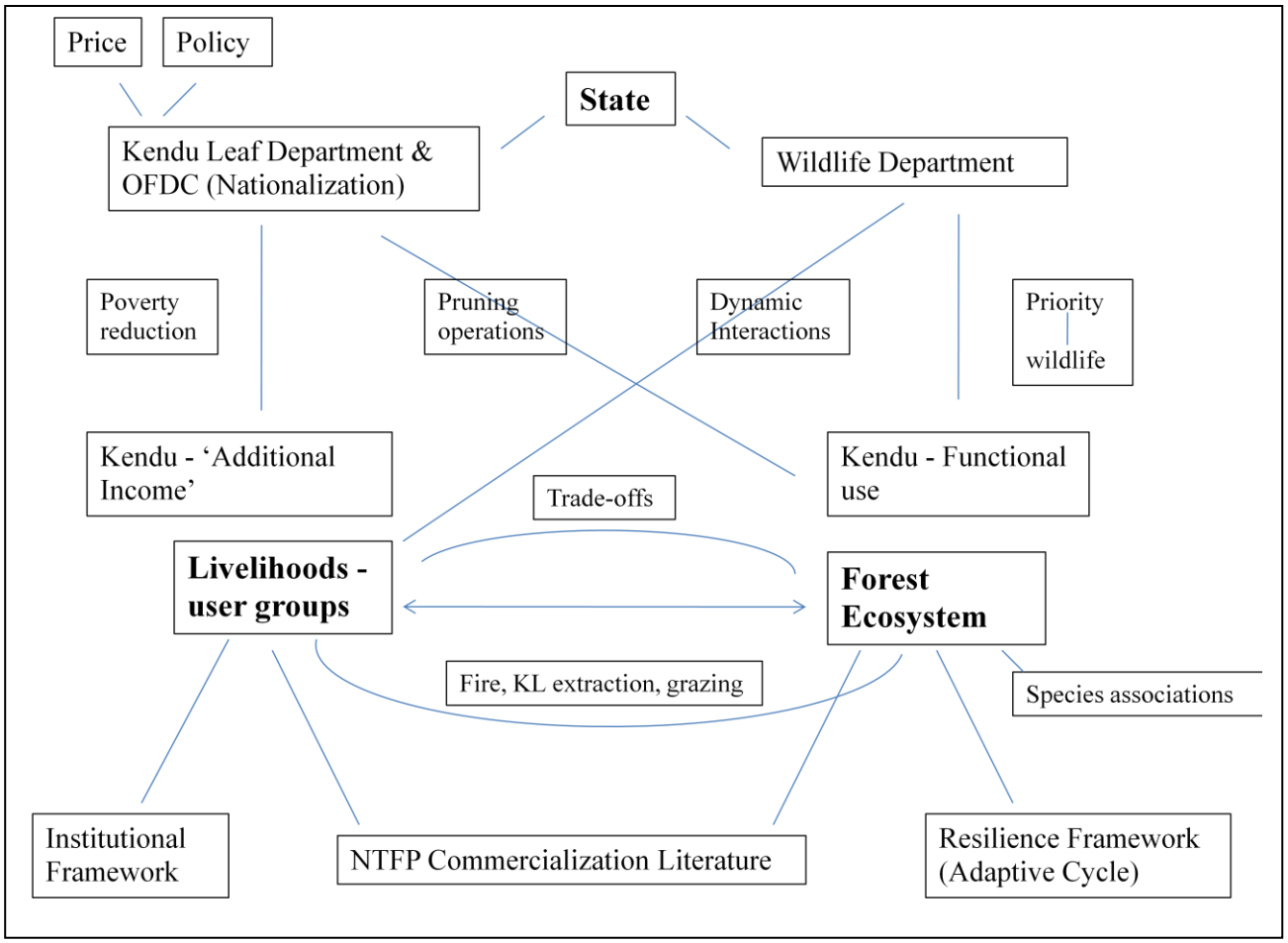
- Quantitative changes do not adequately capture the variations. Subtle qualitative changes in fact may reveal the loss of functional associations which is an important aspect for the livelihoods of the user groups (trade-offs in resource base) and for the sustainability of the ecology itself (also ecological trade-offs). The social and ecological system are inter-connected through various response loops and tweaking any of the linkage leads to changes in the other system.

- Large scale policy/institutional practices focussed on one-species pruning approach in itself will involve trade-offs as it is targeted towards multiple use forests. There is a complete trickle down in this approach even at the village level, as the pruning system will atleast have relatively mild effects in comparison to fires. However, there is little recognition that even such large-scale pruning operations might result in partitioning among resources and reducting in the vulnerability of the system as a whole.

The following figure illustrates the inter-dependence across three main entities (i.e. State, Livelihoods and Ecosystem) and the multiple linkages within the sub-systems. Most of these linkages have been discussed in the above sections. These responses do not necessarily operate

in a linear manner. Moreover, this figure highlights that the interactions function in loops and the responses could be non-linear and non-directional and spread across in multiple sub-systems in varied ways.

Fig. 5.1 The complex network of actors/stakeholders mediating through human and non-human agency



For e.g. Kendu leaf department (under the nationalized system) influences the purchase price of KL. However, through a governance analysis on KL (in the social section), it was found that the prices are significantly low in comparison to the share of the royalty payments of the state. Moreover, the KL grants system is also not implemented properly. However, the current ongoing debates at the state level are to decentralize the process (following FRA, 2006). The decentralization process includes that the net profits be transferred to the primary pluckers in its entirety (both royalty payments as well as KL grants, eliminating the amount 'squandered' by the State). Under this scenario, the income earnings of the pluckers under the KL system will atleast

be improved substantially. This might lead to an increase in optimization and preference for one species and perhaps increased extraction levels which might have effects on the ecological system. However, this is a simplistic linkage. In reality, the decentralized process will in itself bring about a plural set of institutional arrangements and greater power with the panchayat and gram sabha members or the local rural 'elites'. Moreover, even the decentralization can be sought with flaws, as witnessed in the case of Madhya Pradesh, in which the interference of the Forest Department in the cooperative model did not ensure smooth functioning of the system. The range of interactions, negotiations and contestations across social groups and power politics will lead to complex patterns of resource extraction and trade. As noted by Liu et.al.(2007), both markets and governance can cause decisions made in one place to affect people and ecosystems far away. The other factors which might influence KL extraction are the general market trends – the demand of beedis vis-à-vis demand for cigarettes or tobacco. In cases where phadis are relatively closer to the villages, it eases access of depositing KL. Moreover, trader linkages and negotiations with the village members and treating some as middlemen in exchange for commission also leads to instilling greater interest in the extraction and sale process. These interactions are operating at a micro-level in the larger context of the multiple linkages and stakeholders as reflected in the figure (above). At different micro-levels, several of these interactions are taking place, for e.g. between forest guards and villagers, between forest activists and the villagers, between state and policy makers and all of these micro-processes are operating and leading to complex nuanced inter-dependent consequences within a much larger macro-framework.

At the core of these processes is a primary question of 'sustainability' of social-ecological systems and of human-environment relationships and networks. In the ecological context, sustainability is defined as 'maintaining undiminished the ecological basis of human well-being' (Lele et.al.2006). Sustainability has been explored as a theme of "adaptability" or "resilience" referring to – how adaptable is the system to perturbations? How resilient is the system to external forces? Though sustainability has become a popular phenomenon to delve into, however, at the very base of it, some fundamental questions have not been explicitly addressed. These are: how do we measure sustainability? What is to be sustained and at what scale? And sustain for whom? Both subjective (value-judgements) and objective notions have been relied upon to address the set of questions.

At the micro-level, there are changes in the resources extraction patterns and lack of adequate tenure or ownership over forest resources. At the macro-level, there is a larger capitalist system that re-enforces the need for material consumption and the globalization process encourages greater connectedness with the import-export markets, longer trade chains and modern technology. Alongside, there have been changes in the value-systems or traditional ways of using resources or eroding traditional institutions and ways of life.

Sustainability is thus part of a larger debate about the relationship between environment and development, as noted by Lele et.al. (2006). Hence, the question doesn't always remain limited to the choice between open canopy forests vis-a-vis dense forests, but the question also is what if the choice is between forests and mines rather? Moreover, in the process are the economically weaker sections also facing socially exclusion which is further deepening the divide? How should sustainability be addressed in such a context? Moreover sustainability of social-ecological systems includes a critical component i.e. of environmental justice (inter and intra generation equity). Sustainability needs to be addressed not just for the present generation but also for the future generations which would continue to depend on the similar resource base and continue to inherit the value-systems imbibed from the social system.

There is much scope for further research of this study which includes undertaking an in-depth institutional analysis, focusing on specific linkages between both the social and ecological system and tracing their feedbacks over a longitudinal time and scale and addressing the larger question of sustainability by analyzing the plurality of networks, conflicting human and non-human agency and multiple layers of dynamics operating at different scales within the larger context of development and globalization.

References:

1. Agrawal, A., & Gibson, C. C. (1999). Enchantment and disenchantment: the role of community in natural resource conservation. *World development*, 27(4), 629-649.
2. Agrawal, A., & Gibson, C. C. (2001). *Communities and the environment: ethnicity, gender, and the state in community-based conservation*: Rutgers University Press.
3. Agrawal, A., & Yadama, G. (1997). How do local institutions mediate market and population pressures on resources? Forest Panchayats in Kumaon, India. *Development and change*, 28(3), 435-465.
4. Anderies, J. M., Janssen, M. A., & Ostrom, E. (2004). A framework to analyze the robustness of social-ecological systems from an institutional perspective. *Ecology and Society*, 9(1), 18.
5. Armesto, J. J., & Martínez, J. A. (1978). Relations between vegetation structure and slope aspect in the mediterranean region of Chile. *The Journal of Ecology*, 881-889.
6. Belcher, B., Ruíz-Pérez, M., & Achdiawan, R. (2005). Global patterns and trends in the use and management of commercial NTFPs: implications for livelihoods and conservation. *World development*, 33(9), 1435-1452.
7. Belcher, B., & Schreckenberg, K. (2007). Commercialisation of Non-timber Forest Products: A Reality Check. *Development Policy Review*, 25(3), 355-377.
8. Berkes, F., Colding, J., & Folke, C. (2002). *Navigating social-ecological systems: building resilience for complexity and change*: Cambridge University Press.
9. Berkes, F., & Folke, C. (1998*). Linking social and ecological systems for resilience and sustainability. Linking social and ecological systems: management practices and social mechanisms for building resilienc*e, 1-25.
10. Berkes, F., & Seixas, C. S. (2005). *Building Resilience in Lagoon Social-Ecological Systems: A Local-Level Perspective*. Ecosystems, 8(8), 967-974.
11. Boutin, S., Krebs, C., Boonstra, R., Dale, M., Hannon, S., Martin, K., et al. (1995). Population changes of the vertebrate community during a snowshoe hare cycle in Canada's boreal forest. *Oikos*, 69-80.
12. Carmel, Y., & Kadmon, R. (1999). Effects of grazing and topography on long-term vegetation changes in a Mediterranean ecosystem in Israel. *Plant Ecology*, 145(2), 243-254.
13. Cleaver, F. (2002). Reinventing institutions: Bricolage and the social embeddedness of natural resource management. *The European Journal of Development Research*, 14(2), 11-30.
14. Davis, F. W., & Goetz, S. (1990). Modeling vegetation pattern using digital terrain data. *Landscape ecology*, 4(1), 69-80.

15. De Vaus, D. (2001). Research *design in social research*: SAGE Publications Limited.
16. Folke, C., Carpenter, S., Walker, B., Scheffer, M., Elmqvist, T., Gunderson, L., et al. (2004). Regime shifts, resilience, and biodiversity in ecosystem management. *Annual Review of Ecology, Evolution, and Systematics*, 557-581.
17. Franklin, J. F., & Spies, T. A. (1991). *Composition, function, and structure of old-growth Douglas-fir forests. Wildlife and Vegetation of Unmanaged Douglas-fir Forests*. USDA Forest Service General Technical Report PNW-GTR-285, 71-80.
18. Hall, P., & Bawa, K. (1993). Methods to assess the impact of extraction of non-timber tropical forest products on plant populations. *Economic botany*, *47*(3), 234-247.
19. Hecht, S.B., Anderson, A.B., and May, P. 1988. The Subsidy from Nature: Shifting Cultivation, Successional Palm Forests, and Rural Development, *Human Organization 47*:25-35
20. Hobbs, R. J., & Huenneke, L. F. (1992). Disturbance, diversity, and invasion: implications for conservation. *Conservation biology*, 6(3), 324-337.
21. Holling, C. S. (1973). Resilience and stability of ecological systems. *Annual review of ecology and systematics*, *4*, 1-23.
22. Holling, C. S. (2001). *Understanding the Complexity of Economic, Ecological, and Social Systems. Ecosystems*, *4*(5), 390-405.
23. Janssen, M. A., Anderies, J. M., & Ostrom, E. (2007). Robustness of social-ecological systems to spatial and temporal variability. *Society and Natural Resources*, *20*(4), 307-322.
24. Jodha, N. S. (1986). Common property resources and rural poor in dry regions of India. *Economic and political weekly*, 1169-1181.
25. Jorgensen, D. L. (1989*). Participant observation: A methodology for human studies* (Vol. 15): Sage Publications, Incorporated.
26. King, E. G., & Hobbs, R. J. (2006). Identifying linkages among conceptual models of ecosystem degradation and restoration: towards an integrative framework. *Restoration Ecology*, *14*(3), 369-378.
27. Lele, S. (1998). Resilience, sustainability, and environmentalism. *Ecological Economics*, *2*, 1-7.
28. Lélé, S. (1994). Sustainable use of biomass resources: A note on definitions, criteria, and practical applications. *Energy for Sustainable Development*, *1*(4), 42-46.
29. Lélé, S. (2006). Thinking about ecological sustainability. Paper presented at the SEMINAR-NEW DELHI-.
30. Lélé, S., & Norgaard, R. B. (2002). Sustainability and the scientist's burden. *Conservation Biology*, *10*(2), 354-365.

31. Liu, J., Dietz, T., Carpenter, S. R., Alberti, M., Folke, C., Moran, E., et al. (2007). Complexity of coupled human and natural systems. *Science, 317*(5844), 1513-1516.
32. Magurran, A. E. (1988). *Ecological diversity and its measurement* (Vol. 168): Princeton university press.
33. Magurran, A. E. (2004). *Measuring biological diversity*.
34. Marshall, E., Schreckenberg, K., & Newton, A. (2006). Commercialization of non-timber forest products: Factors influencing success: Lessons learned from Mexico and Bolivia and policy implications for decision-makers: UNEP/Earthprint.
35. Middleton, B., Saberwal, V., & Rangarajan, M. (2003). Ecology and objective based management: Case study of the Keoladeo National Park, Bharatpur, Rajasthan. *Battle over nature: Science and the Politics of Conservation*, 86-116.
36. Mueller-Dombois, D., & Ellenberg, H. (1974). *Aims and methods of vegetation ecology*.
37. Neumann, R. P., & Hirsch, E. (2000). Commercialisation of non-timber forest products: review and analysis of research: *Cifor*.
38. Newing, H. (2010). *Conducting research in conservation: social science methods and practice*: Routledge.
39. Norgaard, R. B. (1989). The case for methodological pluralism. *Ecological Economics, 1*(1), 37-57.
40. Olsson, P., & Folke, C. (2001). Local ecological knowledge and institutional dynamics for ecosystem management: a study of Lake Racken watershed, Sweden. *Ecosystems, 4*(2), 85-104.
41. Ostrom, E. (1992). *Crafting institutions for self-governing irrigation systems.*
42. Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science, 325*(5939), 419-422.
43. Peet, R. K. (1974). The measurement of species diversity. *Annual review of ecology and systematics, 5*, 285-307.
44. Pickett, S., Kolasa, J., Armesto, J., & Collins, S. (1989). The ecological concept of disturbance and its expression at various hierarchical levels. *Oikos*, 129-136.
45. Rai, N. D., & Uhl, C. F. (2004). Forest *product use, conservation and livelihoods: the case of Uppage fruit harvest in the Western Ghats, India. Conservation and Society, 2*(2), 289.
46. Redman, C. L., Grove, J. M., & Kuby, L. H. (2004). Integrating Social Science into the Long-Term Ecological Research (LTER) Network: Social Dimensions of Ecological Change and Ecological Dimensions of Social Change. *Ecosystems, 7*(2), 161-171.
47. Runkle, J. R., Pickett, S., & White, P. (1985). *Disturbance regimes in temperate forests.* The ecology of natural disturbance and patch dynamics, 17-33.

48. Saha, S., & Howe, H. F. (2003). Species composition and fire in a dry deciduous forest. *Ecology, 84*(12), 3118-3123.
49. Scherr, S. J., & McNeely, J. A. (2008). Biodiversity conservation and agricultural sustainability: towards a new paradigm of 'ecoagriculture'landscapes. Philosophical Transactions of the Royal Society B: *Biological Sciences, 363*(1491), 477-494.
50. Schreckenberg et al. (2006). *Commercialisation of Non-Timber Forest Products: What Determines Success?* Forestry Briefing, ODI.
51. Simberloff, D. (2004). Community ecology: is it time to move on? *The American Naturalist, 163*(6). 787-799.
52. Stringham, T. K., Krueger, W. C., & Shaver, P. L. (2003). State and transition modeling: an ecological process approach. *Journal of Range Management,* 106-113.
53. Walker, B., Kinzig, A., & Langridge, J. (1999). Original articles: plant attribute diversity, resilience, and ecosystem function: the nature and significance of dominant and minor species. *Ecosystems, 2*(2).
54. Walker, B. H., Anderies, J. M., Kinzig, A. P., & Ryan, P. (2006). Exploring resilience in social-ecological systems through comparative studies and theory development: introduction to the special issue. Ecology and *Society, 11*(1), 12.
55. Ward, R. M., & Krebs, C. J. (1985). Behavioural responses of lynx to declining snowshoe hare abundance. *Canadian Journal of Zoology, 63*(12), 2817-2824.
56. Weinstein, S., & Moegenburg, S. (2004). Acai palm management in the Amazon Estuary: Course for conservation or passage to plantations? *Conservation and Society, 2*(2), 315.
57. Westoby, M., Walker, B., & Noy-Meir, I. (1989). Opportunistic management for rangelands not at equilibrium. *Journal of range manage*ment, 266-274.
58. Whittaker, R. H. (1967). Gradient Analysis of Vegetation. *Biological Reviews*, 42(2), 207-264.
59. Wiersum, K. (2004). Forest gardens as an 'intermediate' land-use system in the nature–culture continuum: characteristics and future potential. *Agroforestry Systems, 61*(1), 123-134.
60. Wollenberg, E., & Inglés, A. (1998). Incomes from the forest: methods for the development and conservation of forest products for local communities: *Cifor.*

Annex I: The PEFESPA project

This thesis will serve as a sub-project to this larger project. The project titled, "Political Ecology of Forest Ecosystem Services" is a combined initiative of University of East Anglia (UEA), UK, Ashoka Trust for Research in Ecology and the Environment (ATREE), Bangalore and Vasundhara, Odisha. This two-year long project (2010-12) is funded by the National Environment Research Council, UK. The principal investigators of this project are Dr. Oliver Springate-Baginski (UEA) and Dr. Sharachchandra Lele (ATREE) and the co-investigators are Debal Deb, Madhu Sarin and Prasad Dash (Vasundhara).

The broader goal of this project is to "integrate the assessment of forest ecosystem services (biophysical and economic) with the political economy of pro-poor governance" and the key research objectives are:

- "To generate insights into the nature and magnitude of tradeoffs between forest ESs and service users or rights holders under different management regimes.
- To understand the influence of changes in rights, institutional arrangements and larger governance mechanisms on the distribution of ES benefits, especially to the poor.
- To develop a conceptual framework and methodology that incorporates the core concepts of ecological complexity, tradeoffs and institutions into an assessment framework.''

(Directed Proposal, Springate-Baginski, 2010)

This project aims at a multi-disciplinary analysis by reconciling the views of ecologists and political economists/ecologists, anthropologists in order to develop a much nuanced and holistic perspective of ecosystem services. While the former emphasize on the benefits derived from the forests and on valuation of services, the latter point to trade-offs, to the role of institutions and to the issues of equity and rights of pro-poor in the context of forest governance. The inter-disciplinary approach will combine ecosystem functioning, economic and non-economic valuation and the politics of access and control over natural resources.

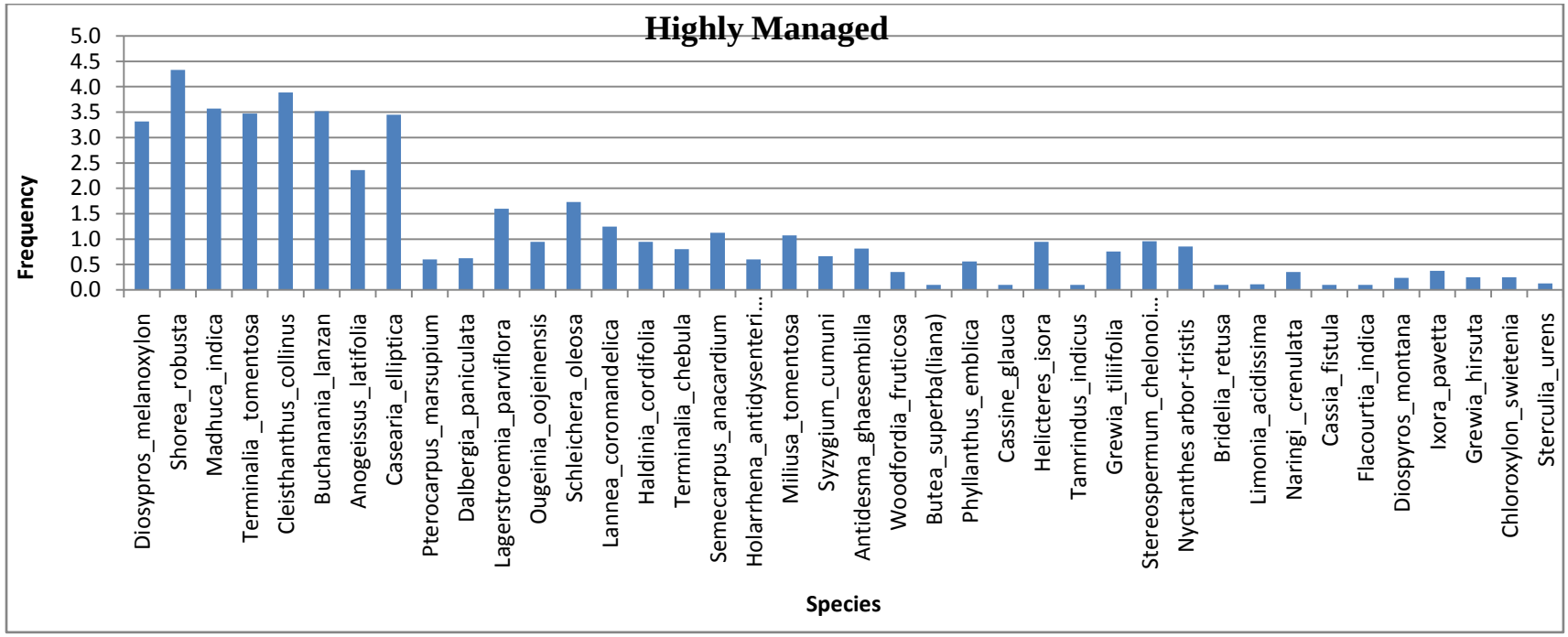
This study is based in Eastern Ghats, in the state of Odisha, which comprises of a significant tribal population dependent on forests. And the field study is carried out in three different

management regimes, Community Forest Management (CFM), State managed Reserve Forests (RF) and Protected Area (PA). This will facilitate comparison of the institutions, the trade-offs among services and the impacts on livelihoods across regimes.

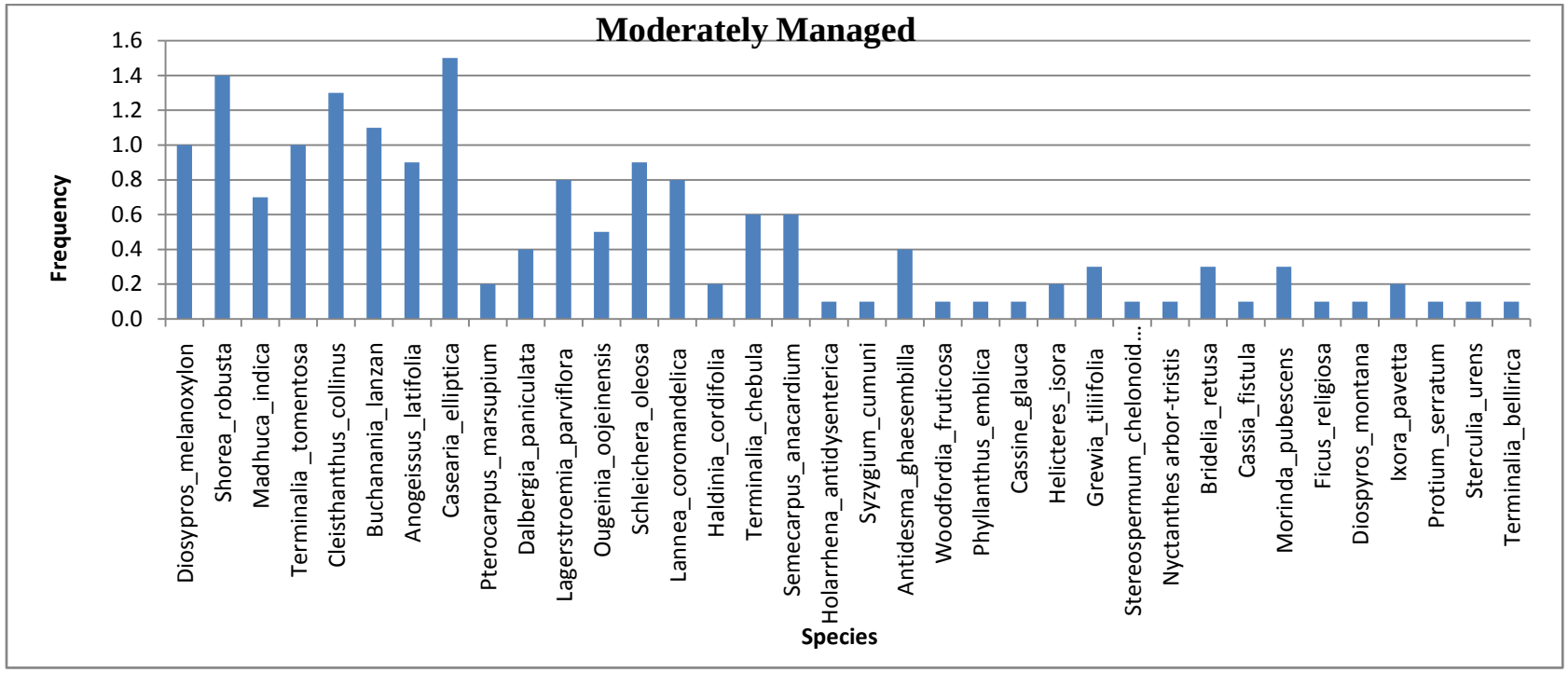
Under the three governance regimes, three sites have been selected to study based on certain criteria. Ranpur and Dengajhari have been selected as CFM sites, Aranga as the RF site and Baisipalli Wildlife Sanctuary as the PA site. Within each case study the flow of the bundle of ecosystem services will be mapped and their distribution among different stakeholders assessed. Species attention will be given to trade-offs between ecosystem services across different management regimes and their effects on service beneficiaries.

Annex II: Frequency Distribution

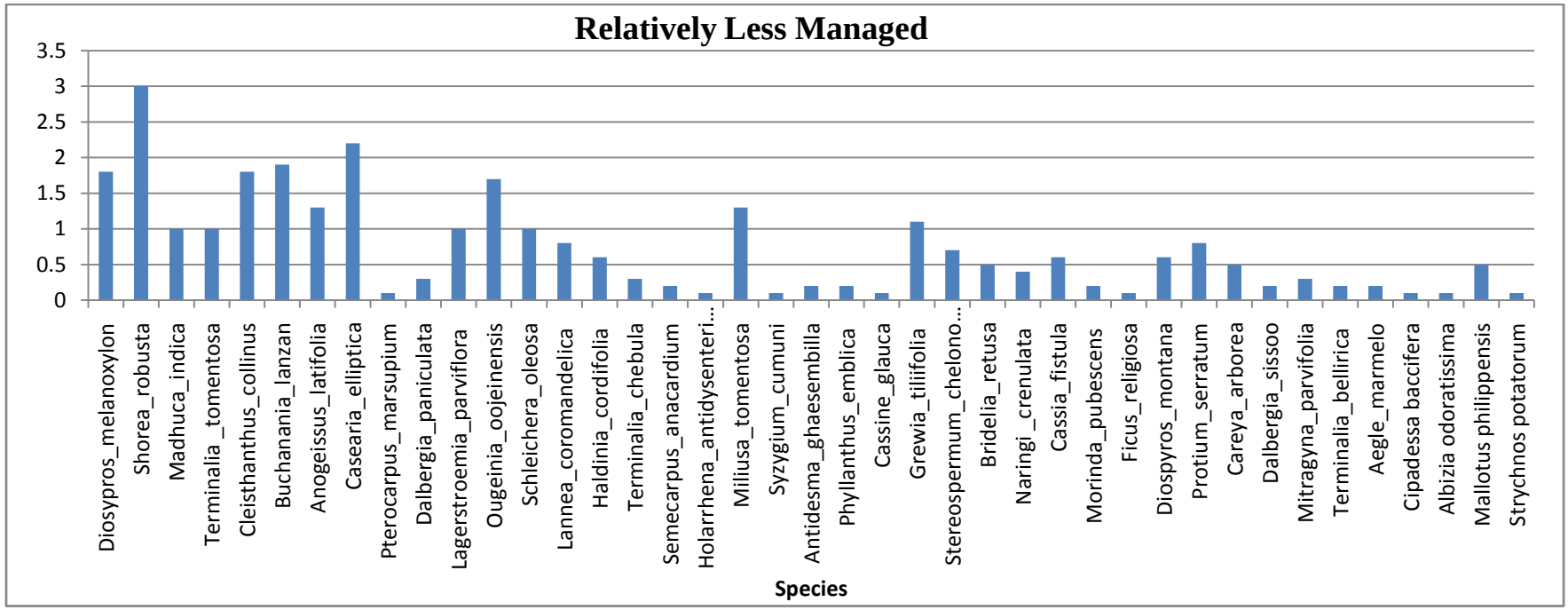
Frequency distribution of species across all sites in HM



Frequency distribution of species across all sites in MM



Frequency Distribution of Species across all sites in RLM



Annex III: Household Survey PEFESPA

(Only relevant sections of the entire questionnaire have been pasted here)

Date:

Enumerator:

No answer/Mistake=99

Village name (& hamlet name if any)	
Household number (from HH list)	

1. Household demography, occupation and assets

1.1. Household demography:

Name of head:

Person who answered:

Caste/tribe of head (1.1.1)	

Household member	Name (of first 6 household members) (1.1.3)	Age (**years**) (1.1.4)	Sex (**M-1, F-2**) (1.1.5)	Relationship to head (**CODES**) (1.1.6)	Level of education (1.1.7)
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					

Household member	Village-based occupation (**CODES**) (1.1.8)	
	Primary (**months/year**)	Secondary (**months/year**)
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		

Codes:

***Relationship to head**: **1**-Self, **2**-Wife/husband, **3**-Child, **4**-Brother/sister, **5**-Father/mother, **6**-Other relatives*

***Level of education**: **0**-Uneducated, **1**-Primary, **2**-Secondary, **3**-Higher*

***Occupation**: **1**-Farming, **2**-Forest collection for sale, **3**-Livestock rearing, **4**-Wage labour (MNREGA), **5**-Small-scale business/trade/manufacturing, **6**-Salaried employment, **7**-Other, namely…*

1.2 Non village-based employment and residence/seasonal migration

How many of the household members seasonally travel to and live in different places to earn money for the household? (1.2.1)	Sex (**M-1, F-2**) (1.2.2)	Type of work (**CODES**) (1.2.3)	Location of work (**CODES**) (1.2.4)

Codes by column:

***Type of work**: **1**-Agriculture, **2**-Construction, **3**-Industry, **4**-Porter, **5**-Other, namely...*

***Location of work**: **1**-Within State, **2**-Outside State*

1.3 Assets

Type of asset	Presence and quantity (1.3.1)
a. Two wheeler	
b. Tractor, harvester, thresher	
c. House (katcha/laterite blocks/pucca)	
d. TV	
e. Salaried job/business (anyone in HH)	
f. Other, namely…	

1.4 Land ownership

	Type	Area (**unit**)	Crop type
a. Own land	Dry		
	Wet/Irrigated		
	Plantation		
	Fallow (short)		
	Fallow (long)		
b. Leased in/Sharecropping			
c. Leased out			
d. Encroached land			

1.4 Other NTFPs

	Collected (**Yes-1, No-2**)? (1.4.1)	Who collects? (**M-1, F-2, C-3**) (1.4.2)	Quantity own use (1.4.3)	Quantity for sale (**year**) (1.4.4)	Effort (**person hours**) (1.4.5)	Period of collection (**days/year**) (1.4.6)	If sold, for what price (**Rs./unit**)? (1.4.7)	Collected from outside CFM boundary?
Kendu leaves								
Siali leaves								
Sal leaves								
Sal seeds								
Oil seeds								
Honey								
Fruits/vegetables								
Bushmeat/fish								
Tubers								
Mushrooms								
Mahua flowers (Mohula)								
Mahua fruits								
Others								
...								
...								

1.3 Medicinal plants

List 5 main species (1.3.1)	
Who collects (**M-1, F-2**) (1.3.2)	
Over the last two years, what critical diseases have been remediated? (1.3.3)	
Constraints regarding collection, use and sale (access/quality/dispute) (1.3.4)	

1.5 NTFPs - Constraints

Constraints regarding collection, use & sale	

Annex IV: List of Floral Species Observed

Local Names	Scientific Names
Sal	*Shorea robusta*
Char	*Buchanania lanzan*
Jamburli	*Antidesma ghaesembilla*
Karada	*Cleisthanthus collinus*
Mahula	*Madhuca indica*
Kusuma	*Schleichera oleosa*
Bahada	*Terminalia bellirica*
Harida	*Terminalia chebula*
Kuruma	*Haldinia cordifolia*
Asana	*Terminalia tomentosa*
Khokhoda	*Casearia elliptica*
Bandhana	*Ougeinia oojeinensis*
Bhalia	*Semecarpus anacardium*
Patuli	*Stereospermum chelonoides*
Kendu	*Diospyros melanoxylon*
Dhaura	*Anogeissus latifolia*
Bhenta	*Naringi crenulata*
Masuri	*Miliusa tomentosa*

Gambhari	*Gmelina arborea*
Jambu	*Syzygium cumuni*
Gangasiuli	*Nyctanthes arbor-tristis*
Kosi	*Bridelia retusa*
Sunari	*Cassia fistula*
Siali	*Bauhinia vahlii*
Moi	*Lannea coromandelica*
Haldia	*Diospyros montana*
Sidha	*Lagerstroemia parviflora*
Amla	*Phyllanthus emblica*
Barabakuli	*Dalbergia paniculata*
Piasala	*Pterocarpus marsupium*
Kumbhi	*Careya arborea*
Kurein	*Holarrhena antidysenterica*
Sunaragouda	*Grewia hirsuta*
Chauli	*Cassine glauca*
Nimboro Moi	*Protium serratum*
Usta	*Ficus religiosa*
Mitibini/Mitikinia	*Mitragyna parvifolia*
Patalagaruda	*Rouvolfia serpentine*

Baincha	*Flacourtia indica*
Pokosungha	*Chromolaena odorata*
Salia baunsa	*Dendrocalamus strictus*
Dhamana	*Grewia tiliifolia*
Arkala	*Millettia extensa*
Anchu	*Morinda pubescens*
Orgha/Adanga	*Cycas sphaerica*
Khajuri	*Phoenix acaulis*
Mura	*Helicteres isora*
Genduli	*Sterculia urens*
Bheru	*Chloroxylon swietenia*
Kaitho	*Limonia acidissima*
Tentuli	*Tamrindus indicus*
Chakhunda	*Cassia siamea*
Anchu	*Morinda pubescens*
Atini Lata/Atandi	*Combretum roxburghii*
Buduli	*Butea superba*
Jhatikiri	*Woodfordia fruticosa*
Telkuruma	*Ixora pavetta*
Sissoo	*Dalbergia sissoo*

Kendu	*Diospyros melanoxylon*
Bel	*Aegle marmelo*
Kamalagundi	*Mallotus philippensis*
Nahalobeli	*Cipadessa baccifera*
Kumutia	*Ventilago denticulata*
Katka	*Strychnos pottatorum*
Siriso	*Albizia odoratissima*