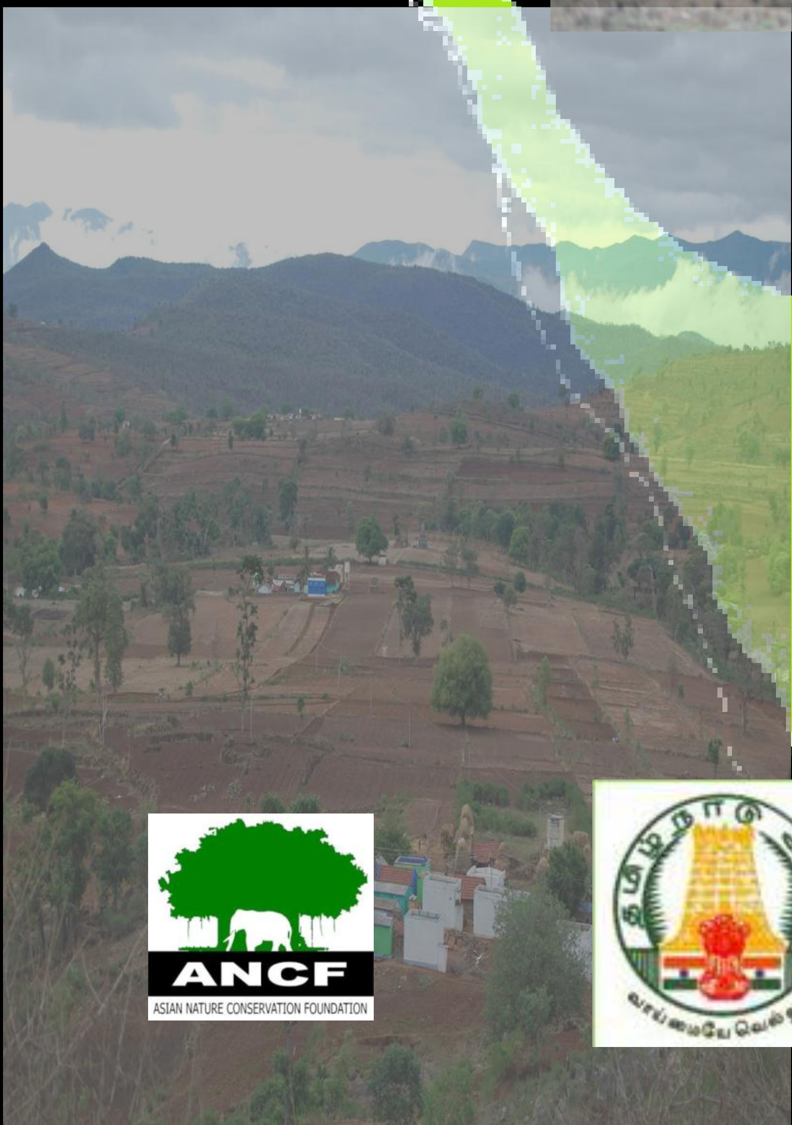
HUMAN DIMENSIONS OF FOREST DEGRADATION IN THE SATHYAMANGALAM LANDSCAPE

Spatial pattern of disturbances, socio-economic status, and sustainability



Narendran Kodandapani PhD
N. Satheesh IFS
Ashutosh Samant Singhar IFS
K. Raj Kumar IFS

ANCF
ASIAN NATURE CONSERVATION FOUNDATION

Centre for Advanced Spatial and Environmental Research

Human dimensions of forest degradation in the Sathyamangalam landscape

<u>Principal Investigators</u>

Narendran Kodandapani PhD
N. Satheesh IFS
Ashutosh Samant Singhar IFS
K. Raj Kumar IFS

<u>Research Assistants</u>

Vinoth M.Sc

2014

Published jointly by
Asian Nature Conservation Foundation (ANCF)
Center for Ecological Sciences, Indian Institute of Science, Bangalore – 560 012, India
www.asiannature.org

Sathyamangalam Forest Division
Tamil Nadu Forest Department

Center for Advanced Spatial and Environmental Research (CASER)
53, 2nd Main, Raghavendra Nagar, Ramamurthy Nagar, Bangalore 560016, India.

Title: Human dimensions of forest degradation in the Sathyamangalam landscape.

Authors: N.Kodandapani, Satheesh, N., Ashutosh, S.S, Raj Kumar, K.

Suggested Citation: Kodandapani, N., Satheesh, N., Ashutosh, S.S., Raj Kumar, K. 2014. Human dimensions of forest degradation in the Sathyamangalam landscape.

First Limited Edition 2014
Published jointly by ANCF, Tamil Nadu Forest Department & CASER

To order a copy of this publication, please write to

Publications Officer
Asian Nature Conservation Foundation (ANCF)
Innovation Center
Indian Institute of Science
Bangalore 560 012
Email: publications@asiannature.org
Or
District Forest Officer
District Forest Office
Sathyamangalam Division,
Gobi Main Road
Sathyamangalam 638 402.

Contents

THIRU. GAUTAM DEY, IFS.,
Principal Chief Conservator of
Forests (Head of Forest Force)

Panagal Maaligai
Sidapet
Chennai 15

Dated: 27.01.2014

PREFACE

The Sathyamangalam Forest Division is an important link between Eastern and Western Ghats in South India situated in the tri junction of three protected areas of Nilgiri Biosphere Reserve. Recent trends in biodiversity conservation efforts all over the world are concentrating more and more on landscape level approaches. The report titled "Human dimensions of forest degradation in the Sathyamangalam landscape" is an attempt to bring out the scientific information on the current status of the forest ecosystem, disturbances and socio-economic conditions in the landscape. Forest disturbances are common in several forest areas of Tamil Nadu. I am very happy that the authors of this pioneering landscape scale research project on spatial characteristics of forest characteristics and disturbances have put sincere efforts in systematic data collection, analysis, mapping and interpretation of the study. Although it is a short term study, the analysis has provided an insight on baseline information on the spatial pattern of forest characteristics and other information in the landscape. I would like to place on record this report, which is the result of dedicated efforts by Thiru.N.Satheesh,IFS., Thiru. Ashutosh Samant Singhar,IFS., K. Raj Kumar, IFS., and Dr.Narendran Kodandapani, and supported by the field staff. I congratulate the authors for their contributions and wish them all success in their effort to conserve the wildlife in the landscape.

I hope this report would benefit the upcoming research on carnivores in this region.

(GAUTAM DEY)

Thiru.Ashutosh Samant Singhar,IFS.,
Additional Principal Chief Conservator
of Forests (Forest Conservation Act)

Office of the Principal Chief
Conservator of Forests
(Head of Forest Force)
Panagal Maaligai
Sidapet, Chennai 15

Dated: 27.01.2014

FOREWORD

Disturbances such as forest fires, grazing, invasive species, and logging are major occurrences in almost all human dominated landscapes in the tropics. The Millennium development goals of the United Nations, estimates that 15 of the 24 provisioning, regulating and cultural services derived from forests, are degraded and unsustainable. The tropics are witnessing increasing pressures on their natural resources, conservation and management of these natural resources will require accurate information of these resources within these regions, as well as the underlying factors contributing to forest degradation. This report provides the first detailed study of different aspects of forest disturbances and socio-economic conditions in the Sathyamangalam forests.

Sathyamangalam is the largest (area wise) forest division in Tamil Nadu. It bridges two unique bio geographic entities, i.e., the Eastern and the Western Ghats in peninsular South India and constitutes a large contiguous natural forest ecosystem. It comprises a large chunk of rain shadow forest area, with lower average annual rainfall. On the other hand it is bestowed with perennial sources of water, such as the Moyar river. Forests here are varied and diverse and represent valuable biodiversity, with several rare and threatened and endangered species. Major area is covered with tropical dry deciduous forests. Considering the biological diversity and importance, about 887 km^2 of reserve forest in the landscape was declared a wildlife sanctuary in 2011. Recently, large portions of the forests in Sathyamangalam were converted into a Project Tiger Area with more conservation inputs, due to presence of a very good population of top carnivores like tigers and large herbivores such as elephants and bisons.

The present report contains information pertaining to forest disturbances, and socio-economic conditions in the Sathyamangalam landscape in Southern India. The timing of this publication is critical in the sense that it provides important baseline and tertiary information for the landscape at a time of increasing global and local environmental changes. Numerous studies around the world indicate an increasing trend in forest degradation. The environmental, ecological, climatic and anthropogenic factors surrounding these disturbances are poorly understood, especially in the tropics. Simultaneously, the tropics are witnessing increasing pressures on their natural resources. Conservation and management of these natural resources will require accurate information on these disturbances as well as the underlying causes of disturbances within the landscape.

The present report is one among several scientific studies carried out in short span of duration in this landscape. The research project titled "Human dimensions of forest degradation in the Sathyamangalam landscape" has tried to systematically collect, analyze and map the spatial patterns of various forest disturbances and socio-economic conditions in the landscape. In a short time period, this study has generated several valuable data and insights critical for conservation planning in the landscape. The recommendations brought out from the field study will help the field managers in providing appropriate management plan for this region.

We put on record our sincere thanks to field staff in Sathyamangalam Forest Division for assistance in the field and staff in the Geomatics Laboratory at the Office of the Principal Chief Conservator of Forests, Chennai and National Remote Sensing Agency, Hyderabad for remote sensing data. Our thanks are due to Thiru. Gautam Dey, IFS., Principal Chief Conservator of Forests (Head of Forest Force) for his constant encouragement and advices.

(ASHUTOSH SAMANT SINGHAR)

Acknowledgements

We would like to thank Thiru Gautam Dey IFS, the Principal Chief Conservator of Forests (HOFF) for giving the permission, encouragement and constant support for the study. Our thanks to Thiru A. Venkatesh IFS, Conservator of Forests, for his kind support. We extend our sincere thanks to the Forest Range Officers of Bhavanisagar, Sathyamangalam, Haasanur, Thalavadi and T.N.Palayam for their help during the study. We especially thank Mr. Siddan, range forest officer, Haasanur for his support. We are grateful to Foresters, Forest Guards, Forest Watchers and anti-poaching watchers for their co-operation to carry out the field work.

We would like to thank Mr. Thomas Mathew, Trustee, ANCF for his encouragement. We are thankful to Prof. R. Sukumar, Centre for Ecological Sciences, IISc for his support. We would like to thank Dr. C. Arivazhagan for continued support. We would like to thank Prof. N. V. Joshi for statistical guidance. Prof. David Martin of Davidson college provided useful suggestions in designing the questionnaire survey and also sampling design for the socio-economic studies.

We place on record our sincere thanks to field staff in Sathyamangalam Forest Division for assistance in the field and staff in the Geomatics Laboratory at the Office of the Principal Chief Conservator of Forests, Chennai and National Remote Sensing Agency, Hyderabad for remote sensing data.

Executive Summary

The report presents information pertaining to forest disturbance characteristics and the underlying causes of forest disturbance in the Satyamangalam landscape in southern India. The timing of this publication is critical in the sense that it provides important baseline and tertiary information for the landscape at a time of increasing global and local environmental changes.

The Millennium development goals of the United Nations, estimates that 15 of the 24 provisioning, regulating and cultural services derived from forests, are degraded and unsustainable. The tropics are witnessing increasing pressures on their natural resources, conservation and management of these natural resources will require accurate information of these resources within these regions, as well as the underlying factors contributing to forest degradation.

Data on forest disturbances were gathered from 60 transects that began randomly from the edge of the village and extended into the forest. We surveyed 18 sampling locations around each village, in all about 360 sampling points were surveyed for seven disturbance indicators. A PCA was conducted on the seven habitat variables, the eigen value analysis indicated that the first three principal components were important to assess habitat disturbance. Together the first three principal components explained 57% of the variability in the seven habitat disturbance variables. Both the ANOVA analysis as well as the linear model showed statistically significant effect of village size (number of households) on the disturbance in the landscape.

We examined one landscape disturbance in-depth, forest fires are annual disturbances in the landscape. Mean (fire-rotation interval) FRI ranges from 2 years to 16 years. The mean area burnt was 16 ± 18 km^2. The least area burnt was in 2011 < 1 km^2 and the maximum area burnt was in 1999 ca. 74 km^2. The polynomial model provided a function of number of fires with increasing distance from the village boundary, with $F_{1,14} = 120$, $R^2 = 0.59$, $p < 0.001$.

In India, it is estimated that 29% of villages (ca. 700 villages), about 160 million people are dependent on forests for a livelihood to different levels. Determining important underlying causes of forest degradation is important to managing and mitigating the effects of these processes and for the conservation of biodiversity. A household semi-structured social survey was conducted in the local language in Tamil in the Sathyamangalam landscape. Twenty villages were randomly sampled from the different vegetation zones. 30% of the households were sampled in each village. In all about 400 households were surveyed in the 20 villages. The survey compiled demographic information of households and included details on the family size, occupation, land holding, and livestock holding, crops cultivated, level of ground water, extraction of NTFPs, and also questions pertaining to the sustainability of resources in the villages.

The mean family size in the Sathyamangalam landscape is highest in the villages Kembanur (5.5) and Germalam (5.3) and it is lowest in Nandipuram (2.5). The mean land holding with tenure in the Sathyamangalam landscape is highest in the village Kalidimbam (2.05 acres) and households in several villages did not possess any land holding under tenure at all. The mean land holding without tenure in the Sathyamangalam landscape is highest in the village Kembanur (3.6 acres) and households in several villages did not possess any land holding without tenure at all. The mean distance travelled to collect firewood in the Sathyamangalam landscape in the present is highest in the village Bangalathotti (2.9 km) and the least distance travelled to collect firewood was in Kembanur (0.6 km). Greater than 70% of households in all villages across the landscape engaged in wage labour. The linear model indicated that the three most important predictors of disturbance in the Sathyamangalam landscape were mean family size ($p = 0.02$), distance travelled to collect fire wood ($p = 0.005$) and % of HH engaged in wage labour in the villages ($p = 0.0005$).

Respondents from the 20 villages uniformly indicated that quantity of NTFPs extracted in present had declined significantly compared to 10-y ago, similar trends were observed for the distance travelled to gather fire wood, and also the ground water level. The mean quantity of *Phyllanthus emblica* extracted in the present in the Sathyamangalam landscape is 40.23 kg/HH/trip. 10-y ago the mean quantity of *Phyllanthus emblica* extracted was 67.23 kg/HH/trip. Similarly, the mean quantity of *Terminalia chebula* extracted in the present in the Sathyamangalam landscape is 29.7 kg/HH/trip. 10-y ago the mean quantity of *Terminalia chebula* extracted was 44.8 kg/HH/trip, similar trends were observed with other NTFPs. The mean distance travelled to collect fire wood in the present is 2.09 km, whereas it was 0.99 km 10-y ago. We also collected information of the groundwater depth in the Sathyamangalam landscape, the mean groundwater depth in the present is 302 feet, it was 121.9 ft 10-y ago.

The Sathyamangalam landscape continues to support a multitude of human needs and could be vital for the livelihood of communities dependent on the forests. Providing alternate income sources could reduce the dependence of communities on these forests, thereby mitigating the effects of forest degradation. The sustainable use of natural resources in the landscape would be important for the conservation of biodiversity and also for the resilience of these ecosystems in sustaining the various ecosystem services provided by the landscape.

Chapter 1

Forest degradation, livelihoods, and forest conservation in India

Introduction

Forests are critical to the wellbeing of humans and provide a variety of services, these include hydrology functions, carbon sequestration, soil conservation, crop pollination sources, food and drinking water, biodiversity conservation, and climate regulation to name a few. Apart from the ecological services provided by forests, forests directly provide cash income to a substantial proportion of the population living on the fringes of forests in several developing countries. However, despite the important role played by forests, there is little information on deforestation and degradation of ecosystems around the world. The Millennium development goals of the United Nations, estimates that 15 of the 24 provisioning, regulating and cultural services derived from forests, are degraded and unsustainable (FAO, 2007).

Human settlements in the Vilankombai village in the Sathyamangalam landscape

In India, it is estimated that 29% of villages (ca. 700 village), about 160 million people are dependent on forests for a livelihood to different levels (Chauhan et al. 2008). In certain states of India, it has been shown that dependence on forest resources for livelihood varies from as low as 30% to 75% (Bahuguna 2000). The percapita availability of forest area in India is 0.05 ha, which is low considering international standards. Thus, it is but natural that there is a huge pressure on Indian forest ecosystems and this has lead to the degradation of the existing forests. India has about 12% of the global livestock population, the grazing activities have resulted in degradation of forests, it is estimated that 400 million tonnes of biomass are grazed by cattle annually (Singh 2008). About 200 million tonnes of fire wood are extracted annually from various forests and fallow lands across the country each year (Singh 2008). Forest fires are common in several forests, about 5 to 10% of the forest area of the country burn each year (Kodandapani unpublished data).

A view of the agriculture practices in the Sathyamangalam landscape

An elaborate system of forest protection has been put in place in the country, there are 90 national parks and 501 wildlife sanctuaries across India, they constitute about 5% of the total geographic area of the country and support about 4.5 million people (Kothari et al. 1989). There are approximately 28 tiger reserves spread across the country; Sathyamangalam is the latest addition to the list of tiger reserves in the country. There are approximately between 30 and 50 million people living within a 10 km radius of the PA network (Singh 2008).

Several studies have reported on the ecological effects of this persistent disturbance within Indian forests, for example, NTFP extractions in the BRT could have impacted, the regeneration, survival, and recruitment of tree species (Murali et al. 1996). Grazing in certain forests has lead to local extinctions and emigrations of several animal species due to the loss of the food species (Madhusudan and Mishra, 2003). The frequent fires in several deciduous forests of southern India, could have an impact on forest regeneration, structure, and biomass, and also the proliferation of invasive species (Kodandapani et al. 2008; Prasad 2012).

A view of the various livelihood options in the landscape

It is in this backdrop of forest dependence by different forest communities and its associated degradation within forests, that we conduct this study in the Sathyamangalam tiger reserve. We have conducted in-depth socio-economic analyses of the present conditions in 20 villages in the reserve. Information on the family size, gender, crops grown, dependence on forests, and sustainability issues have been examined through a semi-structured survey. We also conducted an ecological analysis, 3 transects were enumerated along the fringes of each village, and information such as the occurrence of disturbance, were quantified along these transects.

India is an extremely diverse country in terms of its people, their social and cultural practices coupled with a long duration of human presence, dating back to prehistorical times. The country is also extremely diverse in its ethnicity, contemporary India is an agglomeration of over 40,000 endogamous groups of which 37,000 are structured in the Hindu caste system and the remaining belong to various tribal groups and other religions (Malhotra 1984). The country has also witnessed advanced civilizations beginning with the Indus Valley civilization, followed by large agrarian kingdoms to the current industrialized society. Through all these stages the country has experienced a variety of modes of resource use, extractions, and complex cultural practices. Despite the long history of forest use in India, there still are patches of forest preserved in their primeval conditions due to various social and cultural practices involving resource use. This report presents facts based on the data gathered and the analyses conducted, we do **NOT** in any manner make suggestions regarding the movement of villages or people from the landscape.

References

FAO 2007. The state of food and agriculture. Paying farmers for environmental services. Food and Agriculture Organization of the United Nations. Rome, Italy.

Chauhan, K.V.S., Sharma, A.K., and Kumar, P 2008. Non-timber forest products subsistence and commercial uses: trends and future demands. *International Forestry Review* 10:201-216.

Bahuguna, V.K. 2000. Forests in the economy of the rural poor. An estimation of the dependency level. *Ambio* 29: 126–129.

Singh, K.D. 2008. Balancing fuelwood production and consumption in India. *International Forestry Review* 10:190-200.

Kothari, A., Pande, P., Singh, S., Variava, D. 1989. Management of national parks and sanctuaries in India: a status report. Indian Institute of Public Administration, New Delhi, India.

Murali, K.S., Shankar, U., Uma Shanker, R., Ganeshaiah, K.N., Bawa, K.S., 1996. Extraction of non-timber forest products in the forests of Biligiri Rangan Hills, India. 2. Impact of NTFP extraction on regeneration, population structure, and species composition. *Economic Botany* 50: 252–269.

Madhusudan, M.D., Mishra, C., 2003. Why big, fierce animals are threatened: conserving large mammals in densely populated landscapes. In: Saberwal, V., Rangarajan, M. (Eds.), Battles Over Nature: Science and Politics of Conservation. Permanent Black, New Delhi, pp. 31–55.

Kodandapani, N., Cochrane, M.A. and Sukumar, R. 2008. A comparative analysis of spatial, temporal, and ecological characteristics of forest fires in a seasonally dry tropical ecosystem in the Western Ghats, India. *Forest Ecology and Management*. 256: 607-617.

Prasad, A.E. 2012. Landscape scale relationships between the exotic invasive shrub *Lantana camara* and native plants in a tropical deciduous forest in southern India. *Journal of Tropical Ecology* 28: 55-64.

Malhotra, K.C. 1984. Population structure among the Dhangar caste cluster of Maharashtra, India. In : J.R. Lukaes (Ed.) The People of South Asia. Plenum Press, New York. Pp. 295-324.

Chapter 2

Assessment of forest disturbance and spatial pattern of disturbance

Introduction

Reducing the rate of biodiversity loss from ecosystems around the globe is now one of the priorities for all nations as laid out under the Convention for Biodiversity (CBD) (Pereira et al. 2013). Tropical countries and especially India, face a daunting task as they have to reconcile biodiversity considerations with livelihood needs of people dependent on these forests. Disentangling natural disturbances from human caused disturbances is problematic, further, in a country such as India, where people have been dependent on forests for several millennia, there are critical challenges in assessing the impacts of disturbances in ecosystems (Gadgil and Guha, 1995). Here we developed a methodology to assess the type, intensity, and spatial extent of disturbances caused by humans (Karanth et al. 2006).

Objectives

1. What is the intensity of disturbance across the various villages in the Sathyamangalam landscape?
2. Are the levels of disturbance similar across the various villages in the Sathyamangalam landscape.
3. What is the spatial pattern of disturbance with increasing distance from the village edge?
4. How does village size influence disturbance index at the landscape scale?

Methods: Vegetation analyses

Data on forest disturbances were gathered from 60 transects (three transects per village) that began randomly from the edge of the village and extended into the forest. Each transect was 1 km in length, ecological data was gathered in six sampling points at intervals of 200 m along the transect. The GPS location of each sampling point was recorded with the help of a GPS. We surveyed 18 sampling locations around each village, in all about 360 sampling points were surveyed in the 20 villages. In a couple of villages (Kembanur and Hosetti), the collection of all 18 points was not possible due to the presence of elephants.

Sampling forest disturbances in the landscape

At each point (15 m radius), quantitative information on habitat disturbance variables were collected. The following variables were collected, cut stems, cut bamboo, lopped trees, notched trees, fire occurrence, the presence of cattle trails, the presence of human trails, and the percentage invasive (*Lantana camara*) understorey. Cut stems refers to residual stem remaining after a tree has been cut, the number of cut stems were enumerated in each point sample. Similarly, cut bamboo also refers to bamboo stumps remaining after being cut. Lopped trees refers to branches of trees being cut, the number of such trees were counted at each point sample. Notched trees refer to cuts visible on trees, either during collection of resins or identify paths within the forest. The fire occurrence was the presence of fire on the tree or in the forest patch at the point sample. Similarly, human and cattle trails are clear paths that exist in the forest due to frequent use by humans and cattle. Exotic weeds such as *Lantana* were estimated by noting down the extent of the weeds at each location.

Data gathered on the habitat disturbance variables were classified into none, low, medium, and high, and subsequently represented on a numerical scale between 0 and 3. For example, none, when no cut stems were present at the point, as low, when cut stems ranged from 1 to 5, medium when cut stems ranged from 6 to 10, and high, when cut stems were > 10. For the variables such as fire occurrence, presence of human and cattle trails, a value of 0 was assigned for the absence and a value of 3 for presence. Since most of the disturbance variables were related, a correlation was conducted and variables showing significant correlation were dropped. For example, human and cattle trails were highly correlated, hence only one was retained.

Principal Component Analysis (PCA)

A PCA was conducted on the seven habitat variables, the eigen value analysis indicated that the first three principal components were important to assess habitat disturbance. Scores for the first three principal components were calculated for each sampling location. The PCA was rescaled to values between 0 and 1, corresponding to no disturbance, low, medium, and high disturbance. A first order polynomial regression model was applied to model the relationship between disturbance and distance from village edge.

Results

The first principal component (PC1) explained 23% of the variability in the seven habitat disturbance variables. The second principal component (PC2) explained 18% of the variability in the seven habitat disturbance variables, and the third principal component (PC3) explained 16% of the variability in the seven habitat disturbance variables. Together the first three principal components explained 57% of the variability in the seven habitat disturbance variables. The loadings on the first PC1 had high coefficient values for the disturbance variables cut tree and tree notches, other variables were less influential. The loadings on the second PC2 had high coefficient values for the disturbance variables cut bamboo and fire occurrences, other variables were less influential. The loadings on the third PC3 had high coefficient values for the disturbance variable *Lantana* understorey, other variables were less influential.

Principal components scores and distance from village edge

For Bejalatti, disturbance scores were low and remained low till about 0.6 km from the village edge and declined further at about 1 to 1.2 km from the village edge. The linear model provided a function of disturbance index with increasing distance from the village edge (Fig. 2.1), with $F_{1,16}$ = 4.57, r^2 = 0.22, p = 0.04. For Bunglathotti, the disturbance is higher, and increases from about 0.6 km from the village edge. The linear model provided a function of disturbance index with increasing distance from the village edge (Fig. 2.2), with $F_{1,16}$ = 2.2, r^2 = 0.12, p = 0.15. For Devarnatham, the disturbance is low and remains constant from 0 km onwards. The linear model provided a function of disturbance index with increasing distance from the village edge (Fig. 2.3), with $F_{1,16}$ = 0.97, r^2 = 0.05, p = 0.3. For Geddesal, disturbance is higher close to the village edge, and remains high at all distances from the village edge. The linear model provided a function of disturbance index with increasing distance from the village edge (Fig. 2.4), with $F_{1,16}$ = 0.02, r^2 = 0.001, p = 0.8. For Germalam, the disturbance is moderate near the village edge, and increases monotonically all the way to a distance of 1 km from the edge of the village. The linear model provided a function of disturbance index with increasing distance from the village edge (Fig. 2.5), with $F_{1,16}$ = 0.08, r^2 = 0.005, p = 0.7. For Hassanur, the disturbance index is 0.3 close to the village edge and remains similar to about 1 km from the village edge. The linear model provided a function of disturbance index with increasing distance from the village edge (Fig. 2.6), with $F_{1,16}$ = 0.7, r^2 = 0.04, p = 0.4. For Hosetti, the disturbance index is low close to the village boundary, and increases away from the village boundary. The linear model provided a function of disturbance index with increasing distance from the village edge (Fig. 2.7), with $F_{1,16}$ = 0.4, r^2 = 0.03, p = 0.5. For Ittarai village, the disturbance index is low, but there is some level of disturbance upto a distance of 1 km from the village edge. The linear model provided a function of disturbance index with increasing distance from the village edge (Fig. 2.8), with $F_{1,16}$ = 0.01, r^2 = 0.0009, p = 0.9. For Kalidimbam, the disturbance index is low and remains low to about 1 km from the village edge. The linear model provided a function of disturbance index with increasing distance from the village edge (Fig. 2.9), with $F_{1,16}$ = 0.8, r^2 = 0.05, p = 0.3. For Kembanur, we were able to only sample at four points, hence we did not conduct the linear regression. For Kuliyada, the disturbance index is 0.2 and remains similar until a distance of 1 km from the village edge. The linear model provided a function of disturbance index with increasing distance from the village edge (Fig. 2.10), with $F_{1,16}$ = 0.8, r^2 = 0.04, p = 0.4. For Mavalam the disturbance index is 0.2 close to the village edge, it declines further from the village edge and declines close to about 1 km from the village edge. The linear model provided a function of disturbance index with increasing distance from the village edge (Fig. 2.11), with $F_{1,16}$ = 0.5, r^2 = 0.03, p = 0.5. For Mavanatham, the disturbance index is < 0.2 close to the village edge, it remains low to about 1 km from the village edge. The linear model provided a function of disturbance index with increasing distance from the village edge (Fig. 2.12), with $F_{1,16}$ = 0.97, r^2 = 0.05, p = 0.3. For Muthiyanur, the disturbance index is > 0.4 close to the village edge and it declines as distance increases from the village edge. The linear model provided a function of disturbance index with increasing distance from the village edge (Fig. 2.13), with $F_{1,16}$ = 12.8, r^2 = 0.44, p = 0.002. For Nagaloor, the disturbance index is < 0.2 close to the village and it increases as distance increases from the village edge. The linear model provided a function of disturbance index with increasing distance from the village edge (Fig. 2.14), with $F_{1,16}$ = 2.6, r^2 = 0.14, p = 0.12. For Nandipuram, the disturbance index < 0.2 close to the village, and it remains low to a distance of 0.7 km, before increasing again. The linear model provided a function of disturbance index with increasing distance from the village edge (Fig. 2.15), with $F_{1,16}$ = 0.26, r^2 = 0.01, p = 0.6. For Neithalapuram, the disturbance index is high (0.4) close to the village and remains high as distance increases from the village edge. The linear model provided a function of disturbance index with increasing distance from the village edge (Fig. 2.16), with $F_{1,16}$ = 0.47, r^2 = 0.02, p = 0.5. For Ramaranai, the disturbance index is low for all distances from the village edge. The linear model provided a function of disturbance index with increasing distance from the village edge (Fig. 2.17), with $F_{1,16}$ = 2.17, r^2 = 0.11, p = 0.15.

For Uginium, the disturbance index is low (0.2- 0.3) close to the village edge and increases away from the village edge. The linear model provided a function of disturbance index with increasing distance from the village edge (Fig. 2.18), with $F_{1,16} = 3.69$, $r^2 = 0.18$, $p = 0.07$. Similarly, for Villankombai, the disturbance index is 0.2 close to the village edge and continues to increase away from the village edge. The linear model provided a function of disturbance index with increasing distance from the village edge (Fig. 2.19), with $F_{1,16} = 2.7$, $r^2 = 0.14$, $p = 0.1$. Coefficients are provided in table 2.1. Mean disturbance index and the spatial pattern of the disturbance index in the Sathyamangalam landscape are given in figures 2.20 and 2.21.

Village size and disturbance index in Sathyamangalam

The generalized linear model indicated that village size class was a significant predictor of the principal components disturbance index. Distance, along with the interactions between distance and village size class were not significant predictors of the principal components disturbance index (tables 2.2,2.3). The linear model provided a function of mean disturbance index with increasing village size, with $F_{1,18}$=4.5, r^2=0.2, p=0.04. Two villages, Hasannur and Neithalapuram were extremely large and we considered them as outliers. The linear regression was carried out excluding these two villages (Fig. 2.20). The linear model provided a function of mean disturbance index with increasing village size, with $F_{1,16}$,=11.3, r^2=0.4, p=0.003 (table 2.4).

Discussion

The spatial pattern of disturbance from the village periphery could not be explained by distance, although this has been demonstrated in the Bhadra wildlife sanctuary (Karanth et al. 2006) we did not find support for it in the Sathyamangalam landscape. Only in three villages, Bejalatti, Muthiyanur, and Uginium did distance from the village periphery explain the spatial pattern of disturbance. In most villages in the landscape, the disturbance index remained low or moderate at all distance classes from the edge of the village boundary.

Nevertheless, the village size classes did have an important effect and explained the intensity of disturbance in the landscape. Small villages had lower disturbance levels, compared to medium and large villages. Thus village size, in terms of the number of households was the only significant predictor or disturbance in the Sathyamangalam landscape. Both the ANOVA analysis as well as the linear model showed statistically significant effect of village size (number of households) on the disturbance in the landscape. Thus the presence of small villages within the Sathyamangalam landscape may not be a substantial threat to the forests. Further research on forest tree species richness, regeneration, dynamics, in relation to forest use should be carried out in a systematic manner. The sustainable use of natural resources would be important to meet the livelihood needs of people dependent on forests, while simultaneously conserving biodiversity in forests.

References

Pereira et al. 2013. Essential biodiversity variables. *Science* 339: 277-278.

Gadgil, M. and Guha, R. 1993. This fissured land. Oxford University Press, New Delhi.

Karanth, K.K., Curran, L.M., Reuning-Scherer, J.D. 2006. Village size and forest disturbance in Bhadra Wildlife Sanctuary, Western Ghats, India. *Biological Conservation* 128:145-157.

Gadgil, M. 1996. Western Ghats: A lifescape. *Journal of the Indian Institute of Science* 76: 495-504.

Figure 2.1: Linear model of disturbance index with increasing distance from the village edge in Bejalatti

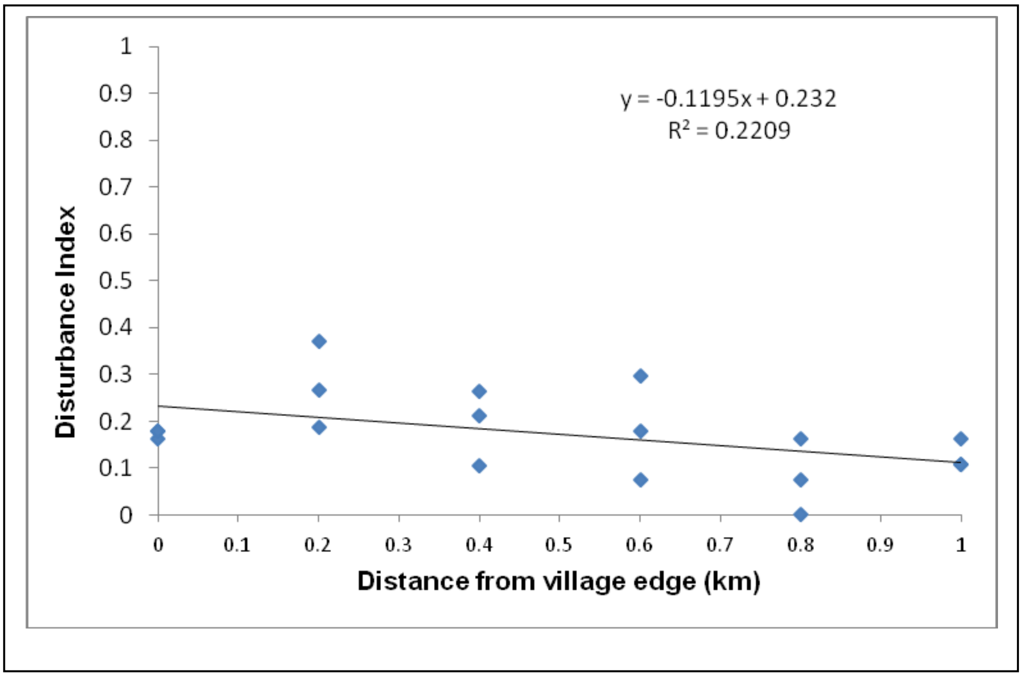


Figure 2.2: Linear model of disturbance index with increasing distance from the village edge in Bunglathotti

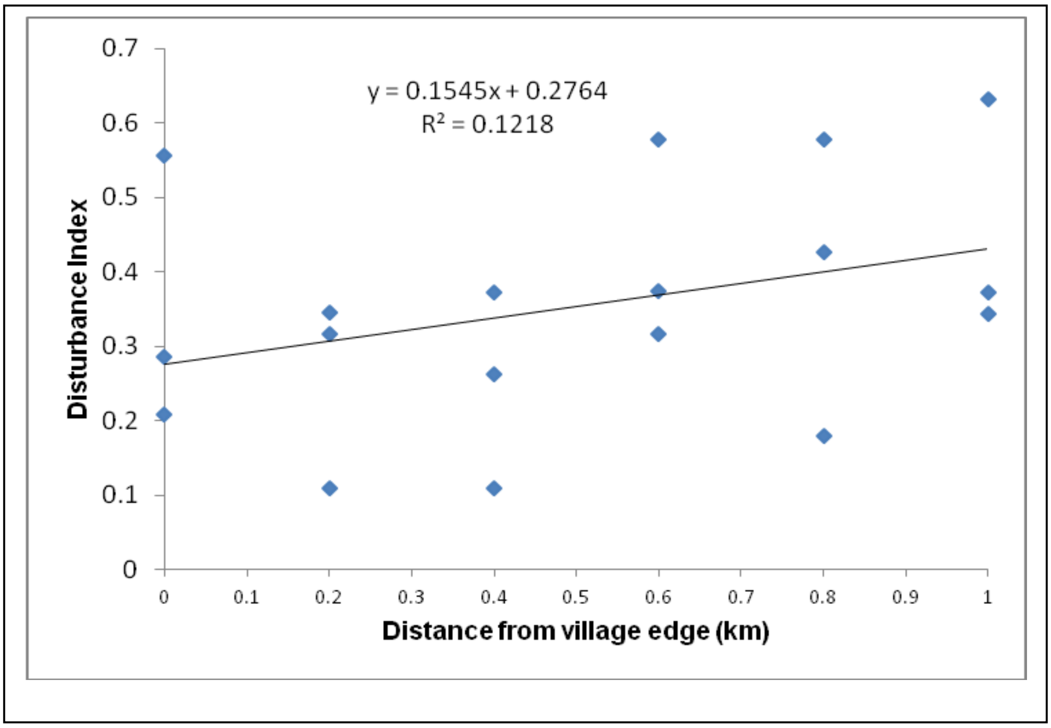


Figure 2.3: Linear model of disturbance index with increasing distance from the village edge in Devarnatham

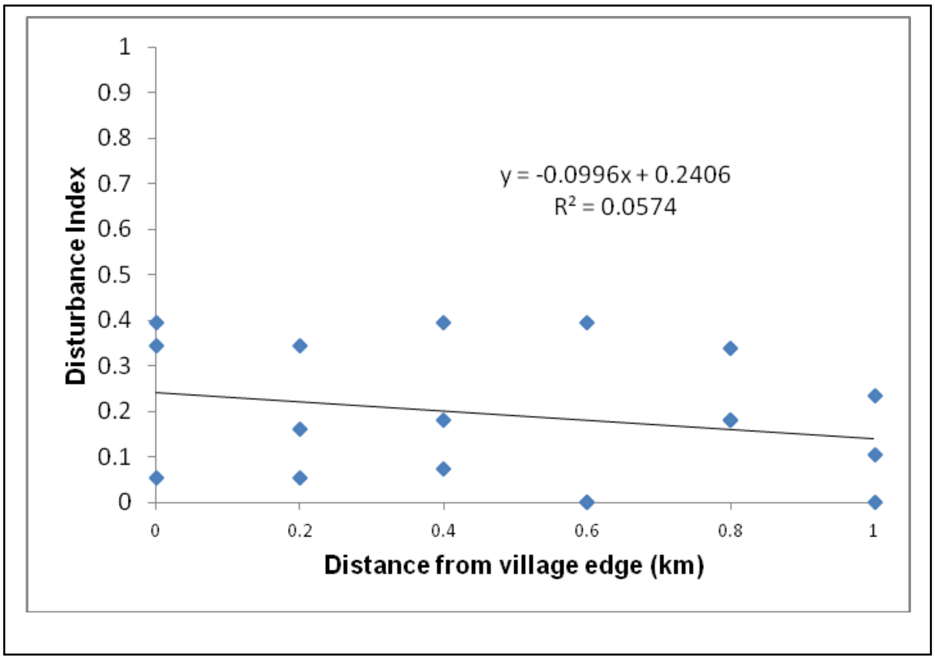


Figure 2.4: Linear model of disturbance index with increasing distance from the village edge in Geddesal

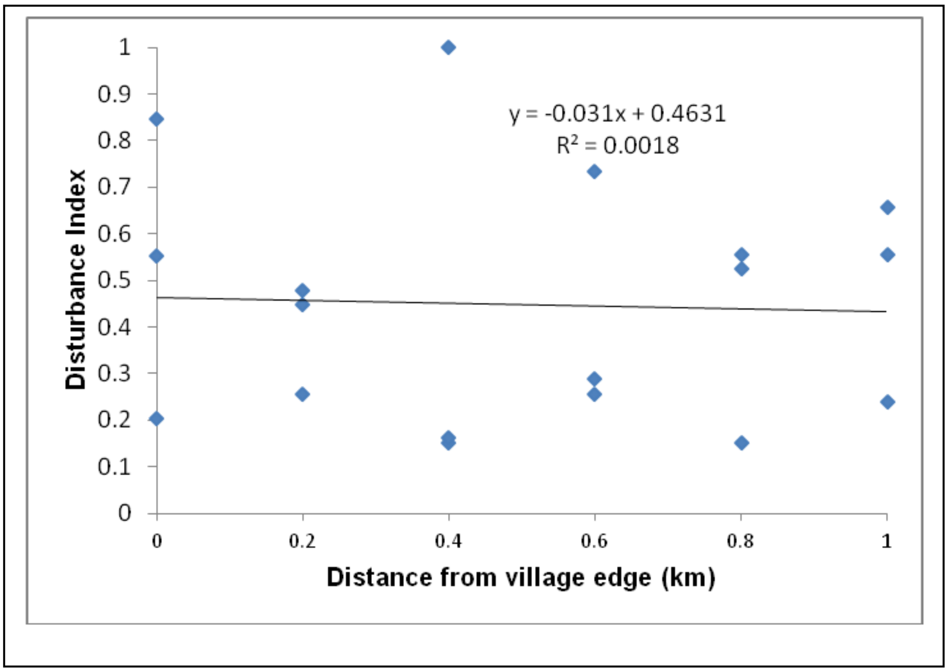


Figure 2.5: Linear model of disturbance index with increasing distance from the village edge in Germalam

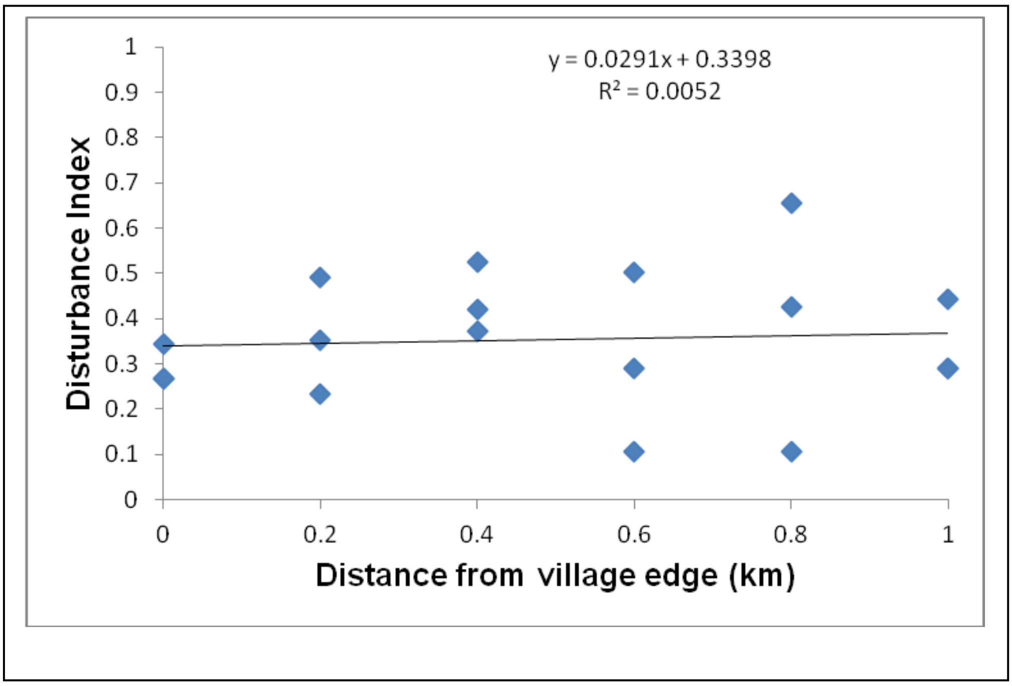


Figure 2.6: Linear model of disturbance index with increasing distance from the village edge in Hassanur

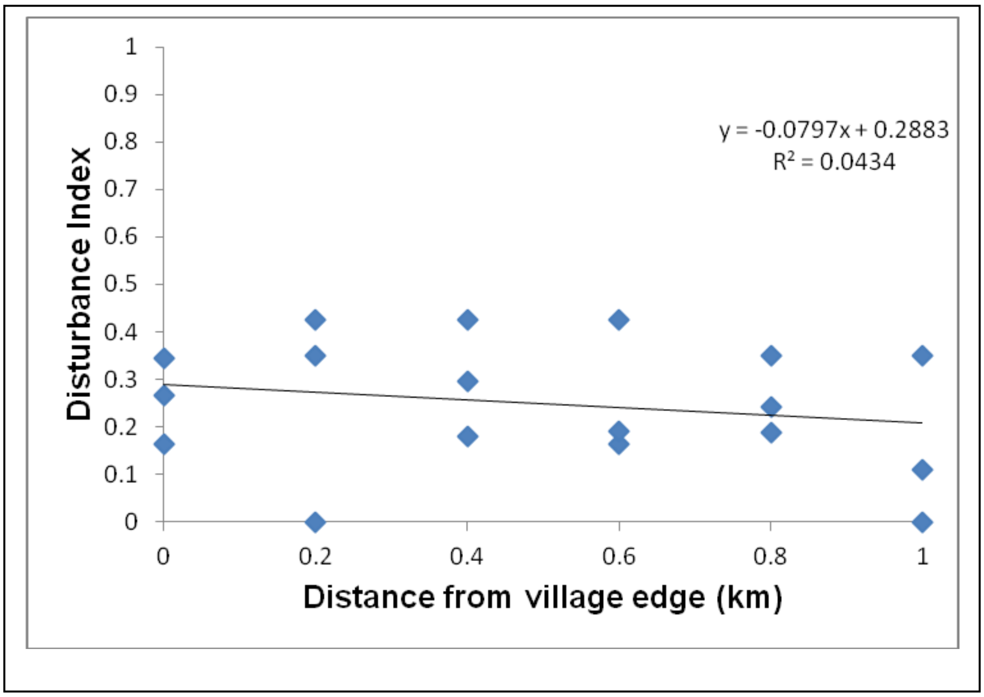


Figure 2.7: Linear model of disturbance index with increasing distance from the village edge in Hosetti

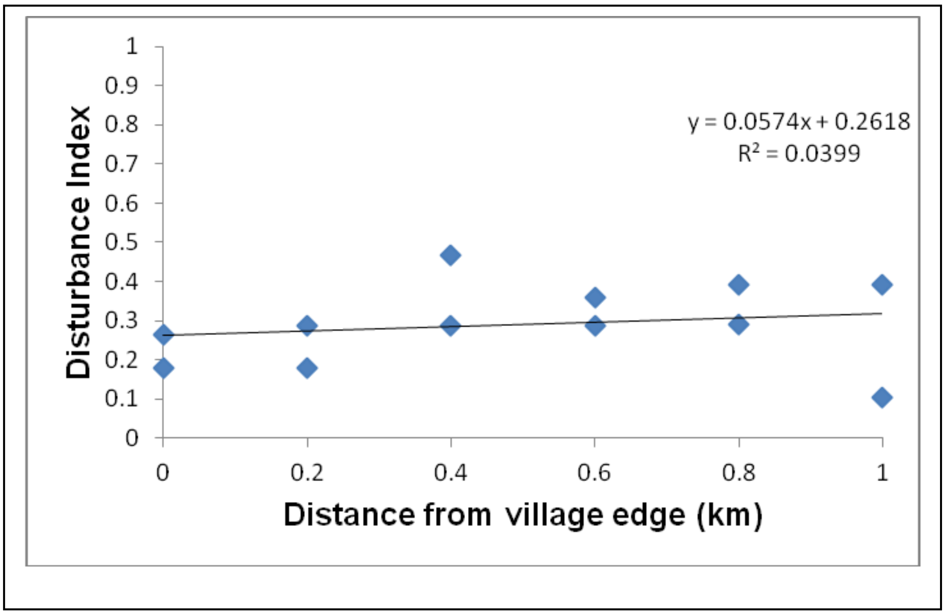


Figure 2.8:Linear model of disturbance index with increasing distance from the village edge in Ittarai

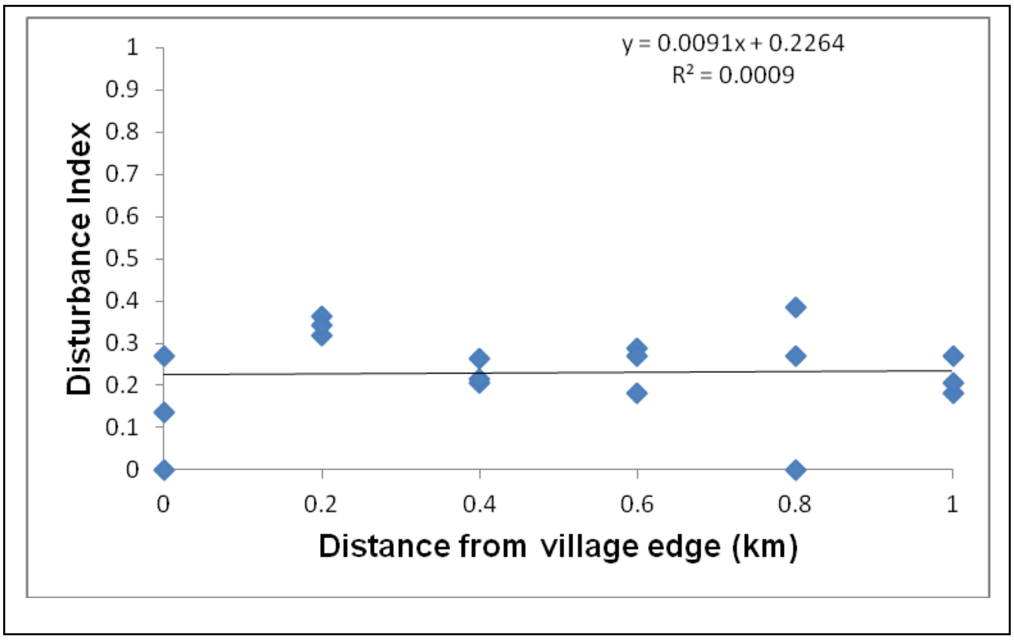


Figure 2.9: Linear model of disturbance index with increasing distance from the village edge in Kalidimbam

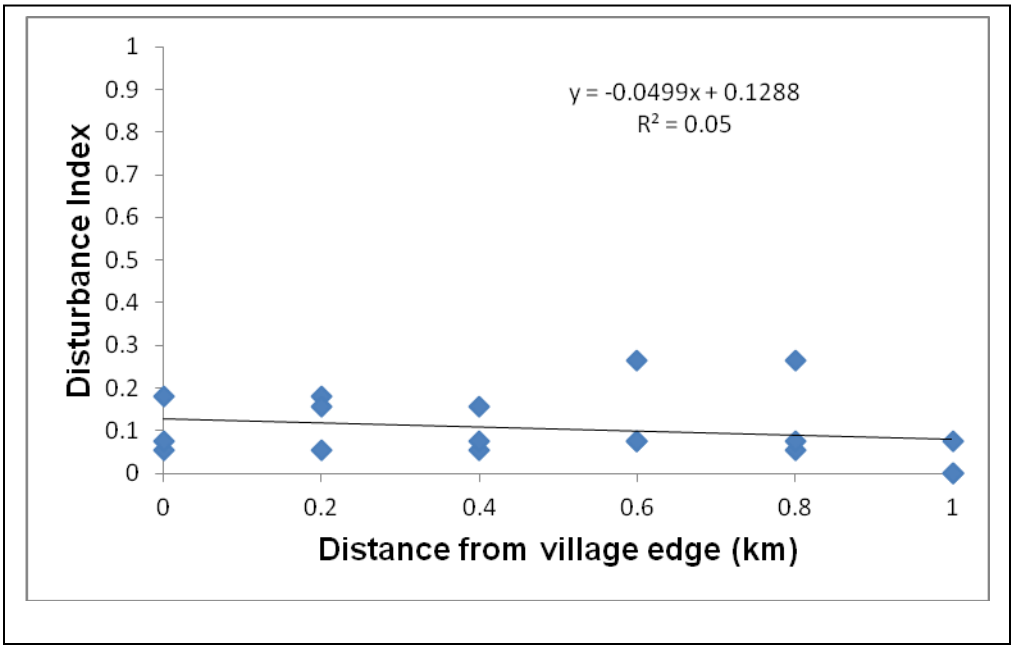


Figure 2.10: Linear model of disturbance index with increasing distance from the village edge in Kuliyada

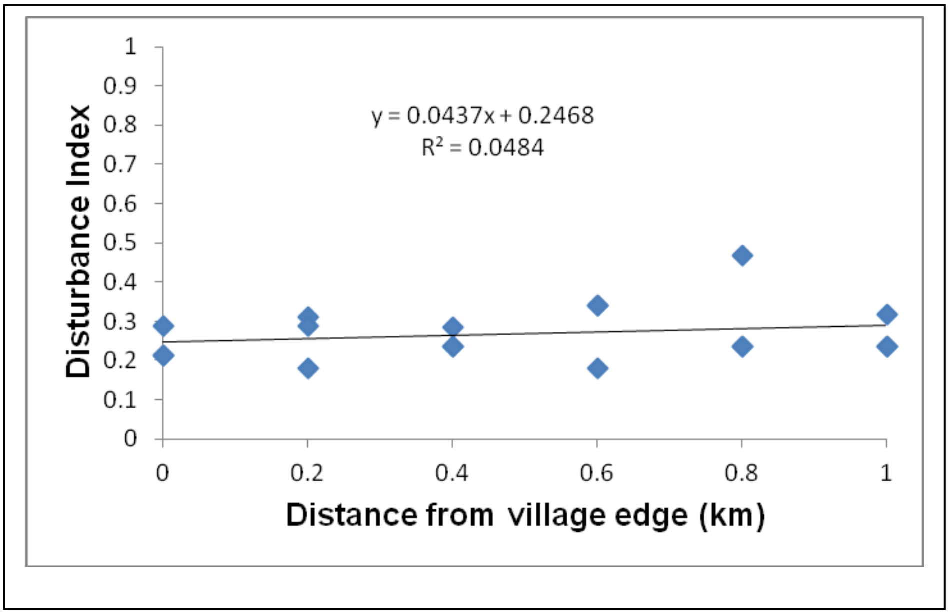


Figure 2.11: Linear model of disturbance index with increasing distance from the village edge in Mavalam

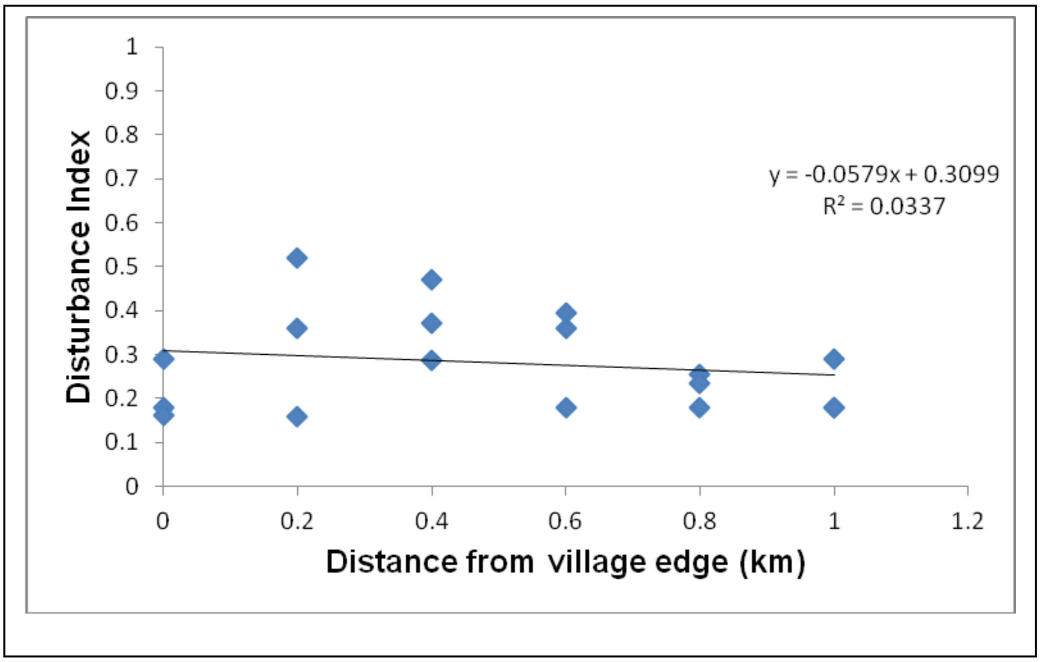


Figure 2.12: Linear model of disturbance index with increasing distance from the village edge in Mavanatham

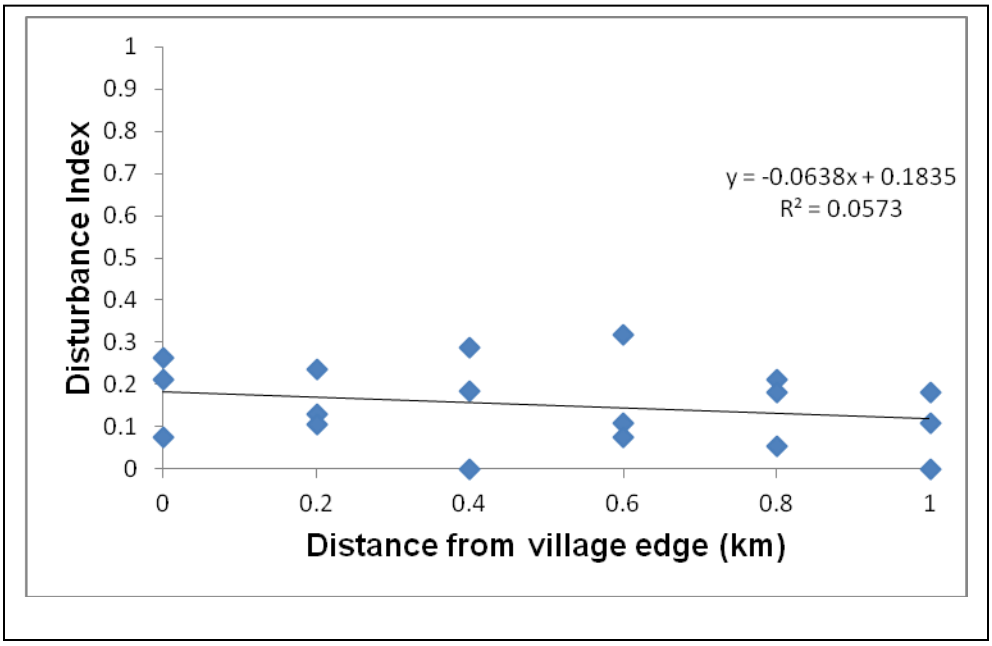


Figure 2.13: Linear model of disturbance index with increasing distance from the village edge in Muthiyanur

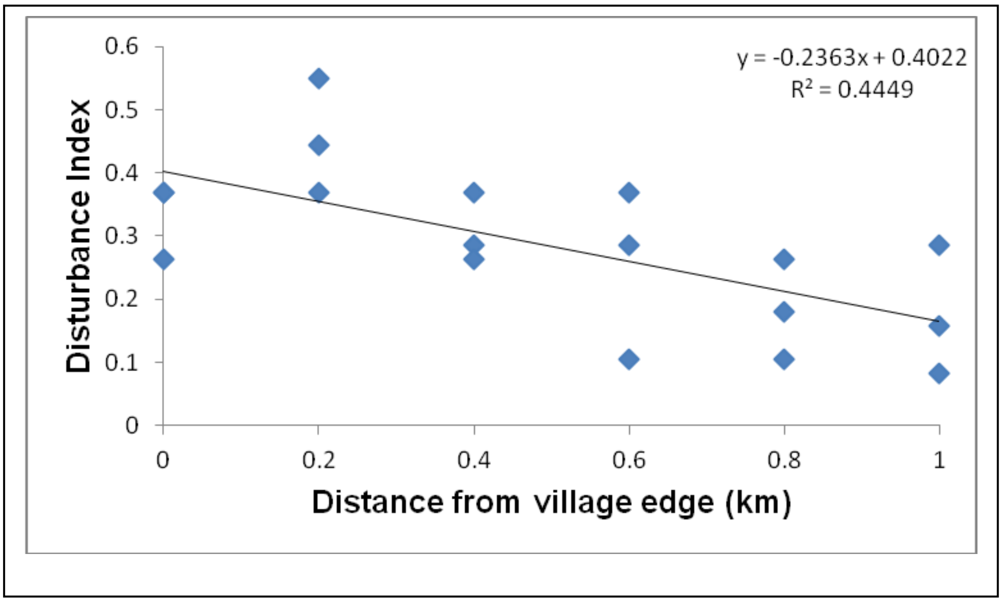


Figure 2.14: Linear model of disturbance index with increasing distance from the village edge in Nagaloor

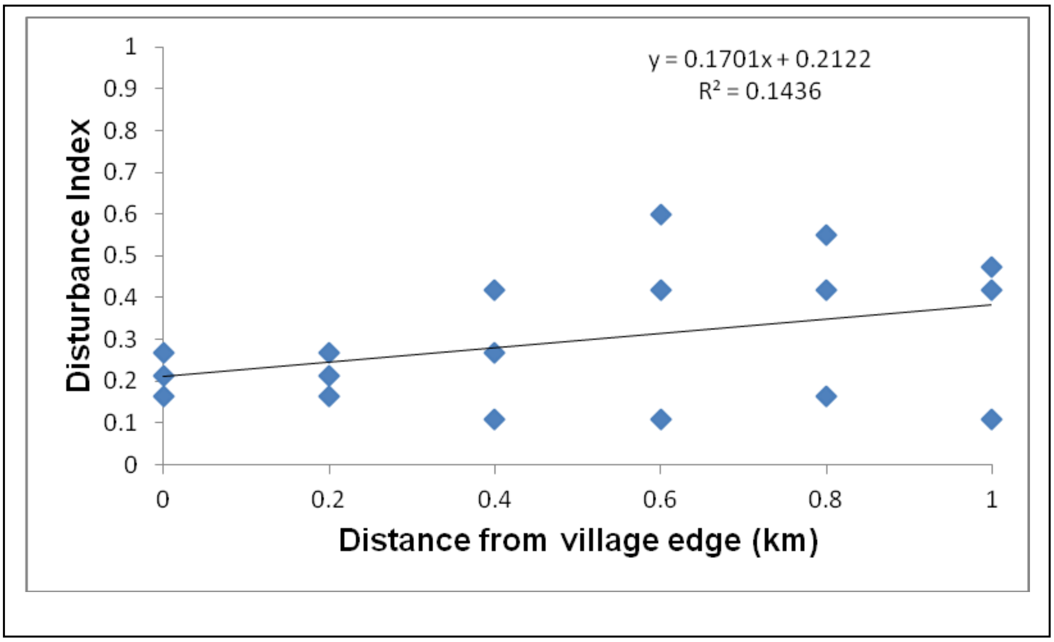


Figure 2.15: Linear model of disturbance index with increasing distance from the village edge in Nandipuram

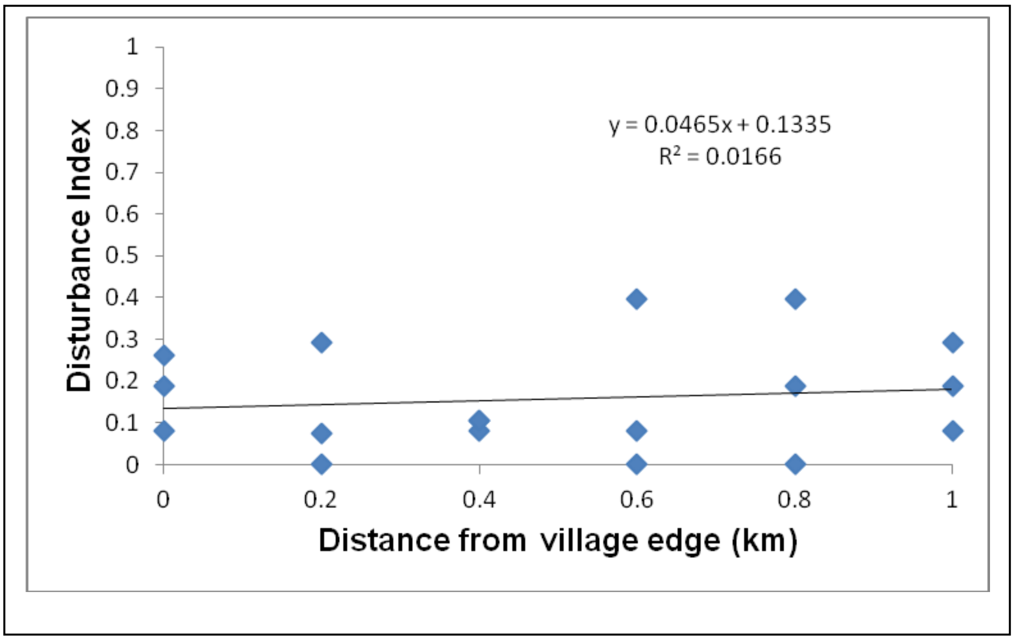


Figure 2.16: Linear model of disturbance index with increasing distance from the village edge in Neithalapuram

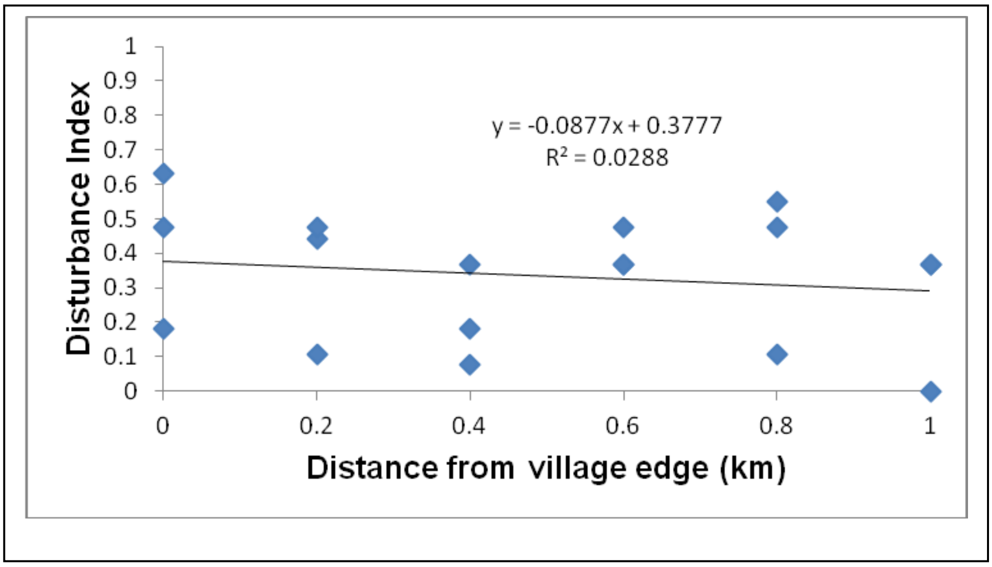


Figure 2.17: Linear model of disturbance index with increasing distance from the village edge in Ramaranai

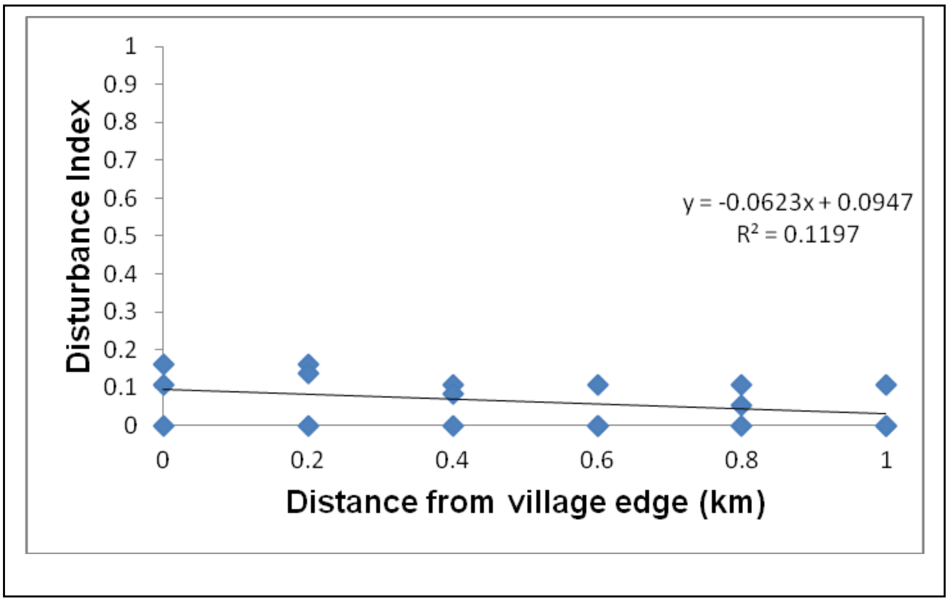


Figure 2.18: Linear model of disturbance index with increasing distance from the village edge in Uginium

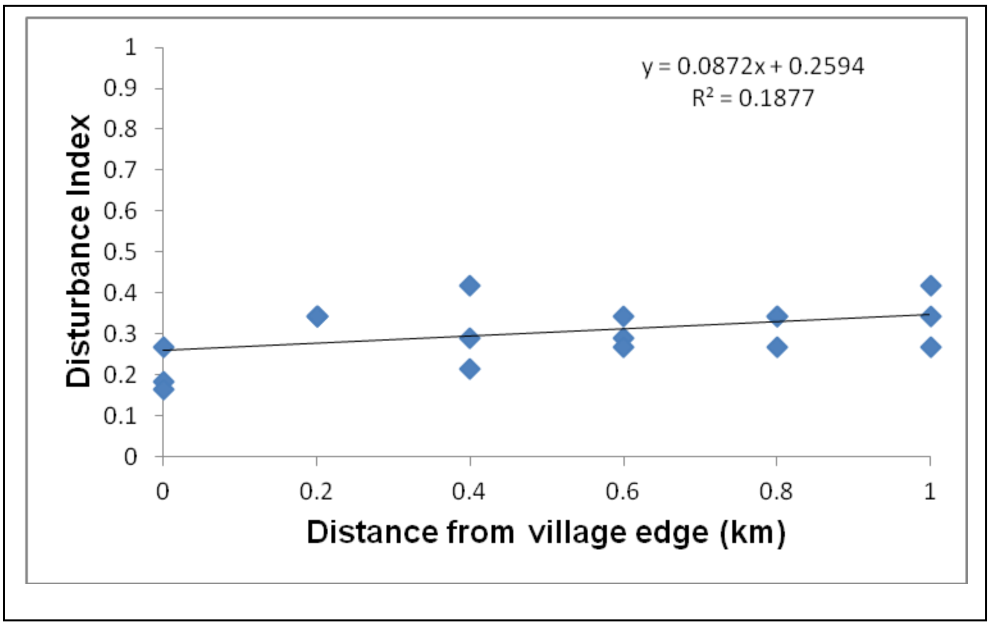


Figure 2.19:Linear model of disturbance index with increasing distance from the village edge in Vilankombai

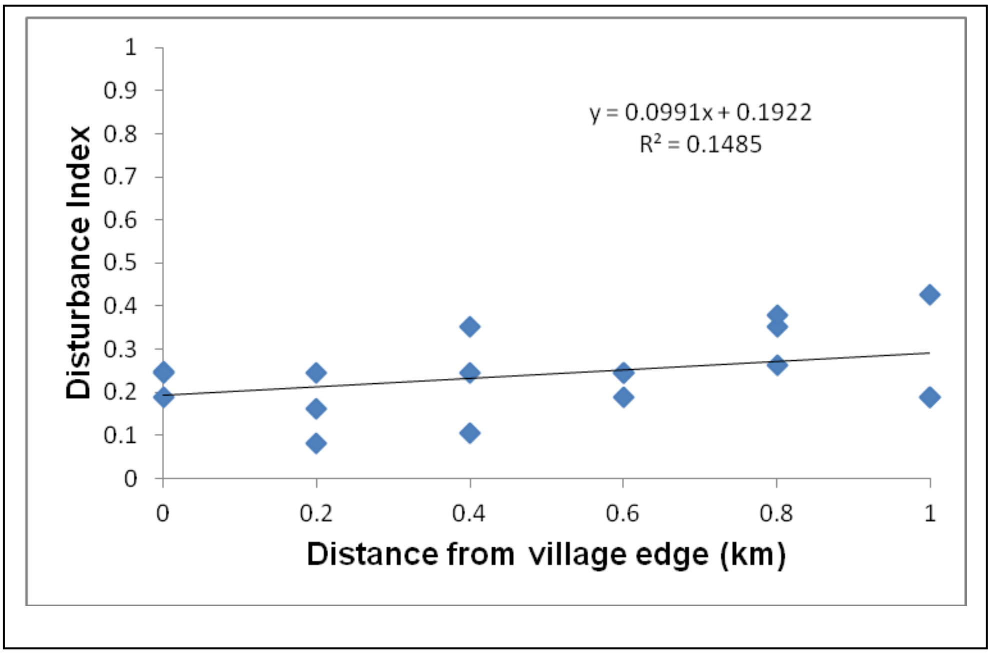


Figure 2.20: Relationship between village size (number of households) and the disturbance index in the Sathyamangalam landscape

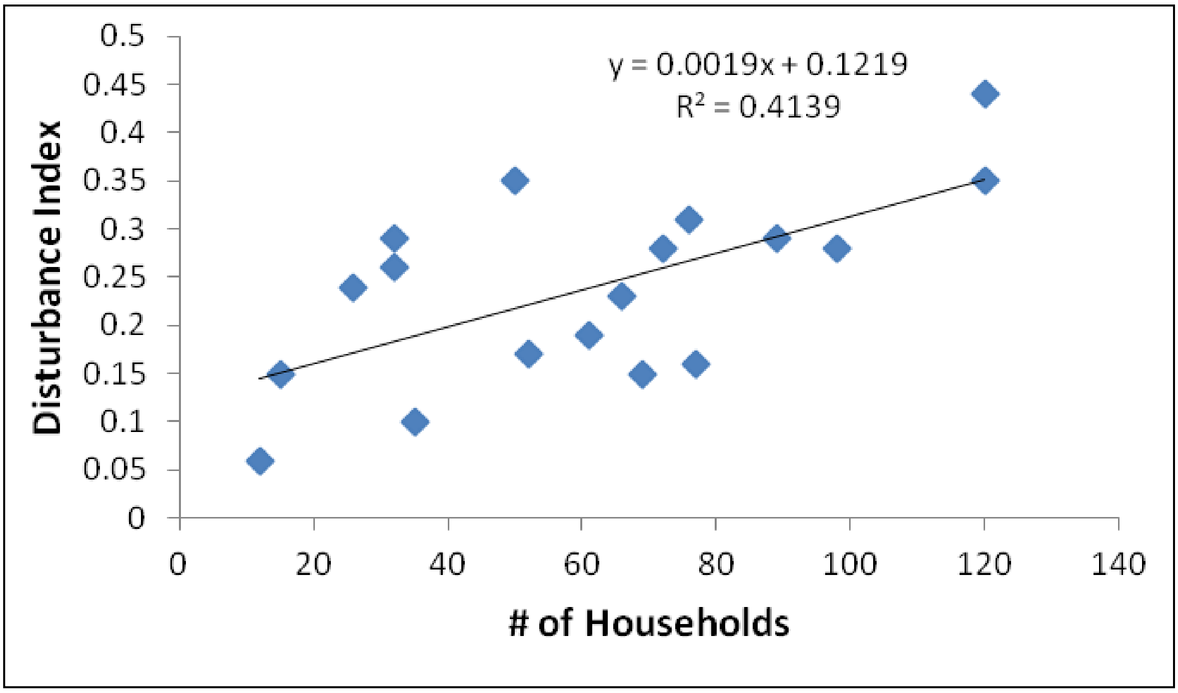


Figure 2.20: Mean disturbance index across villages in the Sathyamangalam landscape

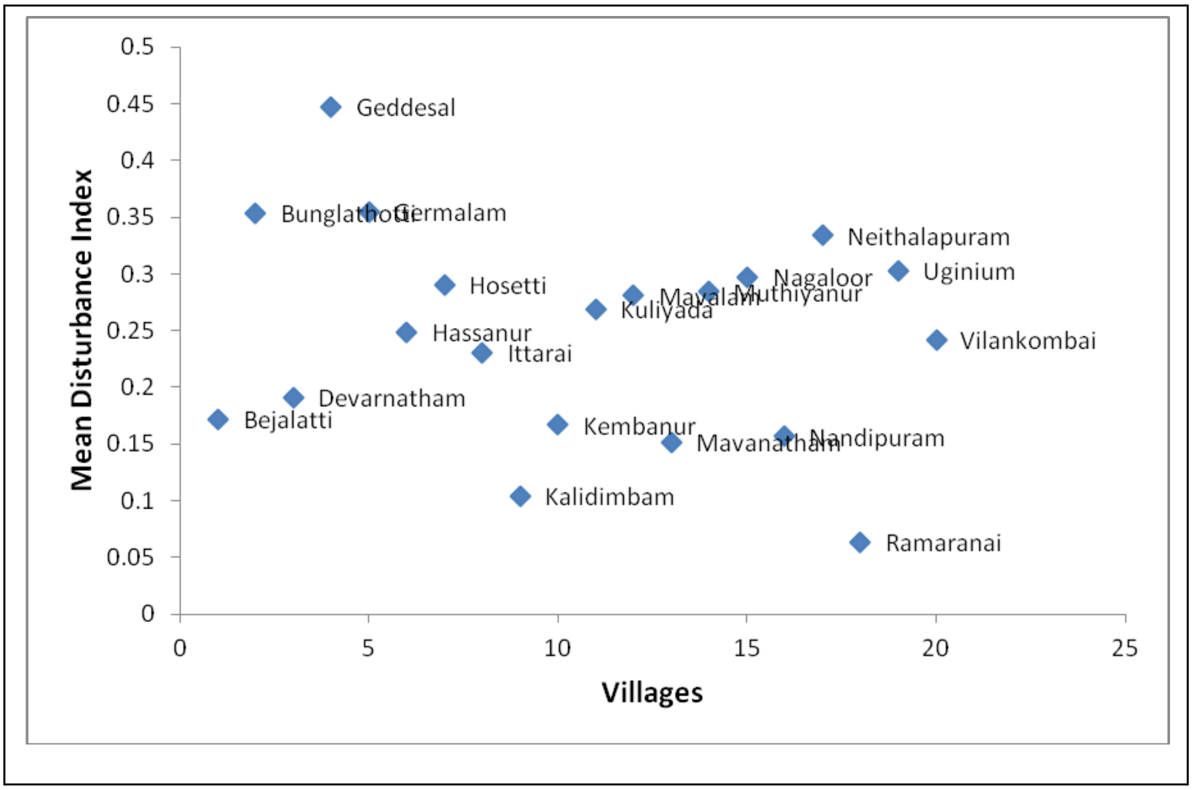


Figure 2.21: Spatial pattern of disturbance index in the Sathyamangalam landscape

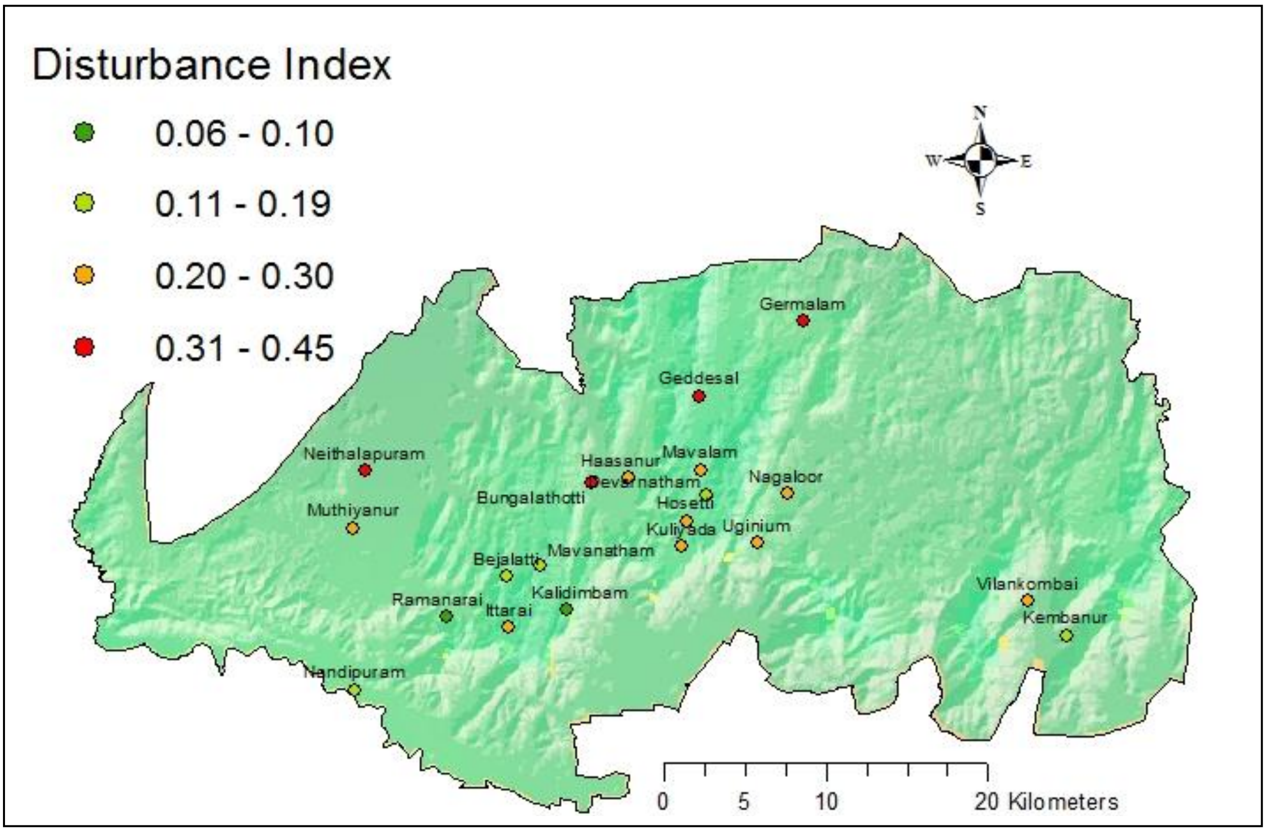


Table 2.1: Coefficients of linear model of disturbance index and distance among the various villages in the Sathyamangalam landscape

Village Name	Estimate	Std. Error	T value	P value
Bejalatti				
Intercept	0.23	0.03	6,8	0.001
Distance	-0.11	0.05	-2.1	**0.04**
Bungalathotti				
Intercept	0.27	0.06	4.4	0.001
Distance	0.15	0.1	1.5	0.1
Devarnatham				
Intercept	0.24	0.06	3.9	0.001
Distance	-0.09	0.1	-0.98	0.33
Geddesal				
Intercept	0.46	0.1	4.24	0.001
Distance	-0.03	0.1	-0.17	0.8
Germalam				
Intercept	0.33	0.06	5.5	0.001
Distance	0.02	0.1	0.28	0.7
Hassanur				
Intercept	0.28	0.05	5.09	0.001
Distance	-0.07	0.09	-0.8	0.4
Hosetti				
Intercept	0.26	0.05	4.8	0.001
Distance	0.05	0.08	0.6	0.5
Ittarai				
Intercept	0.22	0.04	4.9	0.001
Distance	0.009	0.07	0.11	0.9
Kalidimbam				
Intercept	0.12	0.03	3.9	0.002
Distance	-0.04	0.05	-0.91	0.3
Kembanur				
Intercept	0.25	0.08	3.1	0.05
Distance	-0.22	0.16	-1.3	0.27
Kuliyada				
Intercept	0.24	0.02	8.4	0.001
Distance	0.04	0.04	0.9	0.4
Mavalam				
Intercept	0.3	0.04	6.6	0.001
Distance	-0.05	0.07	-0.7	0.4
Mavanatham				
Intercept	0.18	0.03	4.6	0.002
Distance	-0.06	0.06	-0.9	0.3
Muthiyanur				
Intercept	0.4	0.03	10.06	0.001
Distance	-0.23	0.06	-3.5	**0.002**

Nagaloor				
Intercept	0.21	0.06	3.3	0.003
Distance	0.17	0.1	1.63	0.12
Nandipuram				
Intercept	0.13	0.05	2.4	0.02
Distance	0.04	0.08	0.5	0.6
Neithalapuram				
Intercept	0.37	0.07	4.8	0.001
Distance	-0.08	0.12	-0.6	0.5
Ramaranai				
Intercept	0.09	0.02	3.7	0.009
Distance	-0.06	0.04	-1.4	0.15
Uginium				
Intercept	0.25	0.02	9.4	0.001
Distance	0.08	0.04	1.9	**0.07**
Vilankombai				
Intercept	0.19	0.03	5.3	0.001
Distance	0.09	0.05	1.6	0.1

Table 2.2: Analysis of variance for PCA scores

Source	**DF**	**Sum of Squares**	**Mean square**	**F value**	**P value**
Size class	3	1.5	0.503	24.7	**0.0001**
Edge distance (m)	1	0.006	0.005	0.29	0.5
Edge distance sq (m^2)	1	0.02	0.02	1.08	0.3
Size class * edge distance (m)	3	0.004	0.0013	0.06	0.9
Size class * edge dist sq (m^2)	3	0.06	0.02	1.004	0.3

Table 2.3: Generalized linear model based on PCA scores and three disturbances classes predicting disturbance in the Sathyamangalam landscape

	Estimate	**Std. Error**	**T value**	**P value**
Intercept	0.36	0.037	9.8	**0.001**
Distance (m)	-0.12	0.17	-0.69	0.4
Distance Sq (m2)	0.11	0.16	0.66	0.5
Disturbance large	-0.12	0.045	-2.65	**0.008**
Disturbance medium	-0.17	0.05	-3.5	**0.005**
Disturbance small	-0.23	0.06	-3.6	**0.003**

Distance*Size class				
Large	0.27	0.21	1.3	0.19
Medium	0.28	0.23	1.1	0.2
Small	-0.009	0.3	-0.03	0.9
Distance Sq*Size class				
Large	-0.29	0.2	-1.4	0.1
Medium	-0.27	0.22	-1.1	0.23
Small	0.01	0.29	0.04	0.9

Table 2.4: Coefficients of linear model of Disturbance Index and village size in Sathyamangalam

	Estimate	**Std. Error**	**T value**	**P value**
All villages				
Intercept	0.19	0.03	6.4	**0.001**
Households	0.0006	0.0002	2.12	**0.04**
Excluding Hasannur and Neithalapuram				
Intercept	0.12	0.03	3.1	**0.006**
Households	0.0019	0.0005	3.3	**0.003**

Chapter 3

Spatial pattern of forest fires and human settlements

Introduction:

The incidence of forest fires in landscapes varies around the globe, while in certain ecosystems the incidences of fires are natural (Whelan 1995), fires in certain other ecosystems are mainly as a consequence of the human presence within and around these forest ecosystems (Kodandapani et al. 2004). Over centuries, India's rural communities have created extensive savannas bordering their farmlands through extraction of woody biomass, grazing by livestock and annual dry season fires (Gadgil 1993). Studies in the Amazon forests have shown the relationship between fire frequency and the size of forest patches, further these studies have shown the increase in fire-return intervals as function of distance from the forest edge (Cochrane 2001; Cochrane and Laurance 2002). Apart from the relationship between fire-return intervals as a function of distance from forest edge, fires in a landscape depend on a number of landscape characteristics. Fuel, weather and topography drive the behaviour of an individual fire (Brown and Davis 1973; Pyne et al. 1996; Kodandapani et al. 2012). Macroclimate is less variable temporally and spatially at landscape scales, affected by phenomena such as ENSO and orographic effects; whereas microclimate at the scale of a forest patch is more variable both temporally and spatially. Abiotic factors such as firebreaks, slope, aspect, elevation are spatially variable but temporally constant (Grimm 1984). Biotic factors such as fuel load varies with time, specifically with time since previous fire, and fuel composition varies with vegetation type. Complex models have been derived to explain the spread of fire in landscapes and the behaviour of fire (Rothermel 1972; Finney 1998). The spatial pattern of fires over time in the Western Ghats have not been clearly understood, the relationships between fire and human settlements have not been understood.

This chapter describes the spatial pattern of fires in relation to the 20 villages in the Sathyamangalam landscape. The landscape is also extremely diverse in terms of the rainfall pattern, topography, and edaphic factors, which is reflected in vegetation types including the tropical moist deciduous forest ecosystems, tropical semi-evergreen forests, tropical dry deciduous forest ecosystems, and the tropical dry thorn ecosystems.

Objectives:

1. Determine the current fire-return interval in the Sathyamangalam landscape.
2. Assess the spatial pattern of fire incidence in relation to village locations in the Sathyamangalam landscape.

Methods:

Fire-return interval (FRI) map of the Sathyamangalam landscape:

We generated the FRI map for the Sathyamangalam landscape using remote sensing data. Fire maps for Sathyamangalam were obtained from remote sensing data, remote sensing data from 1997 to 2012 were used for the purpose of obtaining fire maps. Details of the remote sensing data, such as sensors, path/row, and date of pass are given in table 3.1. We adopted a novel methodology to classify the burnt areas in the Sathyamangalam landscape. We applied spectral unmixing procedures and selected three endmembers to classify the landscape into burnt and unburnt areas. Prior to conducting the spectral mixture analysis, principal components transform was applied on the dataset. We followed a similar method to delineate fire maps for all years during the study period. The FRI map for the Sathyamangalam landscape was obtained from these fire maps.

Spatial pattern of fire and village locations: We assessed the spatial pattern of fire incidences as a function of distance from the various villages in the Sathyamangalam landscape. Buffers of 1 km from the village boundaries, up to a distance of 20 km, were generated by applying methods of buffer creation in ArcInfo (ESRI, 2002). The number of fires in each buffer distance class (e.g. 0–1, 1–2, 2–3 km, etc.) was then calculated by applying ArcInfo commands (ESRI, 2002).

Results:

Mean FRI ranges from 2 years to 16 years (Figure 3.1). The mean area burnt was 16 ± 18 km^2. The least area burnt was in 2011 < 1 km^2 and the maximum area burnt was in 1999 ca. 74 km^2. Figure 3.2 shows the temporal pattern of fires in the Sathyamangalam landscape.

Spatial pattern of fire in relation to village locations: The number of fires is low close to the villages, 262 fires ≤ 2km from the villages (figure 3.3). The number of fires increases exponentially, to about 7 km from the village edges, where it is 3233 fires. It declines further; however, there is a second peak again at 15 km from the village edges, 1617 fires, (figure 3.4). Similarly, the frequency of fires (1, 2, 3, 4, 5) during the 16 year period also shows peaks at 7 km from the village edges (figure 3.5). The polynomial model provided a function of number of fires with increasing distance from the village boundary (figure 3.6), with $F_{1,14} = 120$, $R^2 = 0.59$, $p < 0.001$.

Discussion:

The contiguous forest area of the Sathyamangalam landscape is currently experiencing a range of fire-rotation intervals (Kodandapani 2013). This pattern in FRI can be attributed to the presence of the tropical moist deciduous forests and tropical semi-evergreen forests classes, where fire occurrence is limited by climatic conditions as well as fuel loads and fuel composition (Kodandapani et al. 2008). In the tropical dry thorn forests, especially, in the Bhavanisagar range, Haasanur range, and Thalavadi ranges, the predominant vegetation type in the tropical dry deciduous and tropical dry thorn forests, where the climate and fuel load composition is favorable to the occurrence of fire. This coupled with in the large human dependence on forests, especially the use of fire for the collection of certain NTFPs, could be contributing to the current spatial pattern of fire in relation to human settlements. The spatial pattern of fires in the landscape could be an indication of the use of natural resources and also the dependence on forests by the local people. The extractions of NTFPs could be one of the many reasons for the spatial pattern of the number of fires in the landscape. While there is no direct correlation between the quantity of NTFPs extracted in the various villages and the fire occurrences in the landscape, nevertheless, the proximity of the fire incidences close to the villages could be an indication of the use of fire in these ecosystems.

References:

Whelan, R.J. (1995). The ecology of fire. Cambridge University Press. Cambridge, UK.

Kodandapani, N., Cochrane, M.A., and Sukumar, R. (2004). Conservation threat of increasing fire frequencies in the Western Ghats, India. Conservation Biology. 18(6):1553-1561.

Kodandapani, N., Mark, A. Cochrane and Sukumar, R. (2008). A comparative analysis of spatial, temporal, and ecological characteristics of forest fires in a seasonally dry tropical ecosystem in the Western Ghats, India. Forest Ecology and Management. 256: 607-617.

Kodandapani, N. (2013). Contrasting fire regimes in a seasonally dry tropical forest and a savanna ecosystem in the Western Ghats, India. Journal of Fire Ecology 9(2):102-115.

Gadgil, M. (1993). Restoring the productivity of Indian savannas. In: World's Savannas: Economic driving forces, ecological constraints and policy options for sustainable land use – (Man & the Biosphere Series, Vol. 12). Ed: Young, M. D. and Solbrig, O.T.

Cochrane, M.A. and C.M. Souza Jr. (1998). Linear mixture model classification of burned forests in the eastern Amazon. International Journal of Remote Sensing. 19:3433-3440.

Cochrane, M.A. (2001). Synergistic interactions between habitat fragmentation and fire in evergreen tropical forests. Conservation Biology. 15(6): 1515-1521.

Cochrane, M.A. and Laurance, W.B. (2002). Fire as a large-scale edge effect in Amazonian forests. Journal of tropical ecology. 18:311-325.

Brown, A.A., and Davis, K.P. (1973). Forest fire: control and use. McGraw-Hill. New York.

Pyne, S.J., Andrews, P.L., and Laven, R.D. (1996). Introduction to wildland fire. John Wiley & Sons Inc. New York.

Rothermel, R.C. (1972). A mathematical model for prediction fire spread in wildland fuels. Research Paper INT-115 (Ogden, UT: USDA Forest Service, Intermountain Research Station).

Finney, M.A. (1998). FARSITE: fire area simulator-model development and evaluation. Gen. Tech. Rep. RMRS-RP-4. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

ESRI, (2002). ARC/INFO1 Software and On-line Help Manual. Environmental Systems Research Institute Inc., Redlands, CA.

Table 3.1: Satellite details, date of acquisition for Sathyamangalam landscape

Satellite/Sensor	Path/Row	Date of Acquisition
IRS-1C	100/65	01-Mar-1997
IRS-1C	100/65	22-Mar-1998
IRS-ID	100/65	21-Mar-1999
IRS-ID	100/65	24-Apr-2000
IRS-ID	100/65	15-Mar-2001
IRS-ID	100/65	28-Feb-2002
IRS-ID	100/65	10-Mar-2003
IRS-P6	100/65	14-Mar-2004
IRS-P6	100/65	13-Feb-2005
IRS-P6	100/65	28-Mar-2006
IRS-P6	100/65	23-Mar-2007
IRS-P6	100/65	22-Feb-2008
IRS-P6	100/65	16-Feb-2009
IRS-P6	100/65	07-Mar-2010
IRS-P6	100/65	02-Mar-2011
IRS-P6	100/65	25-Feb-2012

Figure 3.1: Spatial pattern of mean fire-rotation interval of the Sathyamangalam landscape

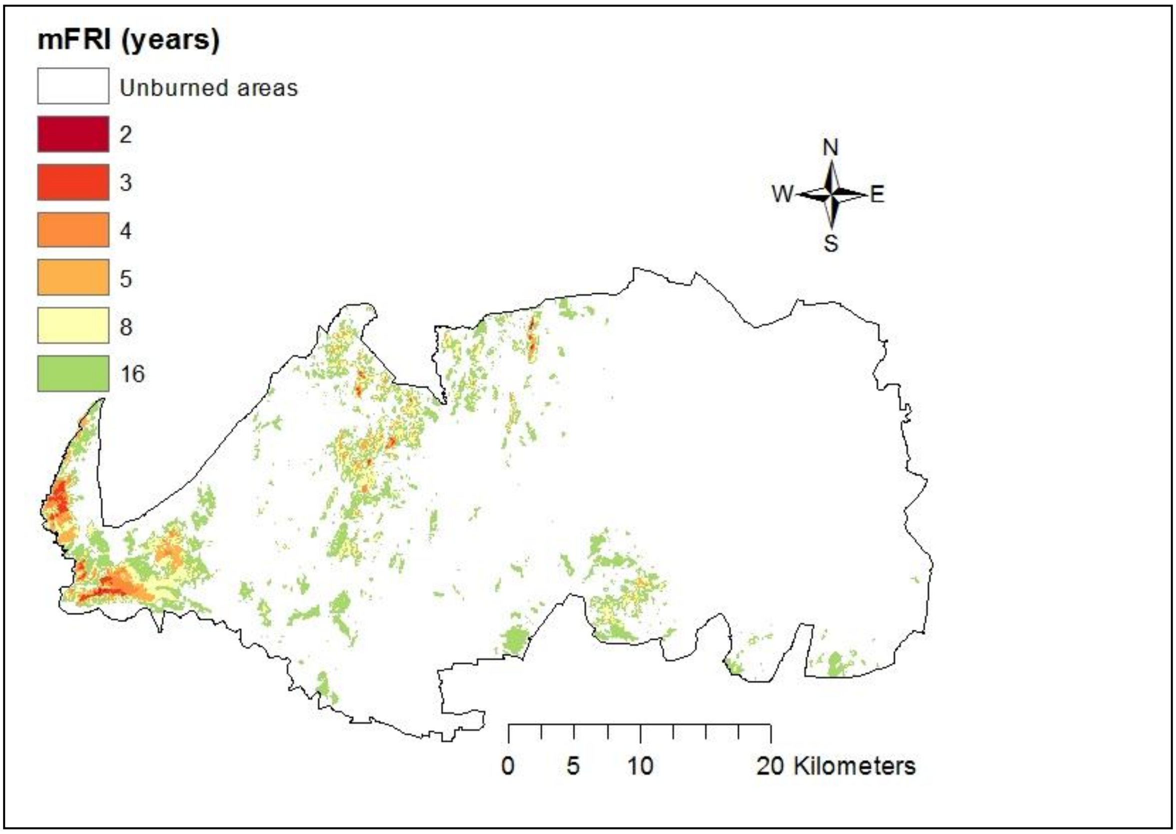


Figure 3.2: Temporal pattern of forest fires in the Sathyamangalam landscape

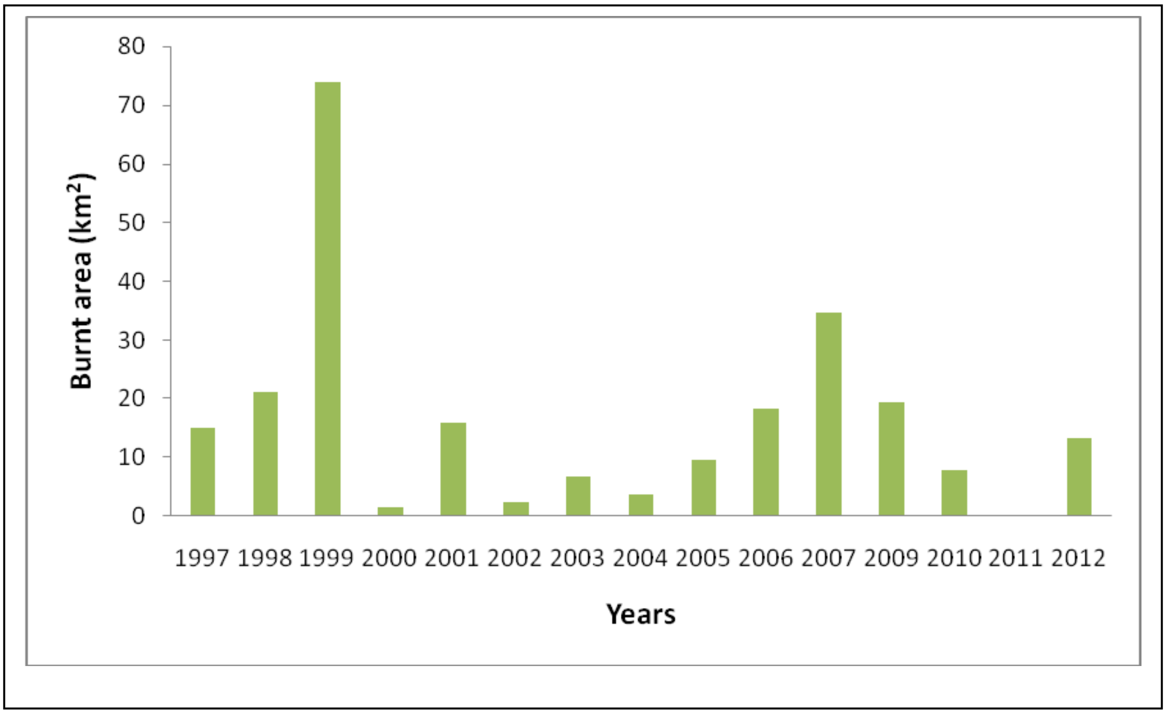


Figure 3.3: Spatial pattern of forest fire incidents and village locations in the Sathyamangalam landscape

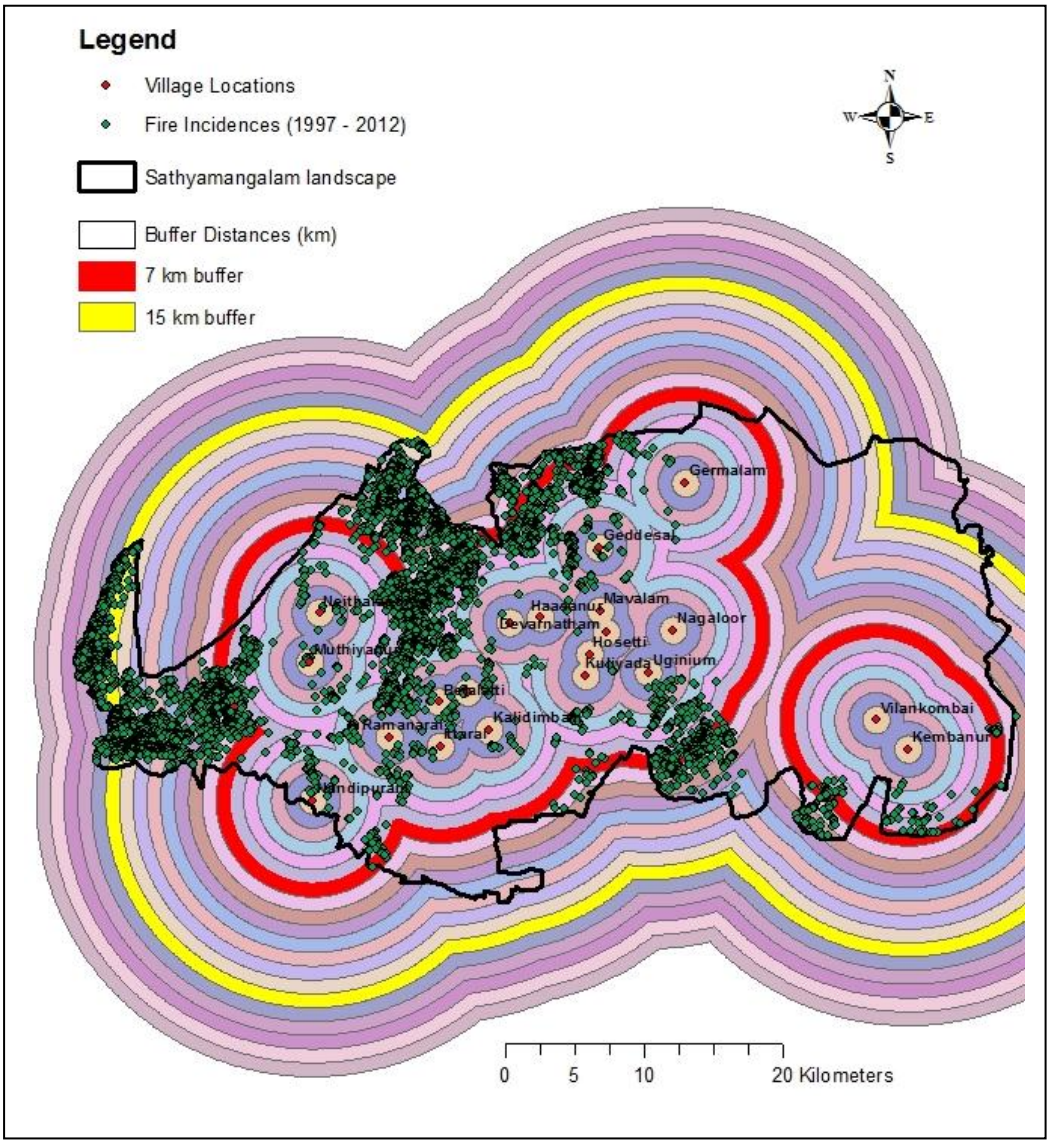


Figure 3.4: Forest fires as a function of distance from the village boundaries

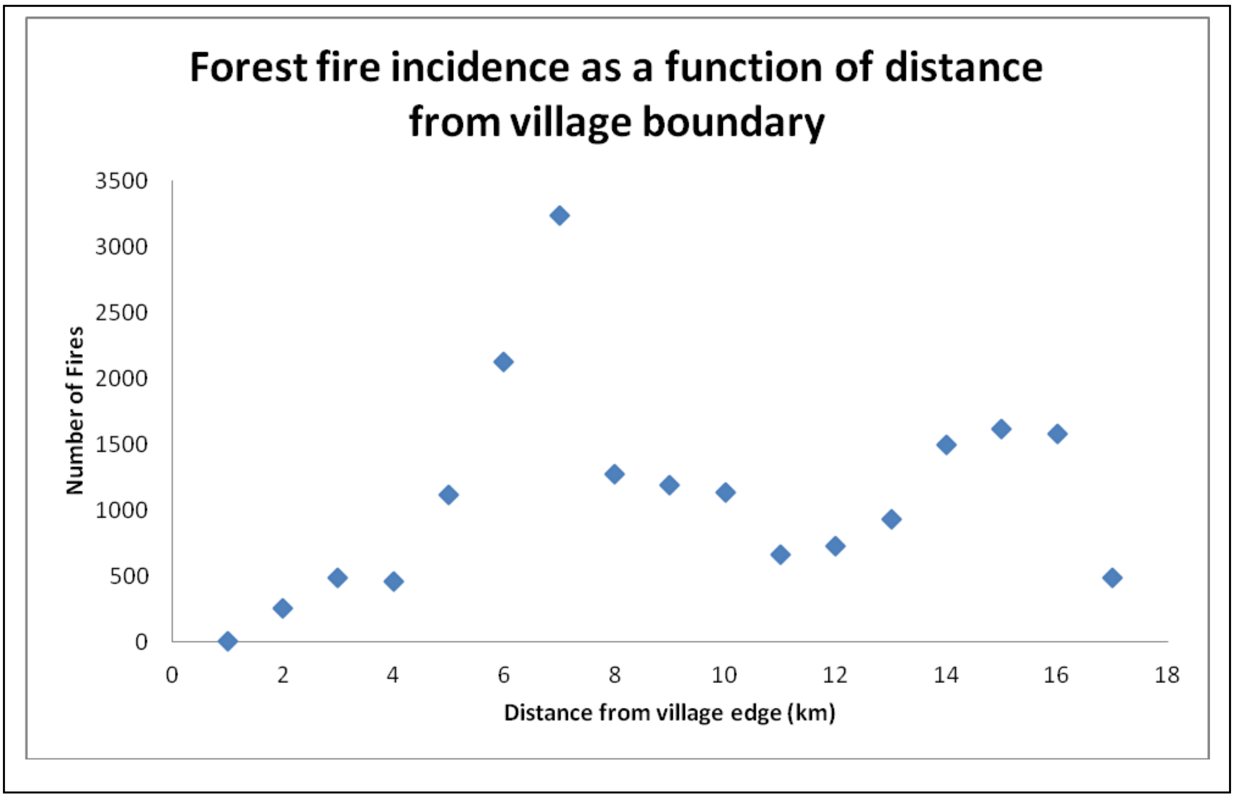


Figure 3.5: Forest fire frequency as a function of distance from the village boundaries

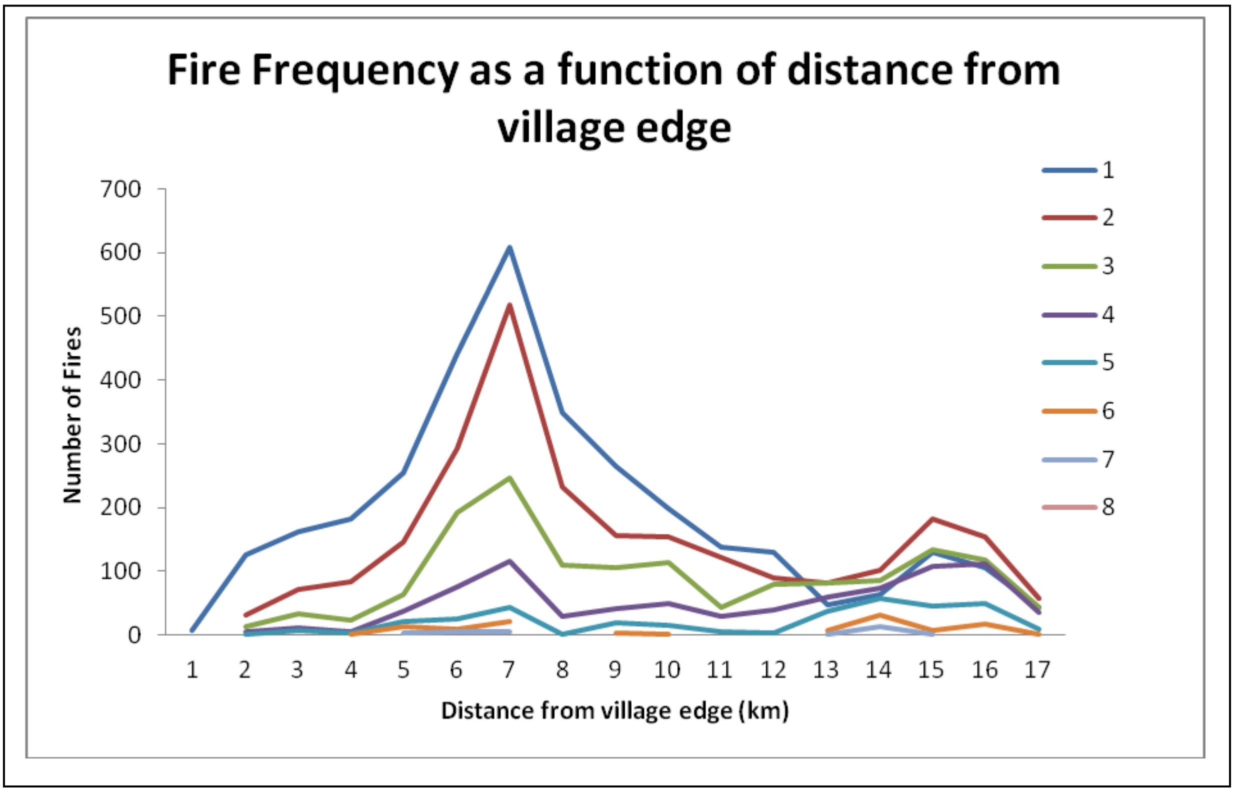
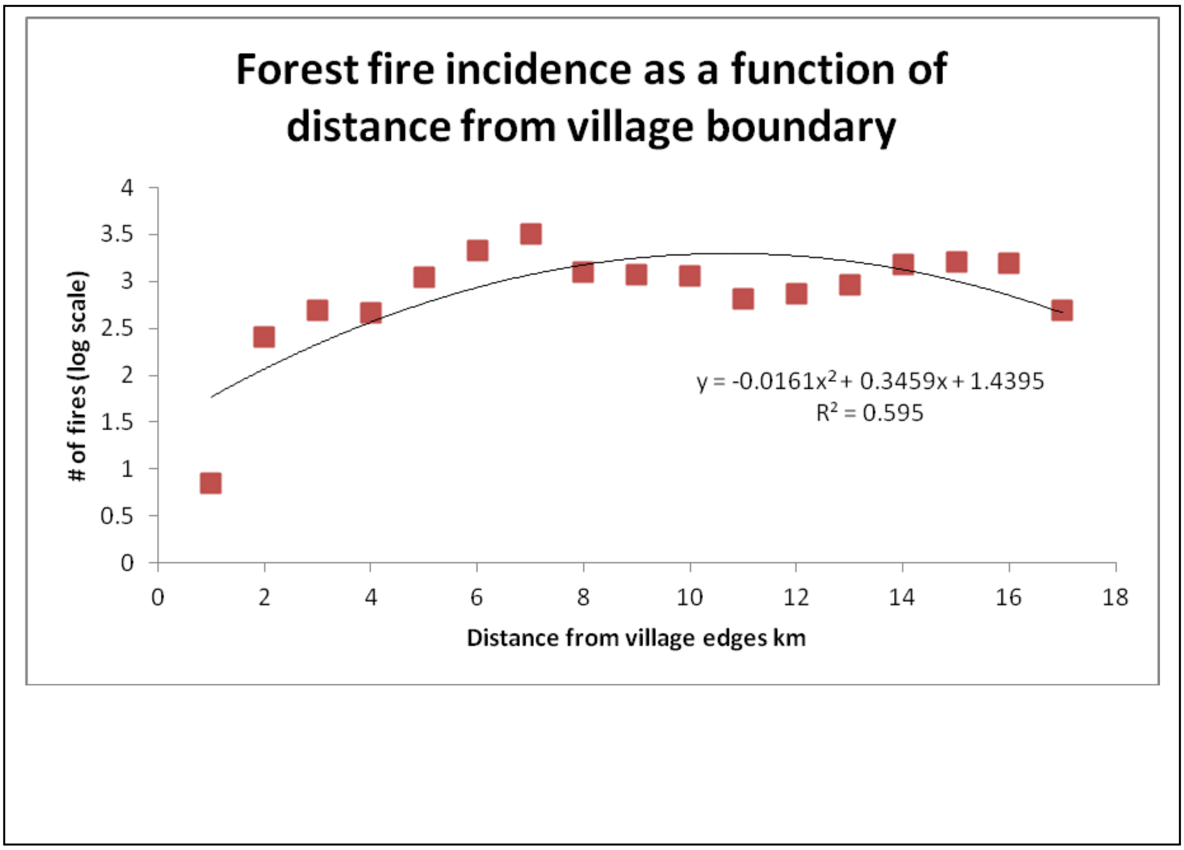


Figure 3.6: Polynomial model of fire incidence and distance from the villages for the Sathyamangalam landscape



Chapter 4

Socio-economic status of sampled villages in the Sathyamangalam landscape

Introduction

In recent years several studies have examined the drivers of land use and land cover change and also the causes of deforestation in the tropics. In more recent times, several studies have examined the proximate and underlying causes of land use and land cover changes in the tropics (Geist and Lambin 2002). The underlying causes of land use and land cover change (social) appear to be the fundamental reasons behind this land use and land cover changes in the tropics. These underlying reasons for forest change in the tropics could be a complex mix of social, economic, technological, cultural, and political variables. Here we examine social, economic, and cultural variables important for understanding the disturbance within ecosystems in the Sathyamangalam landscape.

Objectives

1. What are the prevailing socio-economic conditions in the Sathyamangalam landscape ?
2. What are the underlying causes of forest degradation in the Sathyamangalam landscape?
3. How have natural resource extractions affected their sustainability in the landscape?

Methods

A household semi-structured social survey was conducted by Kodandapani and Vinoth in the local language in Tamil in the Sathyamangalam landscape. Twenty villages were randomly sampled from the four different vegetation zones: tropical semi-evergreen forest, tropical moist deciduous forest, tropical dry deciduous forest, and tropical dry thorn forest. The survey compiled demographic information of households and included details on the family size, occupation, land holding, and livestock holding, crops cultivated, level of ground water, extraction of NTFPs, and also questions pertaining to the sustainability of resources in the villages. 30% of the households were sampled in each village. In all about 400 households were surveyed in the 20 villages (table 4.1). The NTFP survey provided information on the percentage of people involved in NTFP collection, the different NTFPs extracted, the quantities extracted, and the quantities extracted in the past (10-y ago).

Statistical Analysis

ANOVA was conducted to assess differences in the means of the socio-economic, and environmental characteristics of the different villages. All analysis was conducted in the statistical software R (R-Project, 2006).

Conducting the socio-economic surveys in the various villages in the landscape

Results

Socio economic and cultural status of villages in the Sathyamangalam landscape:

Nagaloor

The mean family size is 3.65, the mean number of males is 1.86, and the mean number of females in the households is 1.76. The mean number of years spent in the village by the households is 100-y. 100% of the households belong to various indigenous communities. 96% of the households are engaged in agriculture and wage labour. None of the families in the village own tenured land, however, the mean land holding without tenure is 2.16 acres. Eight crop types are presently cultivated in the village, however only 6 crops were cultivated 10-y ago. The main crops cultivated include, ragi (*Eleusine coracana*), corn (*Zea mays*), tapioca (*Manihot esculenta*), rice (*Oryza sativa*), beans (*Phaseolus vulgaris*), horsegram (*Vicia faba*), and mustard (*Brassica nigra*). Mean distance travelled by households to collect firewood from the forest is 2.18 km, 10-y ago the distance travelled to collect fire wood from the forests was 0.8 km. The mean number of fire wood bundles extracted by the households is 2/week. About 48% of the households are involved in NTFP collections. Five NTFP species are currently extracted from the forests, the dominant NTFPs are *Phyllanthus emblica*, *Terminalia chebula*, *Phoenix loureiroi*, and honey. The mean value of *Phyllanthus emblica* extracted by HH/trip is 42 kg, 10-y ago the mean value extracted by HH/trip was 92 kg. The mean value of *Terminalia chebula* extracted by HH/trip is 38 kg, 10-y ago the mean value extracted by HH/trip was 74 kg. The mean value of *Phoenix loureiroi* extracted by HH/trip is 34 kg, 10-y ago the mean value extracted by HH/trip was 52 kg. The mean value of honey extracted by HH/trip is 0.6 l, 10-y ago the mean value extracted by HH/trip was 1 l. Mean ground water level in the village is 600 ft, 10-y ago it was 200 ft.

Bungalathoti

The mean family size is 4.16, the mean number of males is 2.15, and the mean number of females in the households is 1.89. The mean number of years spent in the village by the households is 100-y. 100% of the households belong to various indigenous communities. 99% of the households are engaged in wage labour and 1% in agriculture. Mean value of tenured land held is 0.05 acres, land holding without tenure is absent. Four crop types are presently cultivated in the village, however only 2 crops were cultivated 10-y ago. The main crops cultivated include, ragi (*Eleusine coracana*), corn (*Zea mays*), and beetroot (*Beta vulgaris*). Mean distance travelled by households to collect fire wood from the forest is 2.94 km, 10-y ago the distance travelled to collect fire wood from the forests was 1.57 km. The mean number of fire wood bundles extracted by the households is 2.05/week. About 99% of the households are involved in NTFP collections. Five NTFP species are currently extracted from the forests, the dominant NTFPs are *Phyllanthus emblica, Terminalia chebula, Phoenix loureiroi*, and honey. The mean value of *Phyllanthus emblica* extracted by HH/trip is 34 kg, 10-y ago the mean value extracted by HH/trip was 62 kg. The mean value of *Terminalia chebula* extracted by HH/trip is 6.5 kg, 10-y ago the mean value extracted by HH/trip was 43 kg. The mean value of *Phoenix loureiroi* extracted by HH/trip is 33 kg, 10-y ago the mean value extracted by HH/trip was 36 kg.

Haasanur

The mean family size is 3.42, the mean number of males is 1.8, and the mean number of females in the households is 1.6. The mean number of years spent in the village by the households is 100-y. 75% of the households belong to various indigenous communities. 99% of the households are engaged in wage labour, and 35% of households are engaged in agriculture. None of the families in the village own non-tenured land, however, the mean land holding with tenure is 0.13 acres. Three crop types are presently cultivated in the village, however 4 crops were cultivated 10-y ago. The main crops cultivated include, ragi (*Eleusine coracana*), corn (*Zea mays*), and beans (*Phaseolus vulgaris*). Mean distance travelled by households to collect fire wood from the forest is 2.45 km, 10-y ago the distance travelled to collect fire wood from the forests was 0.97 km. The mean number of fire wood bundles extracted by the households is 2/week. About 85% of the households are involved in NTFP collections. Five NTFP species are currently extracted from the forests, the dominant NTFPs are *Phyllanthus emblica*, *Terminalia chebula*, *Phoenix loureiroi*, and honey. The mean value of *Phyllanthus emblica* extracted by HH/trip is 36.5 kg, 10-y ago the mean value extracted by HH/trip was 42.5 kg. The mean value of *Terminalia chebula* extracted by HH/trip is 31.5 kg, 10-y ago the mean value extracted by HH/trip was 34 kg. The mean value of *Phoenix loureiroi* extracted by HH/trip is 24 kg, 10-y ago the mean value extracted by HH/trip was 36 kg. The mean value of honey extracted by HH/trip is 1.3 l, 10-y ago the mean value extracted by HH/trip was 2.7 l. Mean ground water level in the village is 486 ft, 10-y ago it was 128 ft.

Germalam

The mean family size is 5.37, the mean number of males is 2.75, and the mean number of females in the households is 2.66. The mean number of years spent in the village by the households is 99-y. 46% of the households belong to various indigenous communities. 80% of the households are engaged in wage labour and 20% of households are engaged in agriculture. Mean land holding size in the village with tenure is 0.87 acres; the mean land holding without tenure is 0.43 acres. Nine crop types are presently cultivated in the village, however only six crops were cultivated 10-y ago. The main crops cultivated include, ragi (*Eleusine coracana*), corn (*Zea mays*), carrot (*Daucus carota*), beans (*Phaseolus vulgaris*), cabbage (*Brassica oleracea*), peas (*Pisum sativum*), garlic (*Allium sativum*), spinach (*Spinacia oleracea*) and onion (*Allium cepa*). Mean distance travelled by households to collect fire wood from the forest is 2.2 km, 10-y ago the distance travelled to collect fire wood from the forests was 1.6 km. The mean number of fire wood bundles extracted by the households is 2.4/week. About 3% of the households are involved in NTFP collections. Four NTFP species are currently extracted from the forests, the dominant NTFPs are *Phyllanthus emblica*, *Terminalia chebula*, *Phoenix loureiroi*, and honey. The mean value of *Phyllanthus emblica* extracted by HH/trip is 30 kg, 10-y ago the mean value extracted by HH/trip was 80 kg. The mean value of *Terminalia chebula* extracted by HH/trip is 30 kg, 10-y ago the mean value extracted by HH/trip was 60 kg. The mean value of *Phoenix loureiroi* extracted by HH/trip is 30 kg, 10-y ago the mean value extracted by HH/trip was 30 kg. Mean ground water level in the village is 585 ft, 10-y ago it was 250 ft.

Kuliyada

The mean family size is 4.28, the mean number of males is 2.2, and the mean number of females in the households is 2.06. The mean number of years spent in the village by the households is 94-y. 99% of the households belong to various indigenous communities. 93% of the households are engaged in both wage labour and agriculture. Mean land holding size in the village with tenure is 1.7 acres, none of the households possess untenured land. Seven crop types are presently cultivated in the village, however only six crops were cultivated 10-y ago. The main crops cultivated include, ragi (*Eleusine coracana*), corn (*Zea mays*), potato (*Solamum tuberosum),* beans (*Phaseolus vulgaris*), and mustard (*Brassica nigra).* Mean distance travelled by households to collect fire wood from the forest is 2.3 km, 10-y ago the distance travelled to collect fire wood from the forests was 1.2 km. The mean number of fire wood bundles extracted by the households is 2/week. About 66% of the households are involved in NTFP collections. Four NTFP species are currently extracted from the forests, the dominant NTFPs are *Phyllanthus emblica*, *Terminalia chebula*, *Phoenix loureiroi*, and honey. The mean value of *Phyllanthus emblica* extracted by HH/trip is 59 kg, 10-y ago the mean value extracted by HH/trip was 79 kg. The mean value of *Terminalia chebula* extracted by HH/trip is 51 kg, 10-y ago the mean value extracted by HH/trip was 71 kg. The mean value of *Phoenix loureiroi* extracted by HH/trip is 15 kg, 10-y ago the mean value extracted by HH/trip was 18 kg. The mean value of honey collected by HH/trip is 1.8 l, 10-y ago the mean value collected by HH/trip was 1.8 l. Mean ground water level in the village is 186 ft, 10-y ago it was 100 ft.

Neithalapuram

The mean family size is 4, the mean number of males is 2.02, and the mean number of females in the households is 1.96. The mean number of years spent in the village by the households is 100-y. 20% of the households belong to various indigenous communities. 90% of the households are engaged in wage labour and 38% of households are engaged in agriculture. Mean land holding size in the village with tenure is 0.9 acres; the mean land holding without tenure is 0.26 acres. Four crop types are presently cultivated in the village, however only three crops were cultivated 10-y ago. The main crops cultivated include, ragi (*Eleusine coracana*), corn (*Zea mays*), beans (*Phaseolus vulgaris*), and sesame (*Sesamum indicum).* Mean distance travelled by households to collect fire wood from the forest is 1.9 km, 10-y ago the distance travelled to collect fire wood from the forests was 0.7 km. The mean number of fire wood bundles extracted by the households is 2.2/week. About 20% of the households are involved in NTFP collections. Four NTFP species are currently extracted from the forests, the dominant NTFPs are *Phyllanthus emblica*, *Terminalia chebula*, *Phoenix loureiroi*, and honey. The mean value of *Phyllanthus emblica* extracted by HH/trip is 41 kg, 10-y ago the mean value extracted by HH/trip was 89 kg. The mean value of *Terminalia chebula* extracted by HH/trip is 40 kg, 10-y ago the mean value extracted by HH/trip was 68 kg. The mean value of *Phoenix loureiroi* extracted by HH/trip is 46 kg, 10-y ago the mean value extracted by HH/trip was 70 kg. The mean value of honey collected by HH/trip is 1.9 l, 10-y ago the mean value collected by HH/trip was 4.2 l. Mean ground water level in the village is 363 ft, 10-y ago it was 145 ft.

Muthiyanur

The mean family size is 4.47, the mean number of males is 2.4, and the mean number of females in the households is 2.05. The mean number of years spent in the village by the households is 100-y. None of the households belong to various indigenous communities. 99% of the households are engaged in wage labour and 40% of households are engaged in agriculture. Mean land holding size in the village with tenure is 0.67 acres; the land holding without tenure is absent. Three crop types are presently cultivated in the village, however only two crops were cultivated 10-y ago. The main crops cultivated include, ragi (*Eleusine coracana*), corn (*Zea mays*), and beans (*Phaseolus vulgaris*). Mean distance travelled by households to collect fire wood from the forest is 1.9 km, 10-y ago the distance travelled to collect firewood from the forests was 0.9 km. The mean number of fire wood bundles extracted by the households is 2.2/week. None of the households are involved in NTFP collections. Mean ground water level in the village is 419 ft, 10-y ago it was 200 ft.

Devarnatham

The mean family size is 4.44, the mean number of males is 2.23, and the mean number of females in the households is 2.23. The mean number of years spent in the village by the households is 100-y. 42% of the households belong to various indigenous communities.

99% of the households are engaged in wage labour and 85% of households are engaged in agriculture. Mean land holding size in the village with tenure is 1.28 acres; the mean land holding without tenure is 0.07 acres. 10 crop types are presently cultivated in the village, however only two crops were cultivated 10-y ago. The main crops cultivated include, ragi (*Eleusine coracana*), corn (*Zea mays*), beans (*Phaseolus vulgaris*), cabbage (*Brassica oleracea*), carrot (*Daucus carota),* garlic (*Allium sativum*), mustard (*Brassica nigra),* potato *(Solanum tuberosum)* and castor (*Ricinus communis).* Mean distance travelled by households to collect fire wood from the forest is 1.95 km, 10-y ago the distance travelled to collect fire wood from the forests was 0.78 km. The mean number of fire wood bundles extracted by the households is 2.15/week. About 77% of the households are involved in NTFP collections. Four NTFP species are currently extracted from the forests, the dominant NTFPs are *Phyllanthus emblica*, *Terminalia chebula*, *Phoenix loureiroi*, and honey. The mean value of *Phyllanthus emblica* extracted by HH/trip is 43 kg, 10-y ago the mean value extracted by HH/trip was 91 kg. The mean value of *Terminalia chebula* extracted by HH/trip is 30 kg, 10-y ago the mean value extracted by HH/trip was 69 kg. The mean value of *Phoenix loureiroi* extracted by HH/trip is 26 kg, 10-y ago the mean value extracted by HH/trip was 30 kg. The mean value of honey collected by HH/trip is 0.25 l, 10-y ago the mean value collected by HH/trip was 0.25 l. Mean ground water level in the village is 300 ft, 10-y ago it was 121 ft.

Hosetti

The mean family size is 4.4, the mean number of males is 2.25, and the mean number of females in the households is 2.06. The mean number of years spent in the village by the households is 100-y. None of the households belong to various indigenous communities. 99% of the households are engaged in wage labour and 88% of households are engaged in agriculture. Mean land holding size in the village with tenure is 1.9 acres; the land holding without tenure is absent. Eight crop types are presently cultivated in the village, however only six crops were cultivated 10-y ago. The main crops cultivated include, ragi (*Eleusine coracana*), corn (*Zea mays*), potato (*Solanum tuberosum),* beans (*Phaseolus vulgaris*), garlic (*Allium sativum*), spinach (*Spinacia oleracea*) and mustard (*Brassica nigra).* Mean distance travelled by households to collect fire wood from the forest is 2.1 km, 10-y ago the distance travelled to collect fire wood from the forests was 1.1 km. The mean number of fire wood bundles extracted by the households is 2.3/week. None of the households are involved in NTFP collections. Mean ground water level in the village is 171 ft, 10-y ago it was 100 ft.

Mavalam

The mean family size is 3.72, the mean number of males is 1.86, and the mean number of females in the households is 1.83. The mean number of years spent in the village by the households is 98-y. 53% of the households belong to various indigenous communities. 97% of the households are engaged in wage labour and 47% of households are engaged in agriculture. Mean land holding size in the village with tenure is 1 acre; the land holding without tenure is absent. Five crop types are presently cultivated in the village, however only six crops were cultivated 10-y ago. The main crops cultivated include, ragi (*Eleusine coracana*), corn (*Zea mays*), beans (*Phaseolus vulgaris*), potato (*Solanum tuberosum) and* coffee *(Coffea spp.)*. Mean distance travelled by households to collect fire wood from the forest is 2.1 km, 10-y ago the distance travelled to collect fire wood from the forests was 1.3 km. The mean number of fire wood bundles extracted by the households is 1.9/week. About 53% of the households are involved in NTFP collections. Four NTFP species are currently extracted from the forests, the dominant NTFPs are *Phyllanthus emblica*, *Terminalia chebula*, *Phoenix loureiroi*, and honey. The mean value of *Phyllanthus emblica* extracted by HH/trip is 34 kg, 10-y ago the mean value extracted by HH/trip was 53 kg. The mean value of

Terminalia chebula extracted by HH/trip is 2.5 kg, 10-y ago the mean value extracted by HH/trip was 3.5 kg. The mean value of *Phoenix loureiroi* extracted by HH/trip is 30 kg, 10-y ago the mean value extracted by HH/trip was 39 kg. Mean ground water level in the village is 530 ft, 10-y ago it was 218 ft.

Uginium

The mean family size is 3.78, the mean number of males is 2, and the mean number of females in the households is 1.7. The mean number of years spent in the village by the households is 100-y. 99% of the households belong to various indigenous communities. 95% of the households are engaged in wage labour and 99% of households are engaged in agriculture. Land holding size in the village with tenure is absent; the mean land holding without tenure is 2.35 acres. Five crop types are presently cultivated in the village, however only two crops were cultivated 10-y ago. The main crops cultivated include, ragi (*Eleusine coracana*), corn (*Zea mays*), horsegram (*Vicia faba),* beans *(Phaseolus vulgaris),* rice *(Oryza sativa).* Mean distance travelled by households to collect fire wood from the forest is 2.3 km, 10-y ago the distance travelled to collect fire wood from the forests was 0.9 km. The mean number of fire wood bundles extracted by the households is 2.2/week. About 99% of the households are involved in NTFP collections. Four NTFP species are currently extracted from the forests, the dominant NTFPs are *Phyllanthus emblica*, *Terminalia chebula*, *Phoenix loureiroi*, and honey. The mean value of *Phyllanthus emblica* extracted by HH/trip is 38 kg, 10-y ago the mean value extracted by HH/trip was 59 kg. The mean value of *Terminalia chebula* extracted by HH/trip is 35 kg, 10-y ago the mean value extracted by HH/trip was 50 kg. The mean value of *Phoenix loureiroi* extracted by HH/trip is 42 kg, 10-y ago the mean value extracted by HH/trip was 42 kg. The mean value of honey collected by HH/trip is 0.16

l, 10-y ago the mean value collected by HH/trip was 1.25 l. Mean ground water level in the village is 446 ft, 10-y ago it was 146 ft.

Ittarai

The mean family size is 4.28, the mean number of males is 1.93, and the mean number of females in the households is 2.4. The mean number of years spent in the village by the households is 100-y. 99% of the households belong to various indigenous communities. 99% of the households are engaged in wage labour and 86% of households are engaged in agriculture. Mean land holding size in the village with tenure is 0.55 acres; the mean land holding without tenure is 1.3 acres. Seven crop types are presently cultivated in the village, however only four crops were cultivated 10-y ago. The main crops cultivated include, ragi (*Eleusine coracana*), corn (*Zea mays*), beans (*Phaseolus vulgaris*), spinach (*Spinacia oleracea*), rice (*Oryza sativa),* and mustard (*Brassica nigra*). Mean distance travelled by households to collect fire wood from the forest is 2.1 km, 10-y ago the distance travelled to collect fire wood from the forests was 0.8 km. The mean number of fire wood bundles extracted by the households is 2.5/week. About 99% of the households are involved in NTFP collections. Four NTFP species are currently extracted from the forests, the dominant NTFPs are *Phyllanthus emblica*, *Terminalia chebula*, *Phoenix loureiroi*, and honey. The mean value of *Phyllanthus emblica* extracted by HH/trip is 42 kg, 10-y ago the mean value extracted by HH/trip was 74 kg. The mean value of *Terminalia chebula* extracted by HH/trip is 30 kg, 10-y ago the mean value extracted by HH/trip was 43 kg. The mean value of *Phoenix loureiroi* extracted by HH/trip is 37 kg, 10-y ago the mean value extracted by HH/trip was 55 kg. The mean value of honey collected by HH/trip is 1.6 l, 10-y ago the mean value collected by HH/trip was 4.4 l. Mean ground water level in the village is 118 ft, 10-y ago it was 62 ft.

Ramanarai

The mean family size is 4.77, the mean number of males is 2.6, and the mean number of females in the households is 2.2. The mean number of years spent in the village by the households is 100-y. 99% of the households belong to various indigenous communities. 99% of the households are engaged in wage labour and 90% of households are engaged in agriculture. Land holding in the village with tenure is absent; the mean land holding without tenure is 2.1 acres. Six crop types are presently cultivated in the village, and six crops were cultivated 10-y ago. The main crops cultivated include, ragi (*Eleusine coracana*), corn (*Zea mays*), beans (Phaseolus *vulgaris*), mustard (*Brassica nigra*), and horsegram (*Vicia faba)*. Mean distance travelled by households to collect fire wood from the forest is 1.7 km, 10-y ago the distance travelled to collect fire wood from the forests was 0.6 km. The mean number of fire wood bundles extracted by the households is 2.2/week. About 99% of the households are involved in NTFP collections. Four NTFP species are currently extracted from the forests; the dominant NTFPs are *Phyllanthus emblica*, *Terminalia chebula*, *Phoenix loureiroi*, and honey. The mean value of *Phyllanthus emblica* extracted by HH/trip is 39 kg, 10-y ago the mean value extracted by HH/trip was 73 kg. The mean value of *Terminalia chebula* extracted by HH/trip is 28 kg, 10-y ago the mean value extracted by HH/trip was 43 kg. The mean value of *Phoenix loureiroi* extracted by HH/trip is 31 kg, 10-y ago the mean value extracted by HH/trip was 38 kg. The mean value of honey collected by HH/trip is 1.7 l, 10-y ago the mean value collected by HH/trip was 3.5 l. Mean ground water level in the village is 128 ft, 10-y ago it was 59 ft.

Kembanur

The mean family size is 5.5, the mean number of males is 2.4, and the mean number of females in the households is 3.2. The mean number of years spent in the village by the households is 100-y. 99% of the households belong to various indigenous communities. 80% of the households are engaged in wage labour and 80% of households are engaged in agriculture. Land holding with tenure is absent; the mean land holding without tenure is 3.6 acres. Seven crop types are presently cultivated in the village, however only six crops were cultivated 10-y ago. The main crops cultivated include, ragi (Eleusine coracana), rice (*Oryza sativa),* sesame (*Sesamum indicum),* castor *(Ricinus communis)* and coriander (*Coriandrum sativum*). Mean distance travelled by households to collect fire wood from the forest is 0.6 km, 10-y ago the distance travelled to collect fire wood from the forests was 0.4 km. The mean number of fire wood bundles extracted by the households is 1.6/week. About 99% of the households are involved in NTFP collections. Four NTFP species are currently extracted from the forests, the dominant NTFPs are *Phyllanthus emblica*, *Terminalia chebula*, *Phoenix loureiroi*, and honey. The mean value of *Phyllanthus emblica* extracted by HH/trip is 30 kg, 10-y ago the mean value extracted by HH/trip was 38 kg. The mean value of *Terminalia chebula* extracted by HH/trip is 29 kg, 10-y ago the mean value extracted by HH/trip was 36 kg. The mean value of *Phoenix loureiroi* extracted by HH/trip is 40 kg, 10-y ago the mean value extracted by HH/trip was 48 kg. The mean value of honey collected by HH/trip is 3.2 l, 10-y ago the mean value collected by HH/trip was 4 l. Mean ground water level in the village is 106 ft, 10-y ago it was 50 ft.

Nandipuram

The mean family size is 2.5, the mean number of males is 1.6, and the mean number of females in the households is 1. The mean number of years spent in the village by the households is 100-y. 99% of the households belong to various indigenous communities. 99% of the households are engaged in wage labour and 60% of households are engaged in agriculture. Land holding with tenure is absent; the mean land holding without tenure is 0.6

acres. Five crop types are presently cultivated in the village, however six crops were cultivated 10-y ago. The main crops cultivated include, ragi (*Eleusine coracana*), chillies (*Capsicum* spp.), horsegram (*Vicia faba*), cotton (*Gossypium spp.)* and marigold flowers. Mean distance travelled by households to collect fire wood from the forest is 1 km, 10-y ago the distance travelled to collect fire wood from the forests was 0.8 km. The mean number of fire wood bundles extracted by the households is 1.2. About 99% of the households are involved in NTFP collections. Four NTFP species are currently extracted from the forests, the dominant NTFPs are *Sapindus emarginata*, *Azadirachta indica*, *Solanum tarvum* and *Tamarindus indicus*. The mean value of *Sapindus emarginata* extracted by HH/trip is 33 kg, 10-y ago the mean value extracted by HH/trip was 56 kg. The mean value of *Azadirachta indica* extracted by HH/trip is 27 kg, 10-y ago the mean value extracted by HH/trip was 52 kg. The mean value of *Solanum tarvum* extracted by HH/trip is 21 kg, 10-y ago the mean value extracted by HH/trip was 39 kg. The mean value of *Tamarindus indicus* extracted by HH/trip is 64 kg, 10-y ago the mean value extracted by HH/trip was 139 kg. Mean ground water level in the village is 425 ft, 10-y ago it was 60 ft.

Questionnaire survey regarding crops grown and sources of water for agriculture

Biodiversity and cultural elements in the landscape

Various crops cultivated in the landscape

Agricultural and pastoral livelihoods in the landscape

Tropical dry thorn forests, riverine habitats, and tropical dry deciduous forests



Blackbuck populations in the landscape

Pastoralism as a livelihood option in the landscape

Extensive view of the agroforestry landscape

Conducting the questionnaire survey in the landscape

Gathering data on forest disturbance in the landscape

Socio-economic questionnaire survey and the vegetation survey

A view of the mammals in the landscape

Bejalatti

The mean family size is 4.1, the mean number of males is 2.05, and the mean number of females in the households is 2.1. The mean number of years spent in the village by the households is 100-y. 99% of the households belong to various indigenous communities. 99% of the households are engaged in wage labour and 95% of households are engaged in agriculture. Mean land holding size in the village with tenure is 0.5 acres; the mean land holding without tenure is 0.4 acres. Five crop types are presently cultivated in the village, however only three crops were cultivated 10-y ago. The main crops cultivated include, ragi (*Eleusine coracana*), corn (*Zea mays*), beans (*Phaseolus vulgaris*), spinach (*Spinacia oleracea*), and mustard (*Brassica nigra*). Mean distance travelled by households to collect fire wood from the forest is 2.3 km, 10-y ago the distance travelled to collect fire wood from the forests was 0.83 km. The mean number of fire wood bundles extracted by the households is 2.05/week. About 99% of the households are involved in NTFP collections. Seven NTFP species are currently extracted from the forests, the dominant NTFPs are *Phyllanthus emblica*, *Terminalia chebula*, *Phoenix loureiroi*, and honey. The mean value of *Phyllanthus emblica* extracted by HH/trip is 41 kg, 10-y ago the mean value extracted by HH/trip was 69 kg. The mean value of *Terminalia chebula* extracted by HH/trip is 28 kg, 10-y ago the mean value extracted by HH/trip was 48 kg. The mean value of *Phoenix loureiroi* species extracted by HH/trip is 38 kg, 10-y ago the mean value extracted by HH/trip was 48 kg. The mean value of honey collected by HH/trip is 1.7 l, 10-y ago the mean value collected by HH/trip was 3.7 l. Mean ground water level in the village is 211 ft, 10-y ago it was 92 ft.

Kalidimbam

The mean family size is 4, the mean number of males is 2.2, and the mean number of females in the households is 1.9. The mean number of years spent in the village by the households is 100-y. 99% of the households belong to various indigenous communities. 99% of the households are engaged in wage labour and 99% of households are engaged in agriculture. Mean land holding size in the village with tenure is 2.05 acres; land holding without tenure is absent. Five crop types are presently cultivated in the village, however only three crops were cultivated 10-y ago. The main crops cultivated include, ragi (*Eleusine coracana*), corn (*Zea mays*), beans (*Phaseolus vulgaris*), spinach (*Spinacia oleracea*), and mustard (*Brassica nigra*). Mean distance travelled by households to collect fire wood from the forest is 2.2 km, 10-y ago the distance travelled to collect fire wood from the forests was 1 km. The mean number of fire wood bundles extracted by the households is 2.7/week. About 99% of the households are involved in NTFP collections. Four NTFP species are currently extracted from the forests, the dominant NTFPs are *Phyllanthus emblica*, *Terminalia chebula*, *Phoenix loureiroi*, and honey. The mean value of *Phyllanthus emblica* extracted by HH/trip is 55 kg, 10-y ago the mean value extracted by HH/trip was 68 kg. The mean value of *Terminalia chebula* extracted by HH/trip is 37 kg, 10-y ago the mean value extracted by HH/trip was 49 kg. The mean value of *Phoenix loureiroi* species extracted by HH/trip is 41 kg, 10-y ago the mean value extracted by HH/trip was 49 kg. The mean value of honey collected by HH/trip is 5.4 l, 10-y ago the mean value collected by HH/trip was 8.8 l. Mean ground water level in the village is 230 ft, 10-y ago it was 100 ft.

Vilankombai

The mean family size is 4.55, the mean number of males is 2.1, and the mean number of females in the households is 2.4. The mean number of years spent in the village by the households is 100-y. 99% of the households belong to various indigenous communities. 99% of the households are engaged in wage labour and 99% of households are engaged in agriculture. Land holding with tenure is absent; the mean land holding without tenure is 3 acres. Eight crop types are presently cultivated in the village, and eight crops were cultivated 10-y ago. The main crops cultivated include, ragi (*Eleusine coracana*), corn (*Zea mays*), beans (*Phaseolus vulgaris*), rice (*Oryza sativa)*, and horsegram (*Vicia faba)*. Mean distance travelled by households to collect fire wood from the forest is 2.2 km, 10-y ago the distance travelled to collect fire wood from the forests was 0.7 km. The mean number of fire wood bundles extracted by the households is 7/week. About 99% of the households are involved in NTFP collections. Four NTFP species are currently extracted from the forests, the dominant NTFPs are *Phyllanthus emblica*, *Terminalia chebula*, *Phoenix loureiroi*, and honey. The mean value of *Phyllanthus emblica* extracted by HH/trip is 42 kg, 50-y ago the mean value extracted by HH/trip was 92 kg. The mean value of *Terminalia chebula* extracted by HH/trip is 38 kg, 10-y ago the mean value extracted by HH/trip was 56 kg. The mean value of *Phoenix loureiroi* species extracted by HH/trip is 33 kg, 10-y ago the mean value extracted by HH/trip was 45 kg. The mean value of honey collected by HH/trip is 1.1 l, 10-y ago the mean value collected by HH/trip was 3.2 l. Mean ground water level in the village is 55 ft, 10-y ago it was 33 ft.

Mavanatham

The mean family size is 4.21, the mean number of males is 2.05, and the mean number of females in the households is 2.1. The mean number of years spent in the village by the households is 100-y. 99% of the households belong to various indigenous communities. 99% of the households are engaged in wage labour and 99% of households are engaged in agriculture. Land holding with tenure is absent; the mean land holding without tenure is 1.6

acres. Eight crop types are presently cultivated in the village, however only six crops were cultivated 10-y ago. The main crops cultivated include, ragi (*Eleusine coracana*), corn (*Zea mays*), beans (*Phaseolus vulgaris*), horsegram (*Vicia faba),* rice (*Oryza sativa),* and mustard (*Brassica nigra*). Mean distance travelled by households to collect fire wood from the forest is 2.1 km, 10-y ago the distance travelled to collect fire wood from the forests was 0.8 km. The mean number of fire wood bundles extracted by the households is 2.1/week. About 99% of the households are involved in NTFP collections. Four NTFP species are currently extracted from the forests, the dominant NTFPs are *Phyllanthus emblica*, *Terminalia chebula, Phoenix loureiroi*, and honey. The mean value of *Phyllanthus emblica* extracted by HH/trip is 38 kg, 10-y ago the mean value extracted by HH/trip was 71 kg. The mean value of *Terminalia chebula* extracted by HH/trip is 33 kg, 10-y ago the mean value extracted by HH/trip was 46 kg. The mean value of *Phoenix loureiroi* species extracted by HH/trip is 34 kg, 10-y ago the mean value extracted by HH/trip was 47 kg. The mean value of honey collected by HH/trip is 1 l, 10-y ago the mean value collected by HH/trip was 3.2 l. Mean ground water level in the village is 146 ft, 10-y ago it was 63 ft.

Geddesal

The mean family size is 4.68, the mean number of males is 2.56, and the mean number of females in the households is 2.13. The mean number of years spent in the village by the households is 97-y. 99% of the households belong to various indigenous communities. 77% of the households are engaged in wage labour and 97% of households are engaged in agriculture. Land holding with tenure is absent; the mean land holding without tenure is 1.6 acres. Eight crop types are presently cultivated in the village, however only six crops were cultivated 10-y ago. The main crops cultivated include, ragi (*Eleusine coracana*), corn (*Zea mays*), beans (*Phaseolus vulgaris*), potato (*Solamum tuberosum), carrot (Daucus carota),* cabbage *(Brassica oleracea),* beetroot *(Beta vulgaris),* spinach (*Spinacia oleracea*), garlic (*Allium sativum),* and mustard (*Brassica nigra*). Mean distance travelled by households to collect fire wood from the forest is 2.11 km, 10-y ago the distance travelled to collect fire wood from the forests was 1.25 km. The mean number of fire wood bundles extracted by the households is 2.6/week. About 99% of the households are involved in NTFP collections. Five NTFP species are currently extracted from the forests, the dominant NTFPs are *Phyllanthus emblica*, *Terminalia chebula*, *Phoenix loureiroi*, and honey. The mean value of *Phyllanthus emblica* extracted by HH/trip is 84 kg, 10-y ago the mean value extracted by HH/trip was 99 kg. The mean value of *Terminalia chebula* extracted by HH/trip is 52 kg, 10-y ago the mean value extracted by HH/trip was 84 kg. The mean value of *Phoenix loureiroi* species extracted by HH/trip is 30 kg, 10-y ago the mean value extracted by HH/trip was 39 kg. The mean value of honey collected by HH/trip is 11 l, 10-y ago the mean value collected by HH/trip was 12 l. Mean ground water level in the village is 360 ft, 10-y ago it was 147 ft.

Statistical analysis of the underlying causes of forest disturbance in the Sathyamangalam landscape

The mean family size in the Sathyamangalam landscape is highest in the villages Kembanur (5.5) and Germalam (5.3) and it is lowest in Nandipuram (2.5) (Fig. 4.1). The ANOVA shows that there are significant differences between the means of the family sizes among the different villages in the landscape, $F=2.05$, $p < 0.01$. The mean number of males/family was highest in Germalam (2.75) and the least in Nandipuram (1.6) (Fig. 4.2). The ANOVA shows that there are significant differences between the means of the number of males/family among the different villages in the landscape, $F=1.5$, $p=0.08$. The mean number of females/family was highest in Kembanur (3.2) and the least in Nandipuram (1) (Fig. 4.3) The

ANOVA shows that there are significant differences between the means of the number of females/HH among the different villages in the landscape, $F=1.64$, $p=0.04$.

The mean land holding with tenure in the Sathyamangalam landscape is highest in the village Kalidimbam (2.05 acres) and households in several villages did not possess any land holding under tenure at all (Fig. 4.4). The ANOVA shows that there are significant differences between the means of the land holding among the different villages in the landscape, $F=7.7$, $p < 0.001$. The mean land holding without tenure in the Sathyamangalam landscape is highest in the village Kembanur (3.6 acres) and households in several villages did not possess any land holding without tenure at all (Fig. 4.5). The ANOVA shows that there are significant differences between the means of the land holding without tenure among the different villages in the landscape, $F=23.1$, $p < 0.001$.

The mean number of firewood bundles collected/week in the Sathyamangalam landscape in the present is highest in the village Vilankombai (7) and the least number of firewood bundles collected/week was in Nandipuram (1.2) (Fig. 4.6). The ANOVA shows that there are significant differences between the means of the number of firewood bundles collected/week among the different villages in the landscape, $F=14.2$, $p < 0.001$.

The mean distance travelled to collect firewood in the Sathyamangalam landscape in the present is highest in the village Bangalathotti (2.9 km) and the least distance travelled to collect firewood was in Kembanur (0.6 km) (Fig. 4.7). The ANOVA shows that there are significant differences between the means of the distance travelled among the different villages in the landscape, $F=2.9$, $p < 0.001$. 10-y ago the mean distance travelled to collect firewood in the Sathyamangalam landscape was highest in the village Bangalathotti (1.6 km) and the least distance travelled to collect firewood was in Kembanur (0.4 km) (Fig. 4.8). The ANOVA shows that there are significant differences between the means the distance travelled among the different villages in the landscape, $F=9.2$, $p < 0.001$.

The mean groundwater depth in the Sathyamangalam landscape in the present is highest in the village Nagaloor (600 ft) and the lowest depth was in Vilankombai (55 ft) (Fig. 4.9). The ANOVA shows that there are significant differences between the means of the groundwater depth among the different villages in the landscape, $F=20.5$, $p < 0.001$. 10-y ago the mean groundwater depth in the Sathyamangalam landscape was highest in the village Germalam (250 ft) and the lowest groundwater depth was in Vilankombai (33 ft) (Fig. 4.10). The ANOVA shows that there are significant differences between the means of the groundwater depth among the villages in the landscape, $F=20.5$, $p < 0.001$.

A variety of crops are cultivated in the various villages in the Sathyamangalam landscape, the number of crops cultivated in the various villages ranges from 3 to 11 (Fig. 4.11). Substantially higher number of crops are cultivated in the villages, Germalam, Geddesal, and Devarnatham. 10-y ago fewer number of crops were cultivated across the various villages, the number of crops cultivated in the various villages ranged from 2 to 8 (Fig. 4.12). Almost all villages reported the application of chemicals and fertilizers for cultivation in the present. 10-y ago almost all villages reported the use of cattle dung as manure for cultivation.

There were three mains sources of income for the villagers in the landscape. Households engaged in the collection of NTFPs, they engaged in wage labour, and they also cultivated crops and sold them in the local markets. Almost 99% of the households engaged in the collection of NTFP products across the different villages. However, in two villages, households did not collect NTFPs, they are Hosetti and Muthiyanur. The number of households engaged in NTFP collections was again lower in the villages Neithalapuram and Germalam (Fig. 4.13).

Greater than 70% of households in all villages across the landscape engaged in wage labour. Households either worked in the landscape or travelled to neighbouring areas in search of wage labour (Fig. 4.14).

Greater than 90% of households in all villages engaged in some form of agriculture, either for subsistence or for cash. However in four villages, Bungalathotti, Haasanur, Mavalam, and Muthiyanur, < 50% of households engaged in agriculture (Fig. 4.15).

The ethnicity of the majority of the villages in the landscape, included various indigenous groups, > 90% of households in several villages included indigenous communities. However, certain villages had either fewer or no indigenous communities. The villages with no indigenous communities were Hosetti and Muthiyanur, villages with < 50% of the households with indigenous communities included Neithalapuram, Devarnatham, and Germalam (4.16).

Households engaged in the collection of NTFPs in several villages across the landscape. Most households collected fruits and other parts of between 5 and 10 species, however, in two villages Hosetti and Muthiyanur, no NTFPs were gathered (Fig. 4.17). The maximum number (7) of NTFPs extracted in the Sathyamangalam landscape was in the villages Bejalatti, Kembanur, and Vilankombai. Four dominant NTFPs were extracted in the landscape, they included, *Phyllanthus emblica*, *Terminalia chebula*, *Phoenix loureiroi* species, and honey.

Most respondents have resided in the village for about 100 years. It was marginally lower in the villages Kuliyada, Mavalam, Geddesal, and Germalam (Fig. 4.18).

The mean quantity of *Phyllanthus emblica* collected/HH/trip in the Sathyamangalam landscape in the present is highest in the village Geddesal (84 kg/trip) and the least quantity collected/HH/trip was in Kembanur (30 kg/trip) (Fig. 4.19). The ANOVA shows that there are significant differences between the means of the quantity of *Phyllanthus emblica* collected/HH/trip among the different villages in the landscape, $F=4.9$, $p < 0.001$.

10-y ago, the mean quantity of *Phyllanthus emblica* collected/HH/trip in the Sathyamangalam landscape was highest in the village Geddesal (120 kg/trip) and the least quantity collected/HH/trip was in Kembanur (38 kg/trip) (Fig. 4.20). The ANOVA shows that there are significant differences between the means of the quantity of *Phyllanthus emblica* collected/HH/trip among the different villages in the landscape, $F=3.09$, $p < 0.001$.

The mean quantity of *Terminalia chebula* collected/HH/trip in the Sathyamangalam landscape in the present is highest in the village Geddesal (52 kg/trip) and the least quantity collected/HH/trip was in Mavalam (2.5 kg/trip) (Fig. 4.21). The ANOVA shows that there are significant differences between the means of the quantity of *Phyllanthus emblica* collected/HH/trip among the different villages in the landscape, $F=7.8$, $p < 0.001$.

Similarly, 10-y ago the mean quantity of *Terminalia chebula* collected/HH/trip in the Sathyamangalam landscape was highest in the village Geddesal (84 kg/trip) and the least quantity collected/HH/trip was in Mavalam (3.5 kg/trip) (Fig. 4.22). The ANOVA shows that there are significant differences between the means of the quantity of *Terminalia chebula* collected/HH/trip among the different villages in the landscape, $F=8.4$, $p < 0.001$.

The mean quantity of *Phoenix loureiroi* species collected/HH/trip in the Sathyamangalam landscape in the present is highest in the village Neithalapuram (46 kg/trip) and the least quantity collected/HH/trip was in Kuliyada (15 kg/trip) (Fig. 4.23). The ANOVA shows that there are no significant differences between the means of the quantity of *Phoenix loureiroi* species collected/HH/trip among the different villages in the landscape, $p > 0.1$.

10-y ago the mean quantity of *Phoenix loureiroi* species collected/HH/trip in the Sathyamangalam landscape was highest in the village Neithalapuram (70 kg/trip) and the least quantity collected/HH/trip was in Kuliyada (18 kg/trip) (Fig. 4.24). The ANOVA shows that there are significant differences between the means of the quantity of *Phoenix loureiroi* species collected/HH/trip among the different villages in the landscape, $p < 0.01$.

The mean quantity of honey collected/HH/trip in the Sathyamangalam landscape in the present is highest in the village Geddesal (11 l/trip) and the least quantity collected/HH/trip was in Devarnatham (0.2 l/trip) (Fig. 4.25). The ANOVA shows that there are no significant differences between the means of the quantity of honey collected/HH/trip among the different villages in the landscape, $p > 0.1$.

10-y ago, the mean quantity of honey collected/HH/trip in the Sathyamangalam landscape was highest in the village Geddesal (12 l/trip) and the least quantity collected/HH/trip was in Devarnatham (0.3 l/trip) (Fig. 4.26). The ANOVA shows that there are significant differences between the means of the quantity of honey collected/HH/trip among the different villages in the landscape, $p < 0.01$.

Linear model of disturbance index and socio-economic variables

The OLS for the disturbance index, with independent variables including, % HH collecting NTFP, % HH indigenous in village, mean patta land holding (acres), mean no patta land holding (acres), mean family size, distance travelled to collect fire wood (km), % of HH engaged in wage labour**,** % HH engaged in agriculture, # of fuelwood bundles collected/week, gave a r^2 of 0.84, the adjusted r^2 was 0.7, with $F=6.05$, $p < 0.001$. The results of the OLS model is presented in Table 4.2, the three most important predictors of disturbance in the villages were mean family size ($p =0.02$), distance travelled to collect fire wood ($p =0.005$) and % of HH engaged in wage labour in the villages ($p = 0.0005$) (table 4.2).

Sustainability in the Sathyamangalam landscape

The mean quantity of *Phyllanthus emblica* extracted in the present in the Sathyamangalam landscape is 40.23 kg/HH/trip. 10-y ago the mean quantity of *Phyllanthus emblica* extracted was 67.23 kg/HH/trip. The t-test revealed significant differences in means ($t=10.35$, $df=352$, $p=0.001$). Similarly, the mean quantity of *Terminalia chebula* extracted in the present in the Sathyamangalam landscape is 29.7 kg/HH/trip. 10-y ago the mean quantity of *Terminalia chebula* extracted was 44.8 kg/HH/trip. The t-test revealed significant differences in means (t=5.9, df=404, p=0.001). The mean quantity of *Phoenix loureiroi* species extracted in the present in the Sathyamangalam landscape is 35 kg/HH/trip. 10-y ago the mean quantity of Phoenix loureiroi species extracted was 41.8 kg/HH/trip. The t-test revealed significant differences in means (t=-3.3, df=387, p=0.001). However, the quantity of honey collected 10-y ago and in the present did not differ significantly.

Similarly, the mean distance travelled to gather fire wood in the present and 10-y ago differed significantly. The mean distance travelled to collect fire wood in the present is 2.09 km, whereas it was 0.99 km 10-y ago. The t-test revealed significant differences in the means (t=20.6, df=662, p=0.0001).

We also examined the groundwater depth in the Sathyamangalam landscape, the mean groundwater depth in the present is 302 feet, it was 121.9 ft 10-y ago. The t-test revealed significant differences in the means (t=12.8, df=296, p=0.0001).

Discussion:

There are significant differences in several socio-economic variables among the different villages in the Sathyamangalam landscape. Most villages in the landscape are homogenous in their composition in terms of the land holdings, the land tenure, small land sizes, and occupations involved in. The collections of NTFPs depends on the type of forest, for example in the village Nandipuram, *Phyllanthus emblica* is not extracted, this is due to the absence/low abundance of this species in the tropical dry thorn forests. The statistical analyses of socio-economic variables and disturbance index, indicates that when mean family size is small, there is a higher disturbance in the forest. Similarly, when the percentage of HH engaged in wage labour is low, the disturbance is high. These results could be explained based on the opportunity cost related to forest extractions. When the family size is small, it is possible that there could be barriers to explore wage labour outside the village, whereas when the family size is large, this could permit wage labour outside the village and hence lower the dependence on the forest. Regarding, the percentage wage labourers, when there are fewer opportunities to work outside the village, residents have little choice but to extract natural resources from the forest in order to meet income needs. Dependence on forests is determined by the extent of forest area available and the natural resources within these forests, the opportunity for other more remunerative occupations, and the social composition (Chauhan et al. 2008). The other significant predictor of disturbance in the landscape was the distance travelled to gather fire wood, this is intuitive, as the further travelled could be due to the absence of fire wood close to the village. This could have occurred due to the extractions of biomass over time and the forest degradation caused by this process (Gadgil, 1996).

The natural resources in the Sathyamangalam landscape, could be under stress, based on the responses, it is quite clear that NTFP yields have significantly declined during the past 10-y, respondents uniformly indicated that they travelled longer distances to collect fire wood, and also that groundwater levels have declined significantly. Further research on fruiting cycles of the NTFP species, their ecology, and impacts of disturbances on the population of the species would be useful (Murlai et al. 1996). There are also reports that collection of certain NTFPs such as *Phonenix loureiroi* could be impacted by the changing socio-economic conditions and the implementation of new government policies (Mandle et al. 2013). Whether ground water declines observed in the Sathyamangalam landscape could be similar to north-west India, where studies indicate declines at the rate of 4 ± 1 cmy^{-1} (Rodell et al. 2009), requires further research.

NTFP species *Phyllanthus emblica* and *Terminalia chebula* in the landscape

References

Chauhan, K.V.S., Sharma, A.K., and Kumar, P 2008. Non-timber forest products subsistence and commercial uses: trends and future demands. *International Forestry Review* 10:201-216.

Gadgil, M. 1996. Western Ghats: A lifescape. *Journal of the Indian Institute of Science* 76: 495-504.

Mandle, L., T.Ticktin, S. Nath, S. Setty and A. Varghese. A framework for considering ecological interactions for common non-timber forest product species: a case study of mountain date palm (*Phoenix loureiroi* Kunth) leaf harvest in South India. *Ecological Processes.*21(1):1-9.

Rodell, M., Velicogna, I., Famiglietti, J.S. 2009. Satellite based estimates of ground water depletion in India. *Nature* 460:999-1001.

Murali, K. S., U. Shankar, R. R.Shanker, K. N. Ganeshaiah, and K. S. Bawa. 1996 Extraction of non-timber forest products in the forests of Biligiri Rangan Hills, India. 2. Impact of NTFP extraction on regeneration, population structure, and species composition. *Economic Botany* 50:252–269

Geist, H. J., and Lambin, E. F. (2002). Proximate causes and underlying driving forces of tropical deforestation. *Bioscience* 52: 143–150.

Table 4.1: Number of HH sampled in the different villages

#	Village Name	# of HH sampled
1	Bejalatti	20
2	Bungalathotti	19
3	Devarnatham	26
4	Geddesal	30
5	Germalam	30
6	Hasaanur	20
7	Hosettti	16
8	Ittarai	15
9	Kalidimbam	10
10	Kembanur	5
11	Kuliyada	15
12	Mavalam	30
13	Mavanatham	20
14	Muthiyanur	20
15	Nagaloor	29
16	Nandipuram	5
17	Neithalapuram	50
18	Ramaranai	10
19	Uginium	20
20	Vilankombai	10

Table 4.2: Coefficients of OLS Model based on Disturbance Index and socio-economic variables predicting forest habitat disturbance in the Sathyamangalam landscape

Variables	**Estimate**	**Standard Error**	**T value**	**P value**
Intercept	1.49	0.28	5.3	0.003
% HH collecting NTFP	0.00002	0.0007	0.027	0.97
% HH indigenous in village	-0.0014	0.00089	-1.6	0.13
Mean patta land holding (acres)	-0.01	0.03	-0.3	0.755
Mean no patta land holding (acres)	0.025	0.03	0.67	0.5
Mean Family size	**-0.07**	**0.029**	**-2.6**	**0.02**
Distance travelled to collect fire wood (km)	**0.13**	**0.03**	**3.5**	**0.005**
% of HH engaged in wage labour	**-0.01**	**0.002**	**-4.945**	**0.0005**
% HH engaged in agriculture	-0.0002	0.0006	-0.37	0.71
# of fire wood bundles collected/week	0.0048	0.01	0.32	0.75

Figure 4.1: Mean family size in the Sathyamangalam landscape

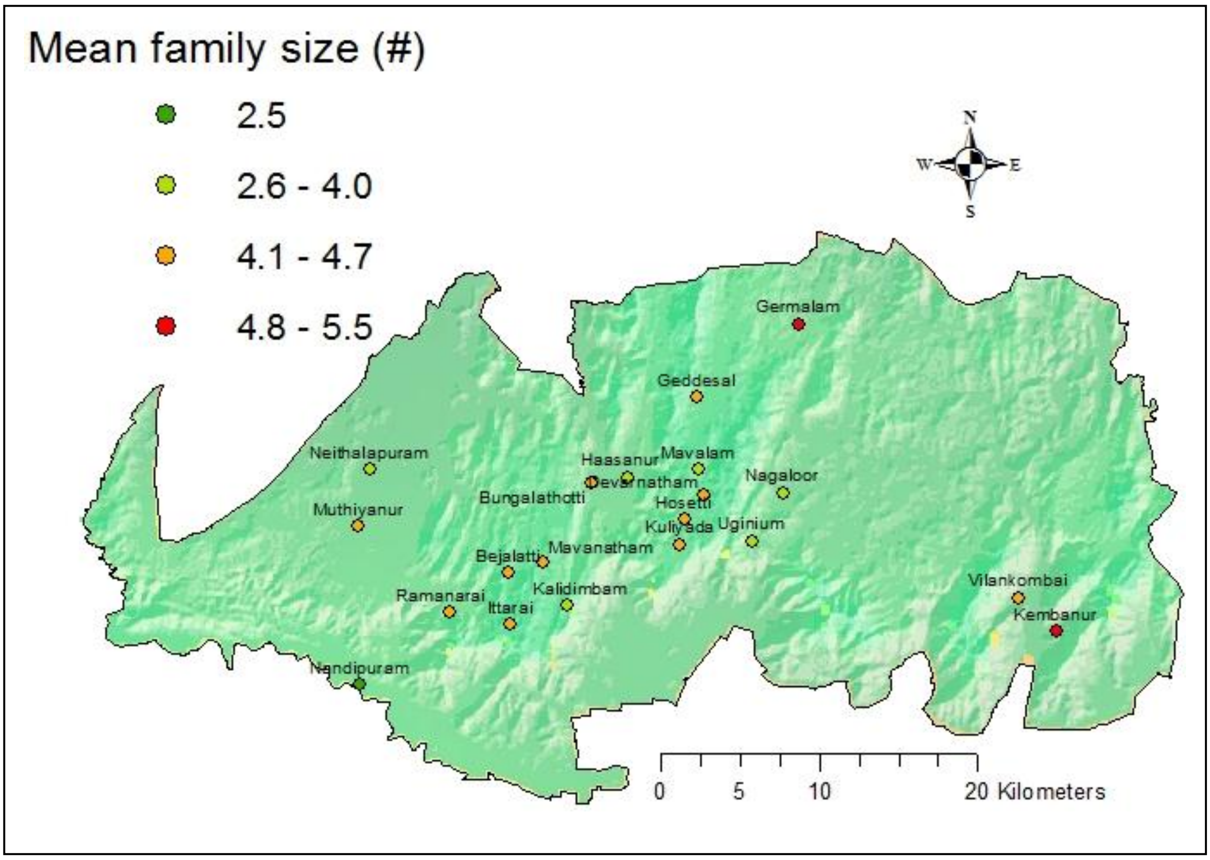


Figure 4.2: Mean number of males/HH in the Sathyamangalam landscape

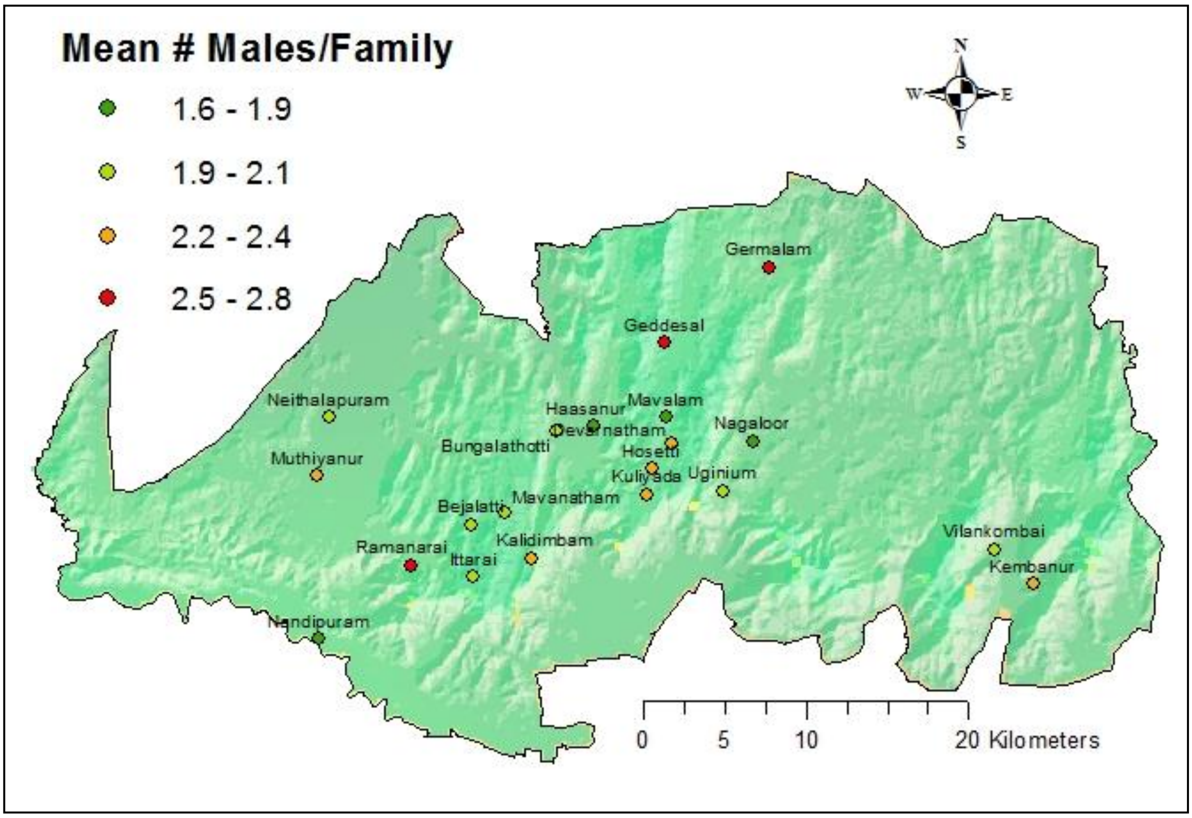


Figure 4.3: Mean number of females/HH in the Sathyamangalam landscape

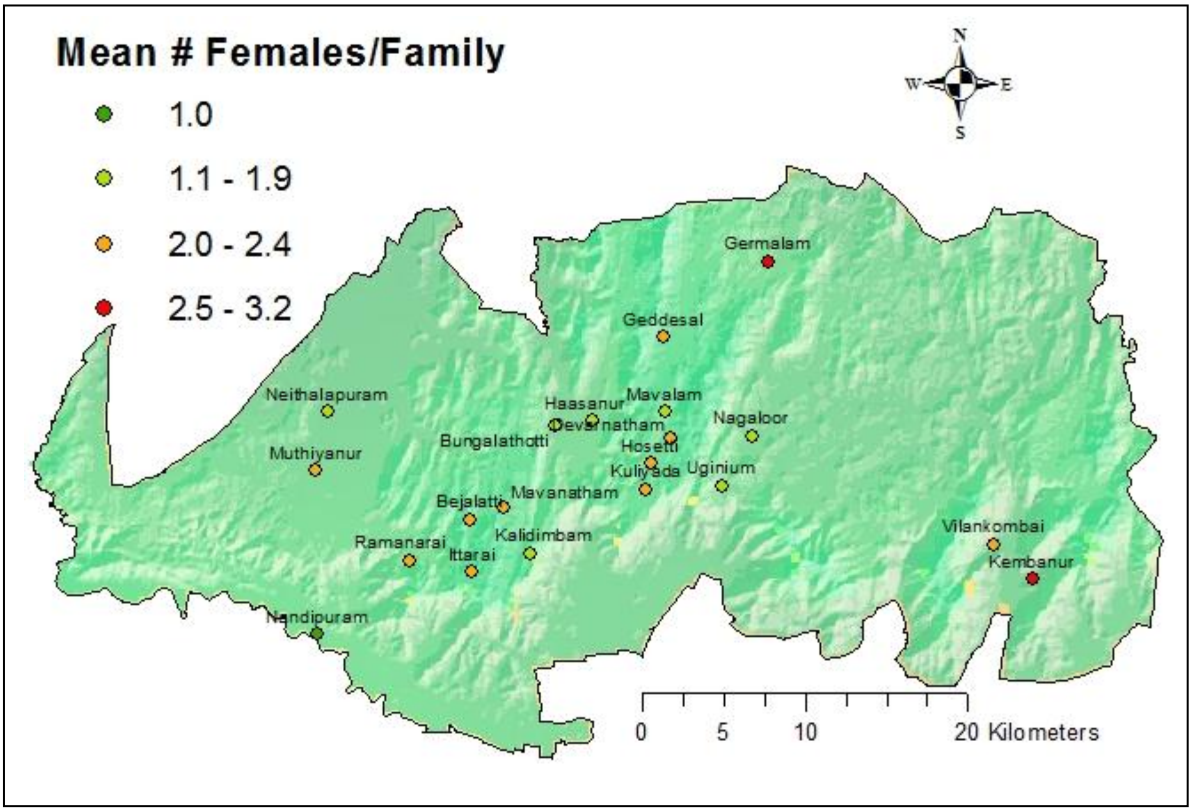


Figure 4.4: Mean land holding in the Sathyamangalam landscape (with tenure)

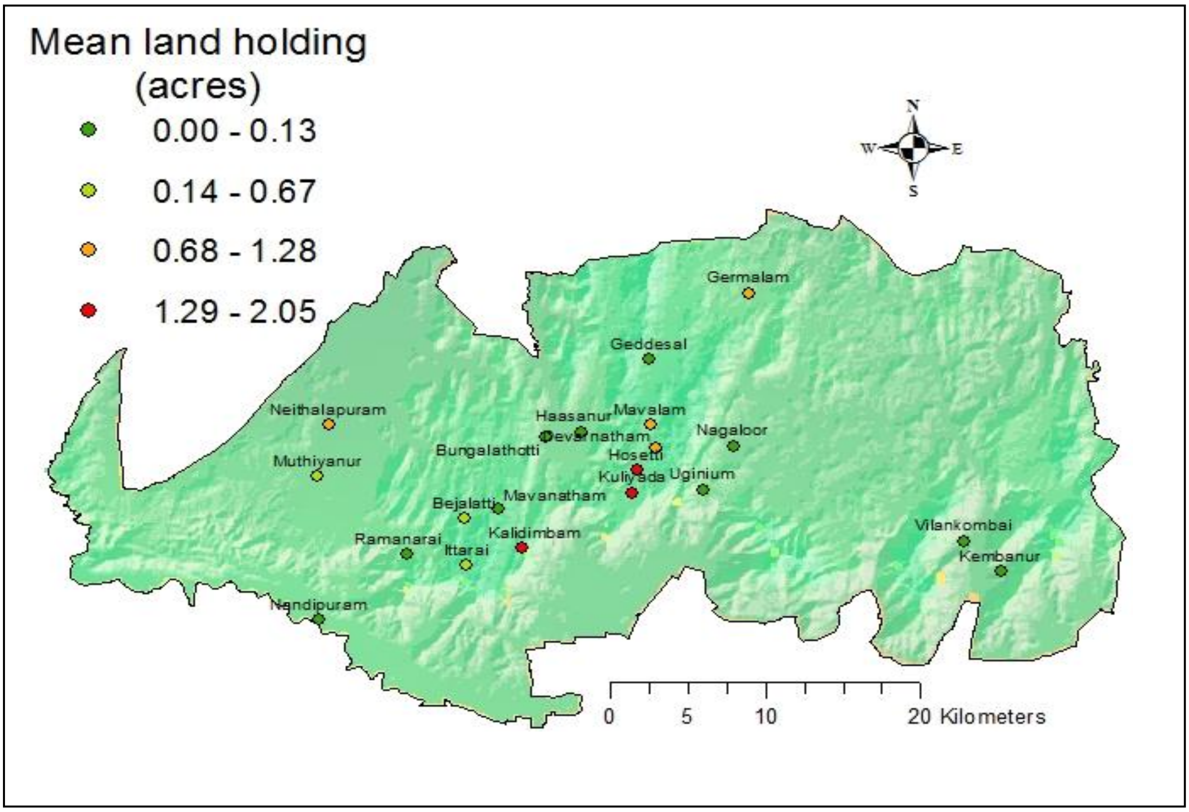


Figure 4.5: Mean land holding in the Sathyamangalam landscape (without tenure)

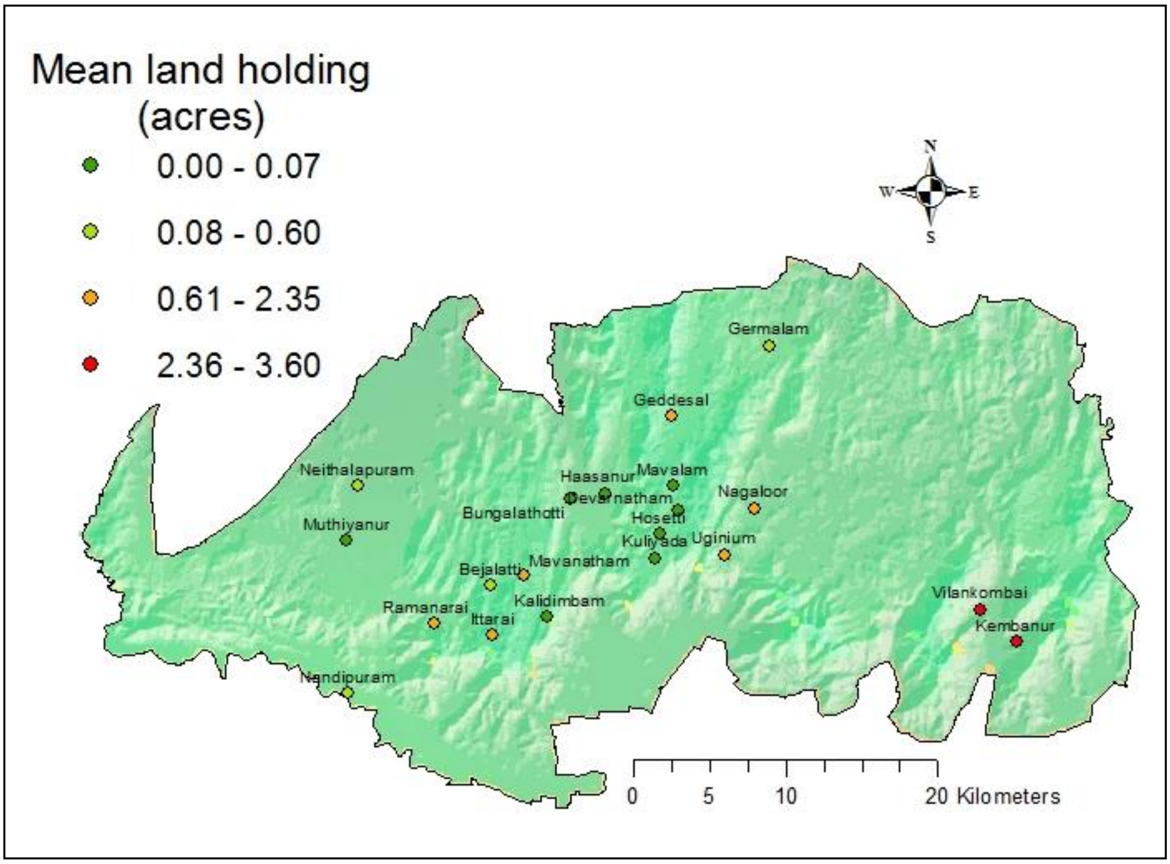


Figure 4.6: Mean number of bundles of firewood collected/HH/week in the Sathyamangalam landscape

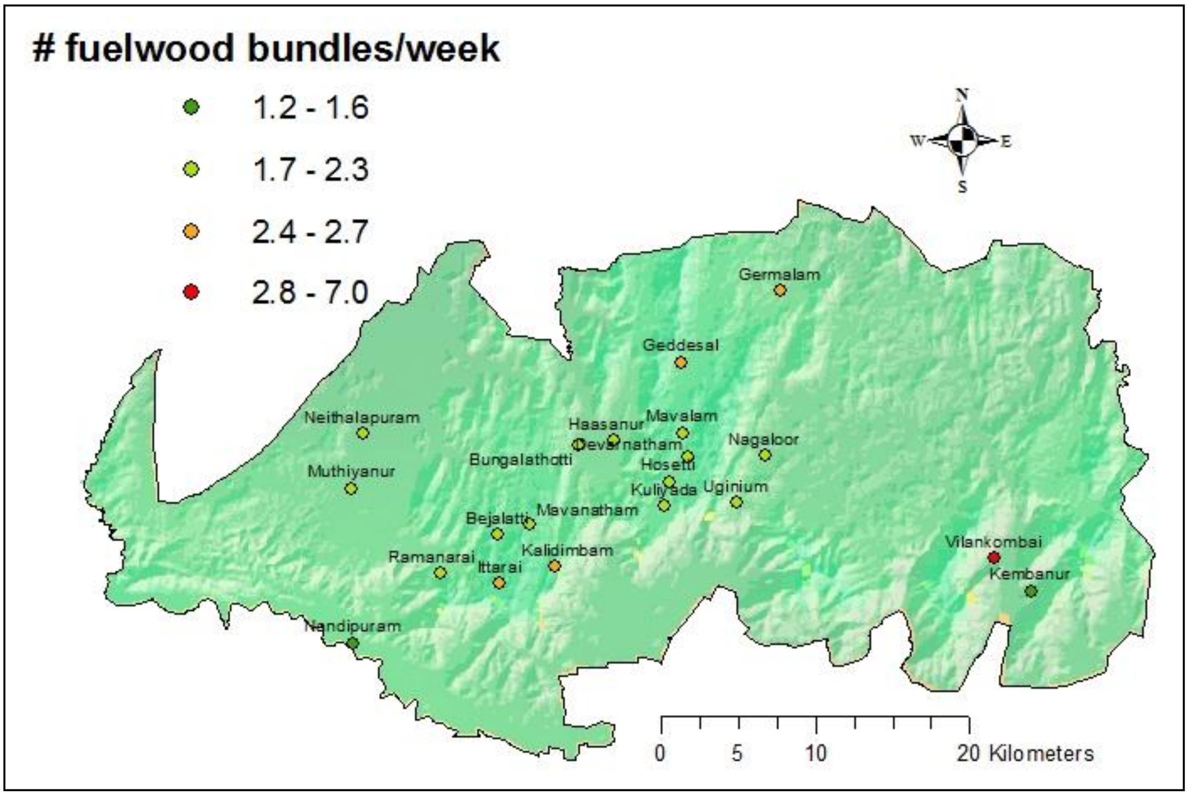


Figure 4.7: Distance travelled to collect firewood in the Sathyamangalam landscape

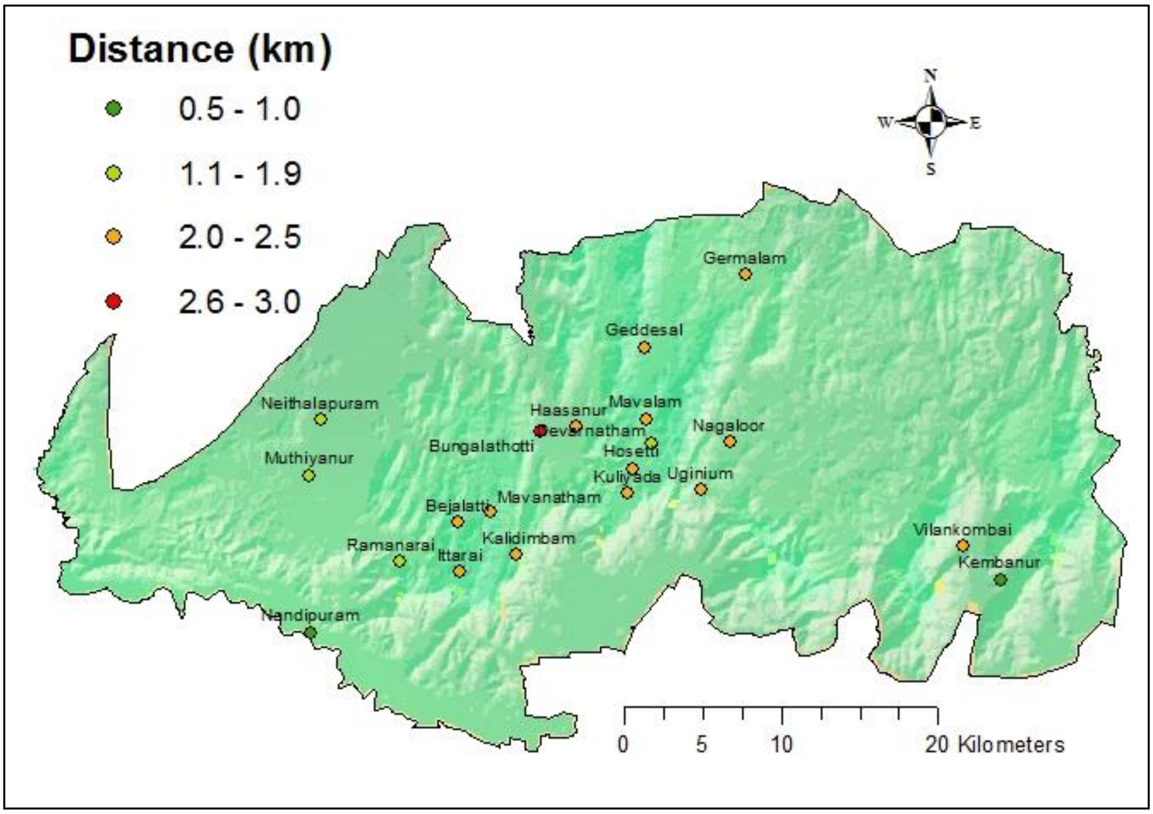


Figure 4.8: Distance travelled to collect firewood in the Sathyamangalam landscape (10-y ago)

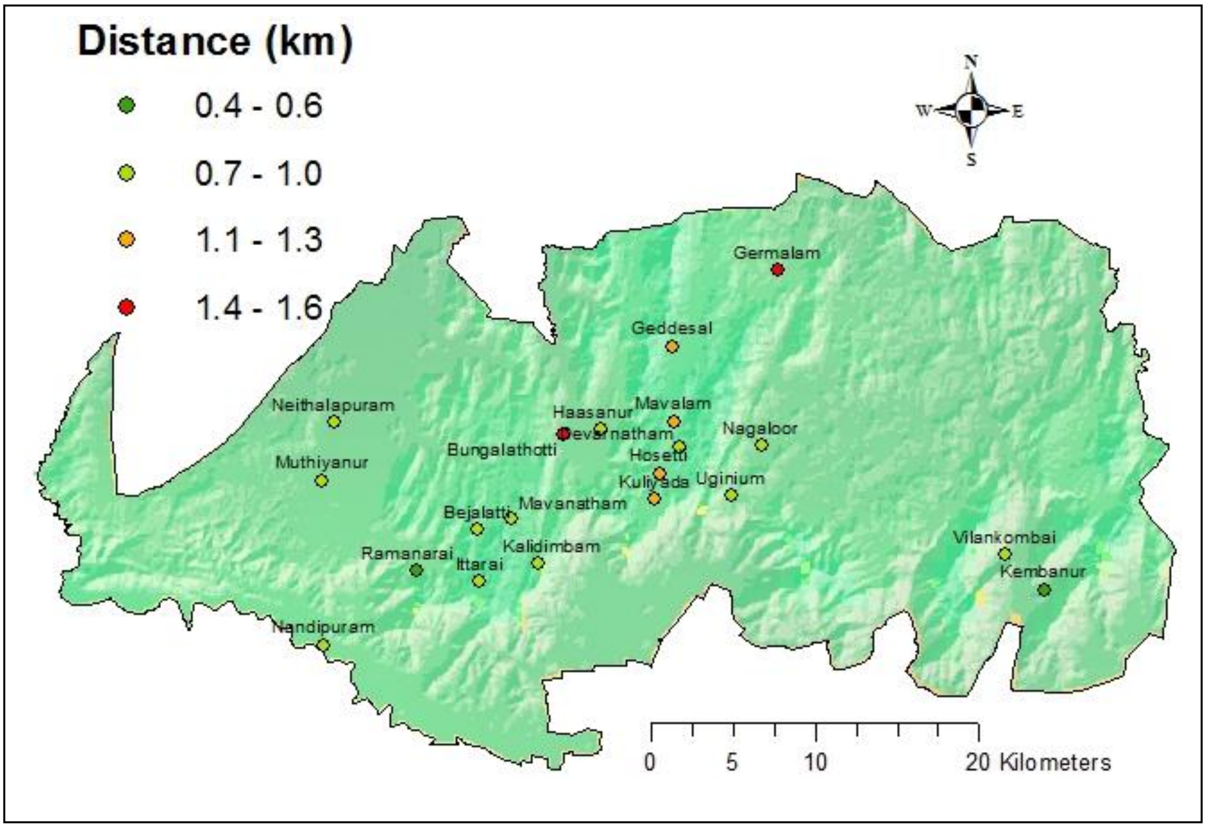


Figure 4.9: Ground water depth in the Sathyamangalam landscape

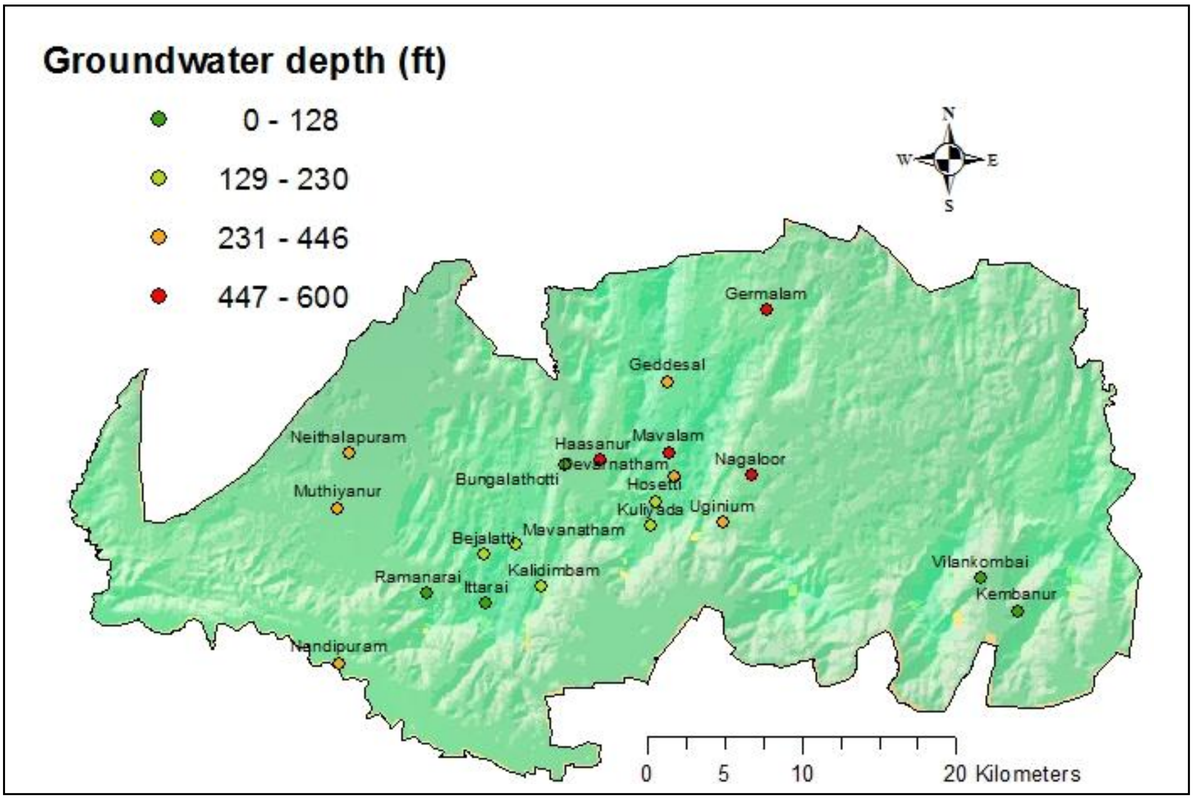


Figure 4.10: Ground water depth in the Sathyamangalam landscape (10-y ago)

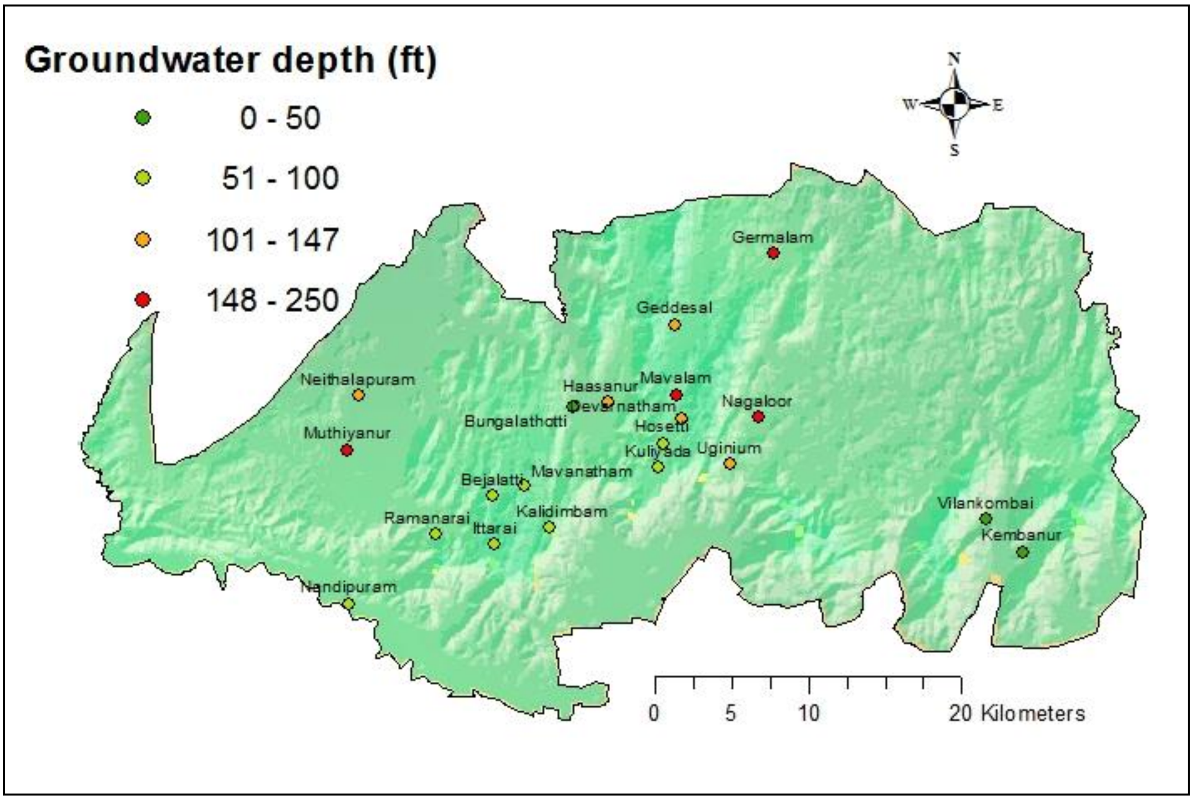


Figure 4.11: Number of crops cultivated in the Sathyamangalam landscape

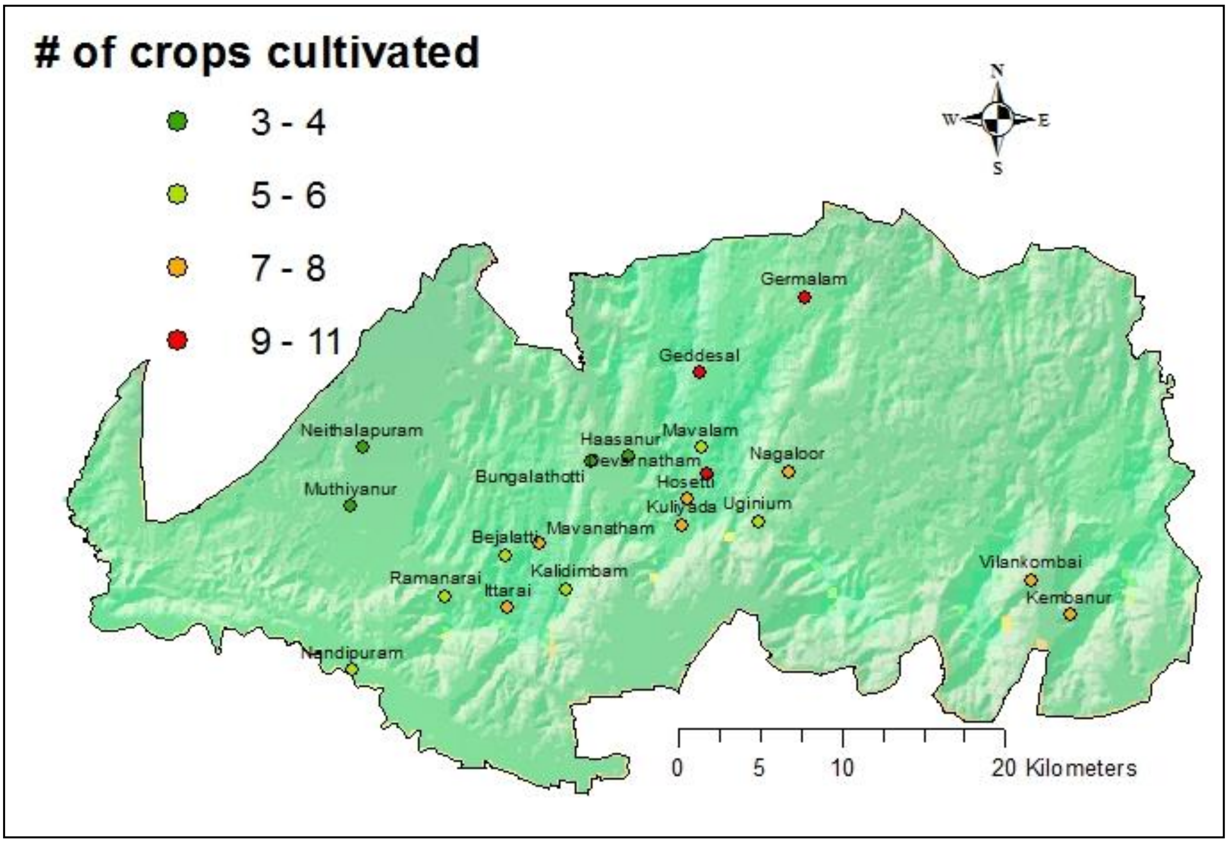


Figure 4.12: Number of crops cultivated in the Sathyamangalam landscape (10-y ago)

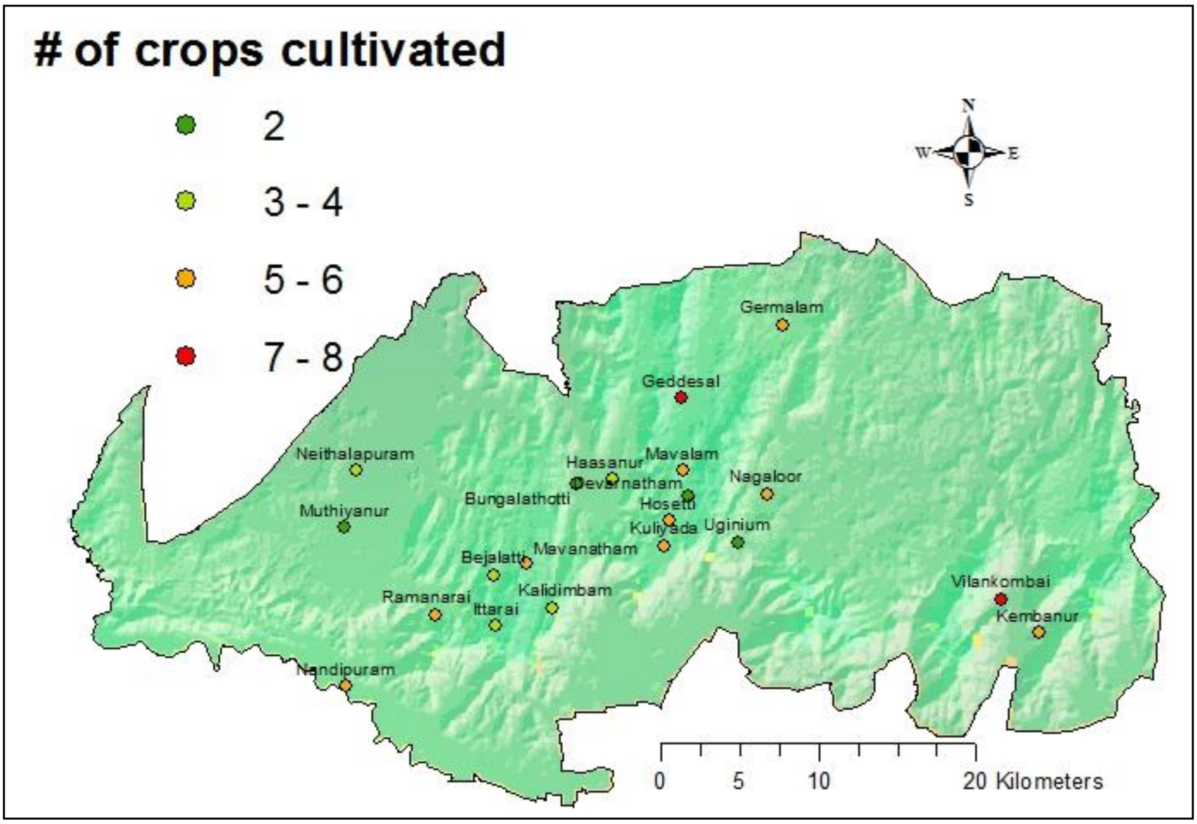


Figure 4.13: % of HH engaged in NTFP collections in the Sathyamangalam landscape

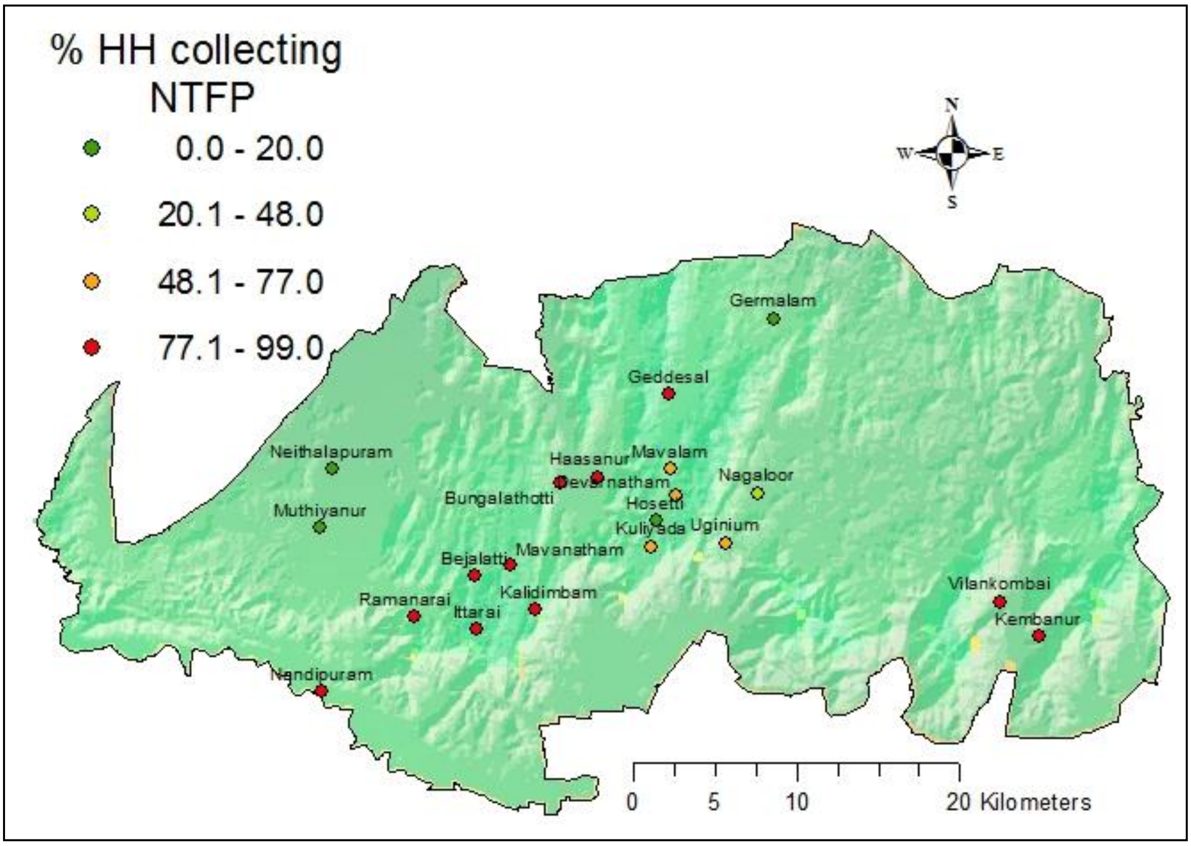


Figure 4.14: Percentage of HH engaged in wage labour in the Sathyamangalam landscape

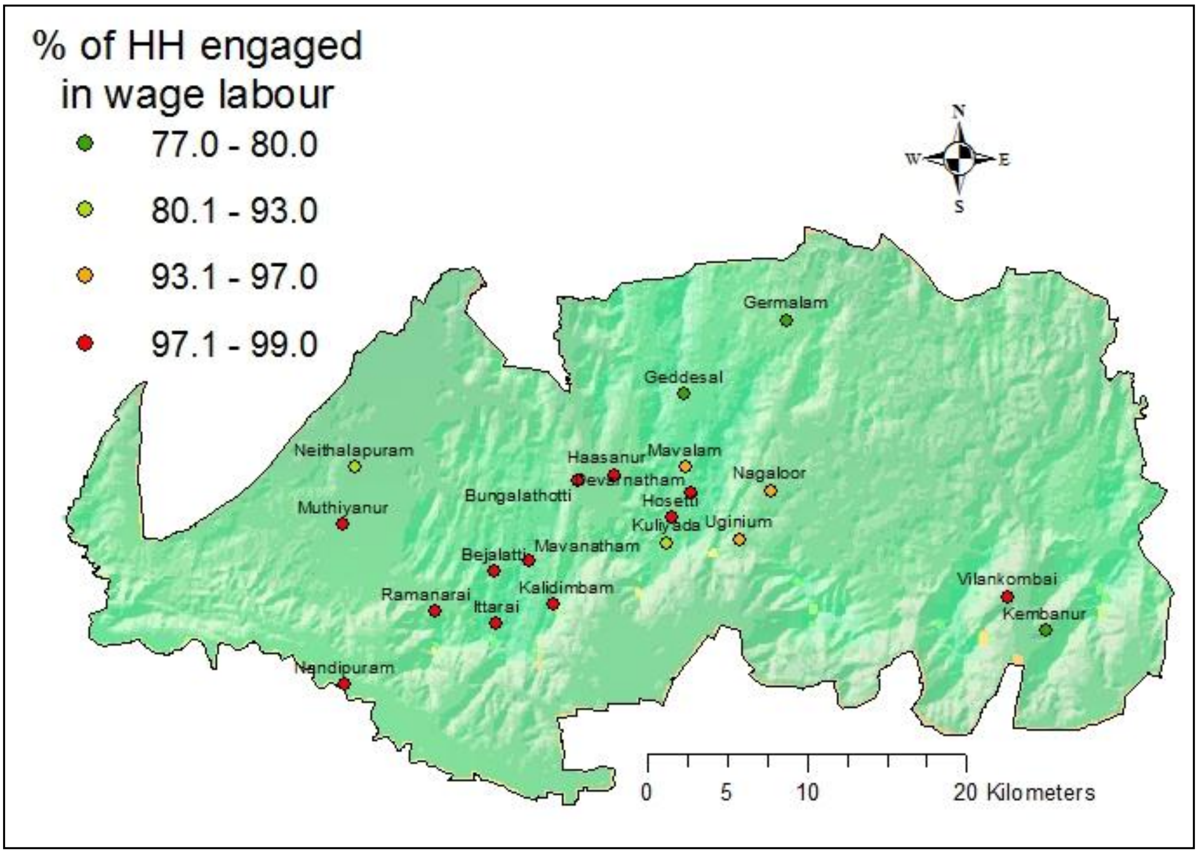


Figure 4.15: Percentage of HH engaged in agriculture in the Sathyamangalam landscape

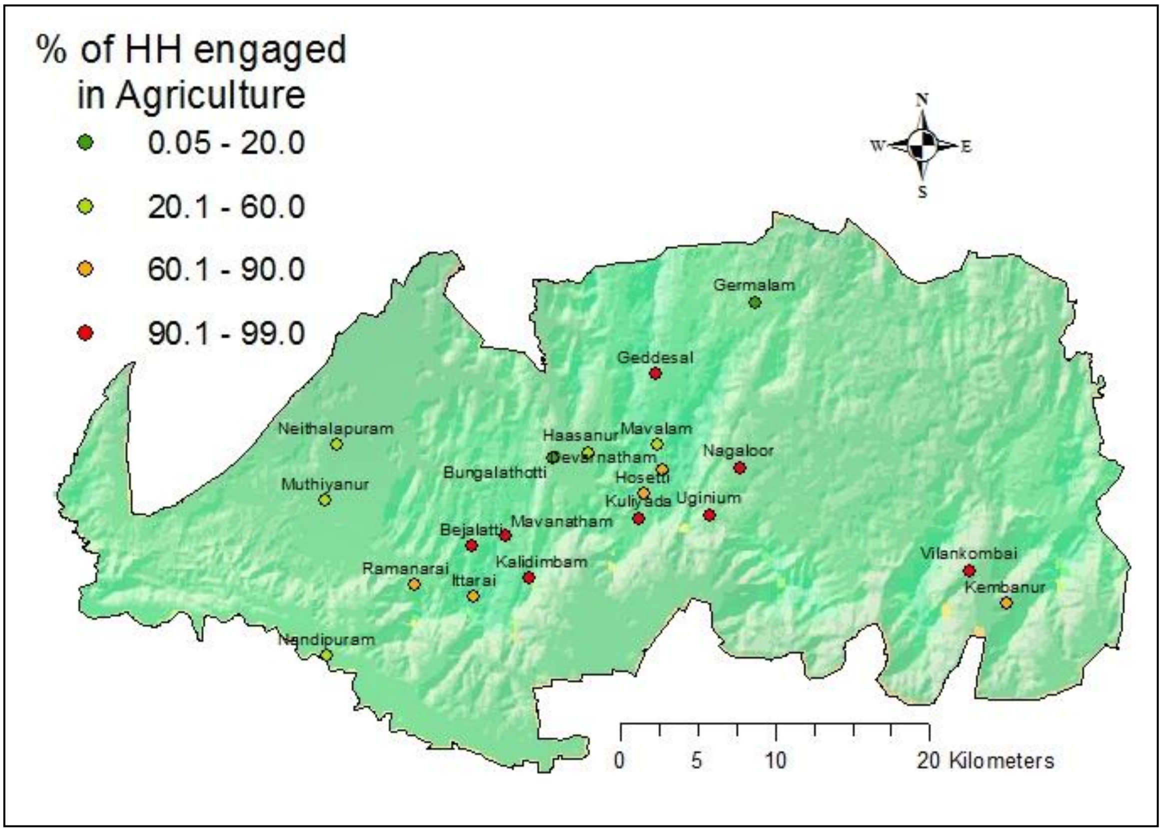


Figure 4.16: Percentage of HH belonging to indigenous communities in the Sathyamangalam landscape

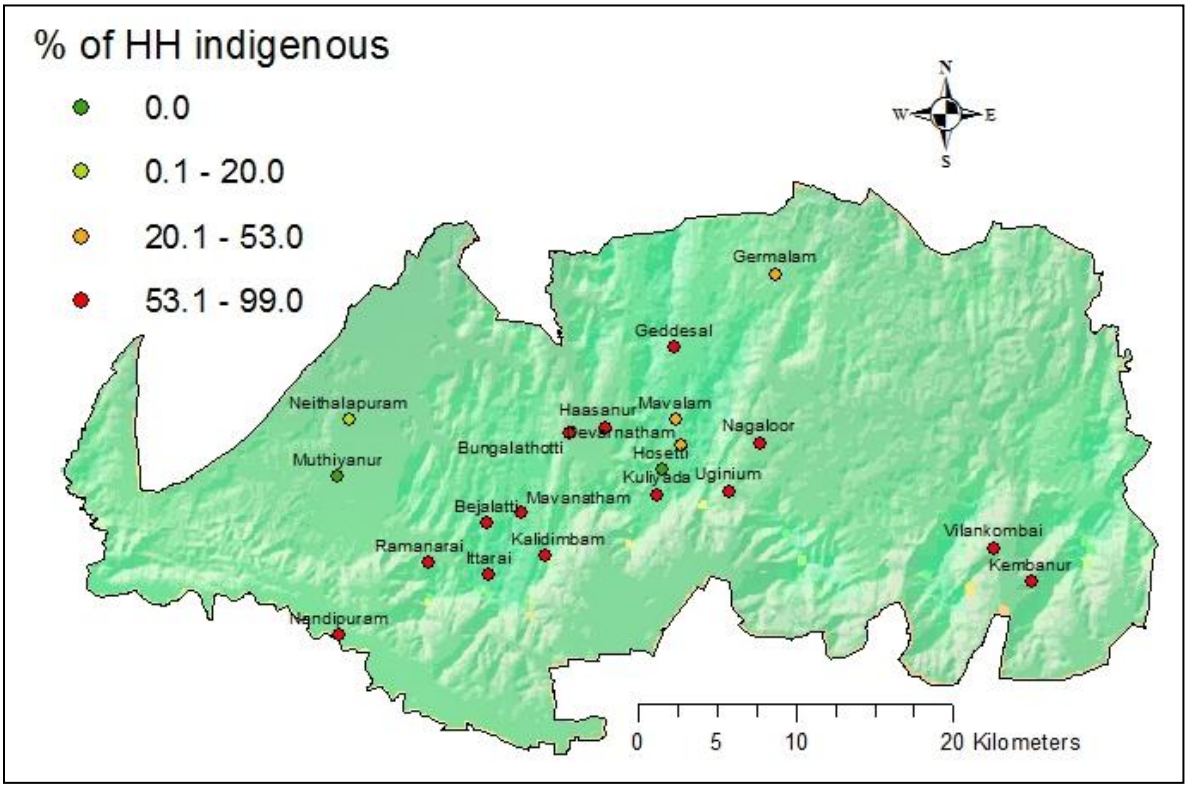


Figure 4.17: Number of NTFP species extracted in the Sathyamangalam landscape

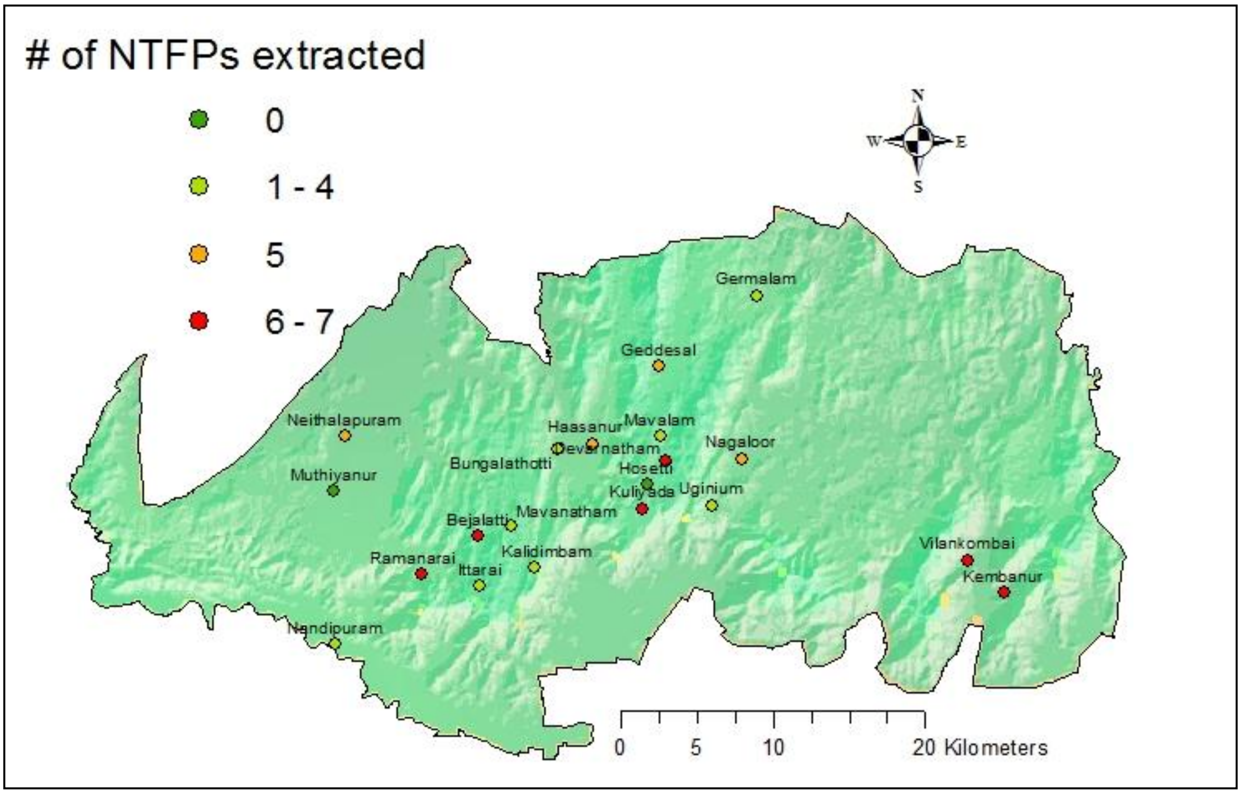


Figure 4.18: Number of years respondents have lived in the Sathyamangalam landscape

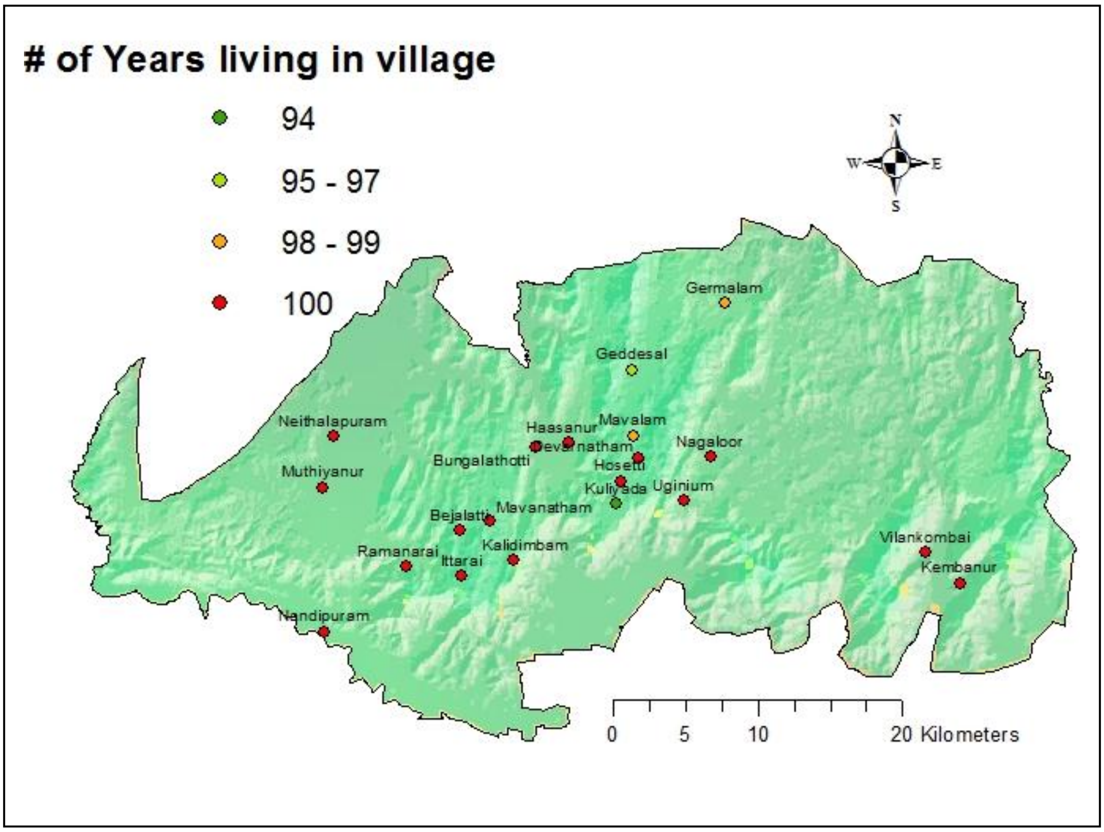


Figure 4.19: Quantity of *Phyllanthus emblica* extracted/HH /trip in the Sathyamangalam landscape

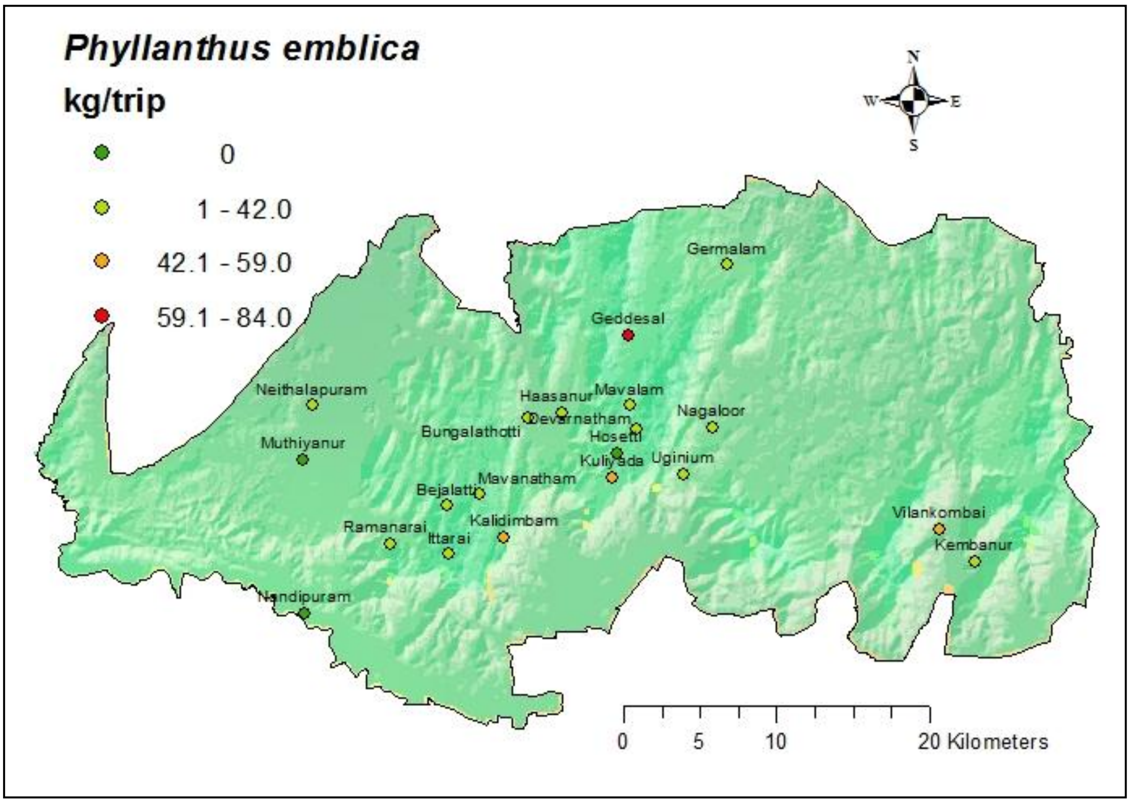


Figure 4.20: Quantity of *Phyllanthus emblica* extracted/HH /trip in the Sathyamangalam landscape (10-y ago)

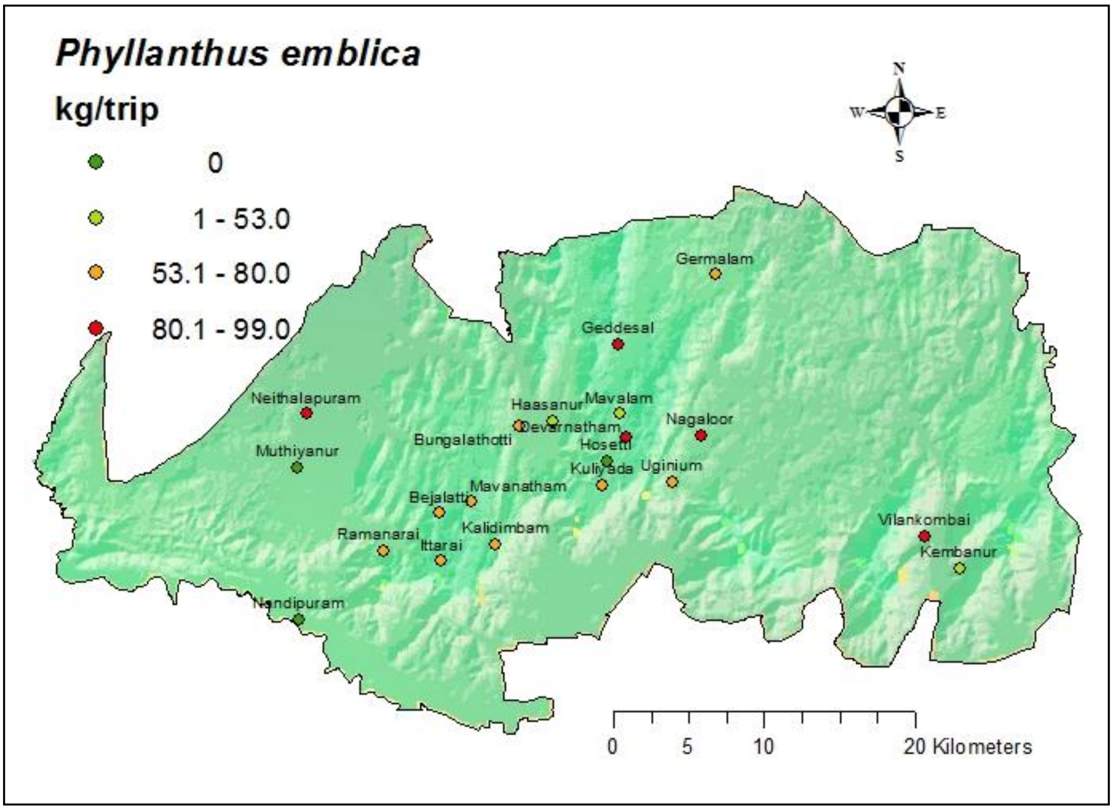


Figure 4.21: Quantity of *Terminalia chebula* extracted/HH /trip in the Sathyamangalam landscape

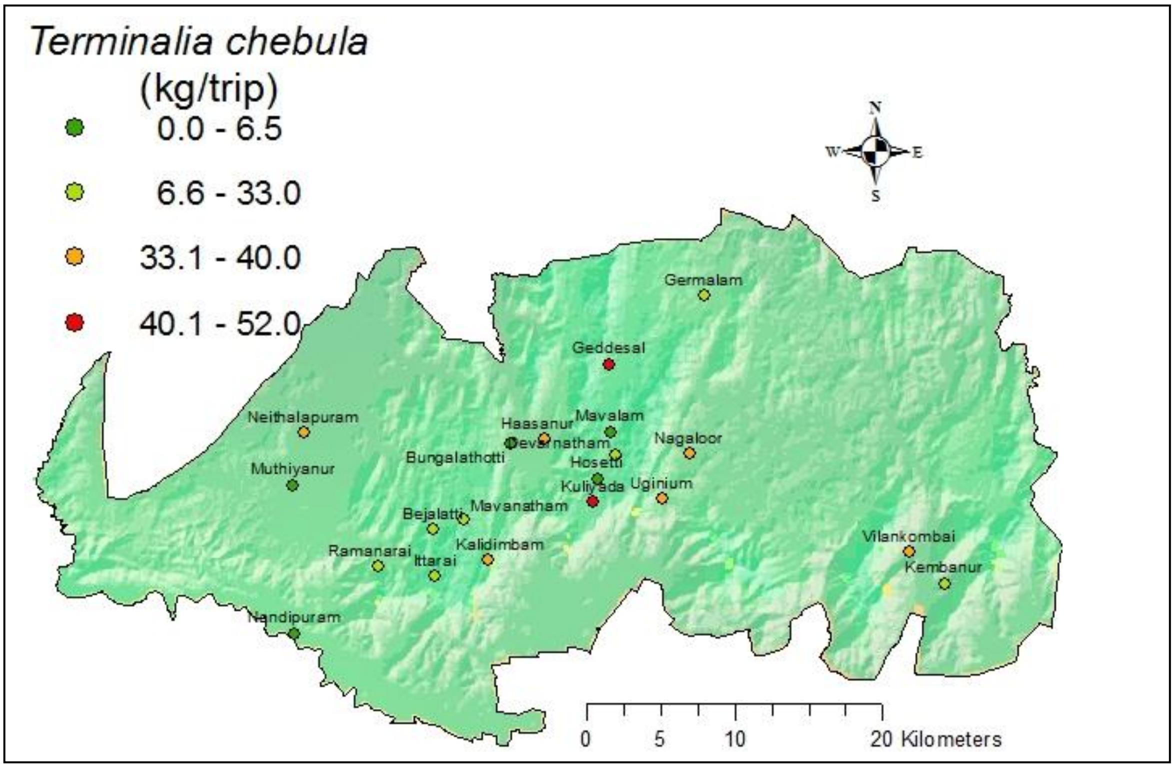


Figure 4.22: Quantity of *Terminalia chebula* extracted/HH /trip in the Sathyamangalam landscape (10-y ago)

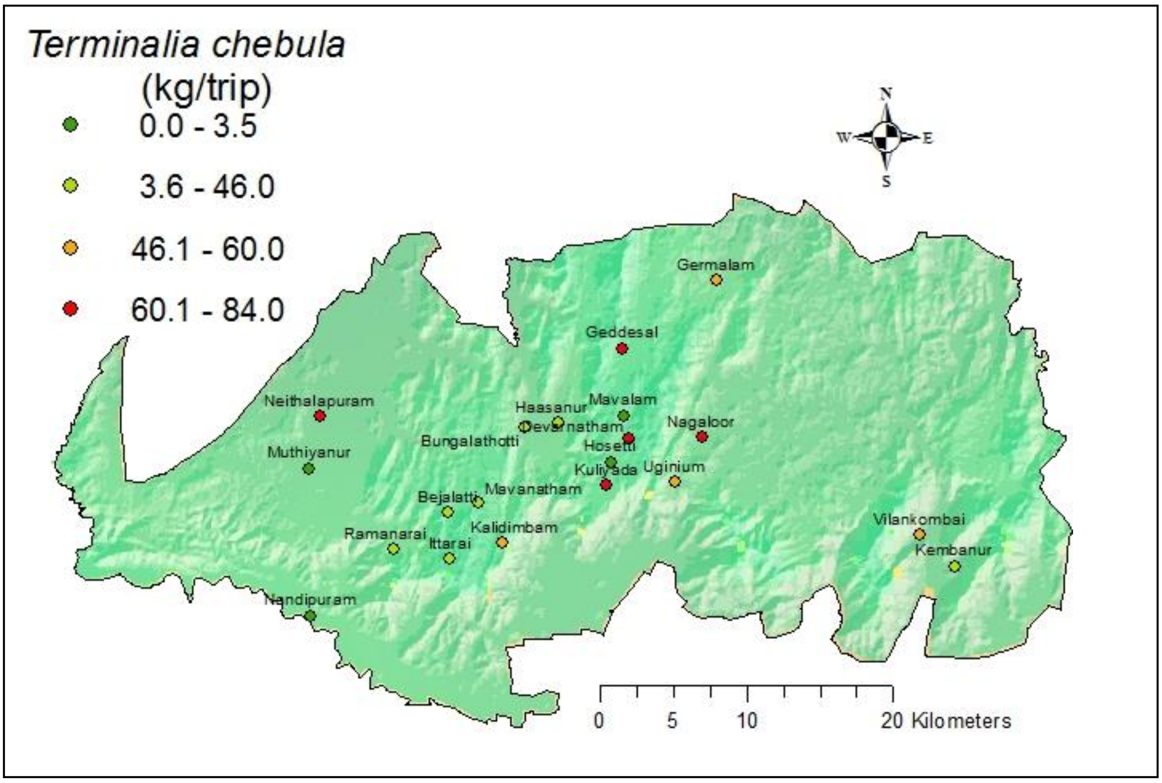


Figure 4.23: Quantity of *Phoenix loureiroi* species extracted/HH/trip in the Sathyamangalam landscape

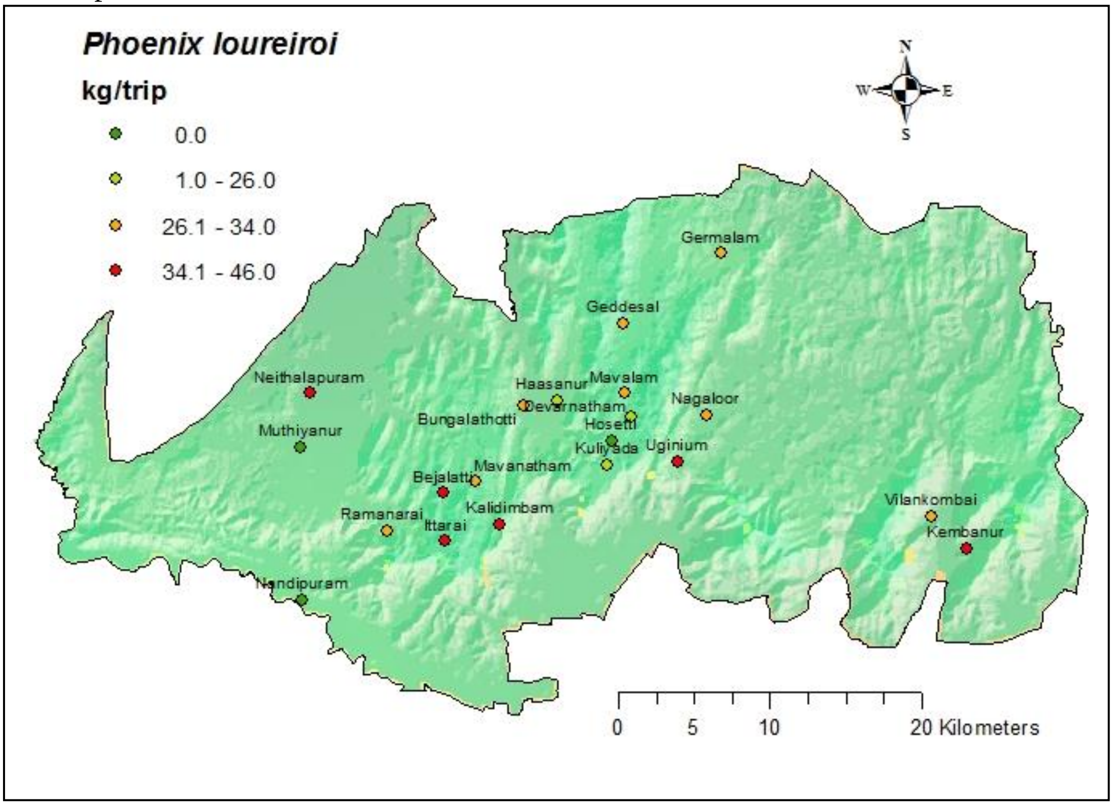


Figure 4.24: Quantity of *Phoenix loureiroi* species extracted/HH/trip in the Sathyamangalam landscape (10-y ago)

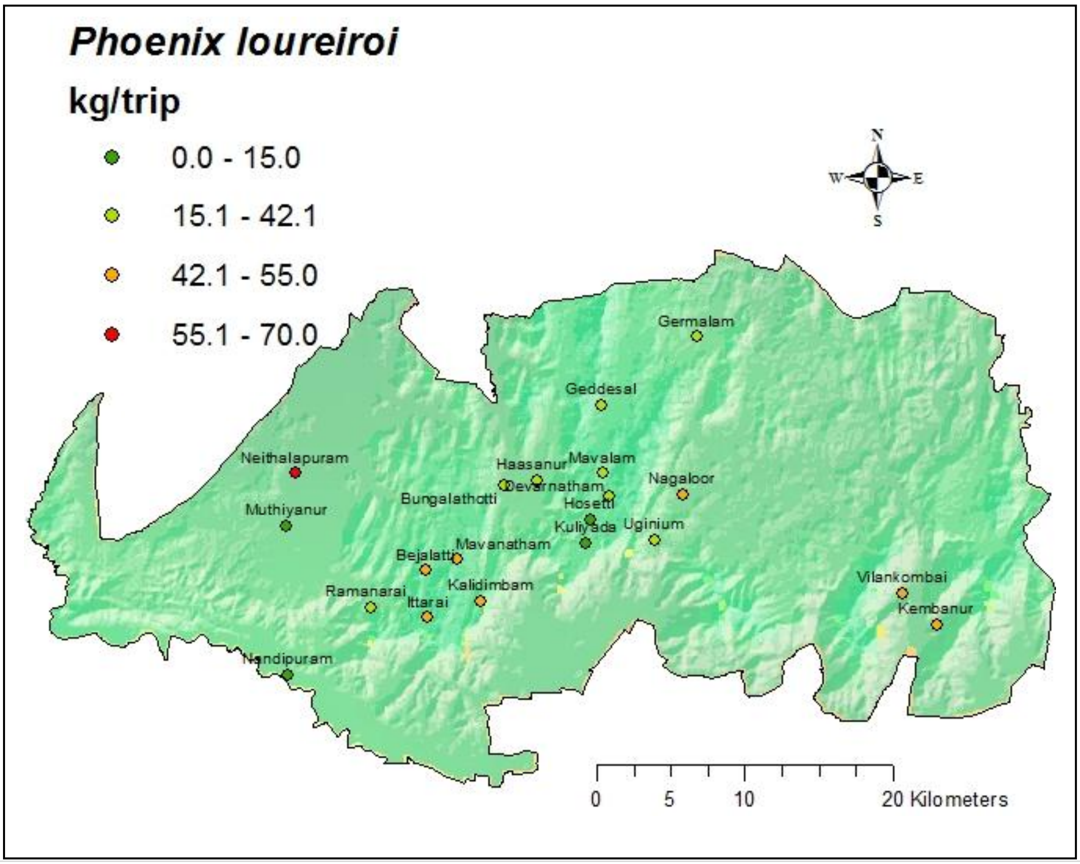


Figure 4.25: Quantity of honey extracted/HH/trip in the Sathyamangalam landscape

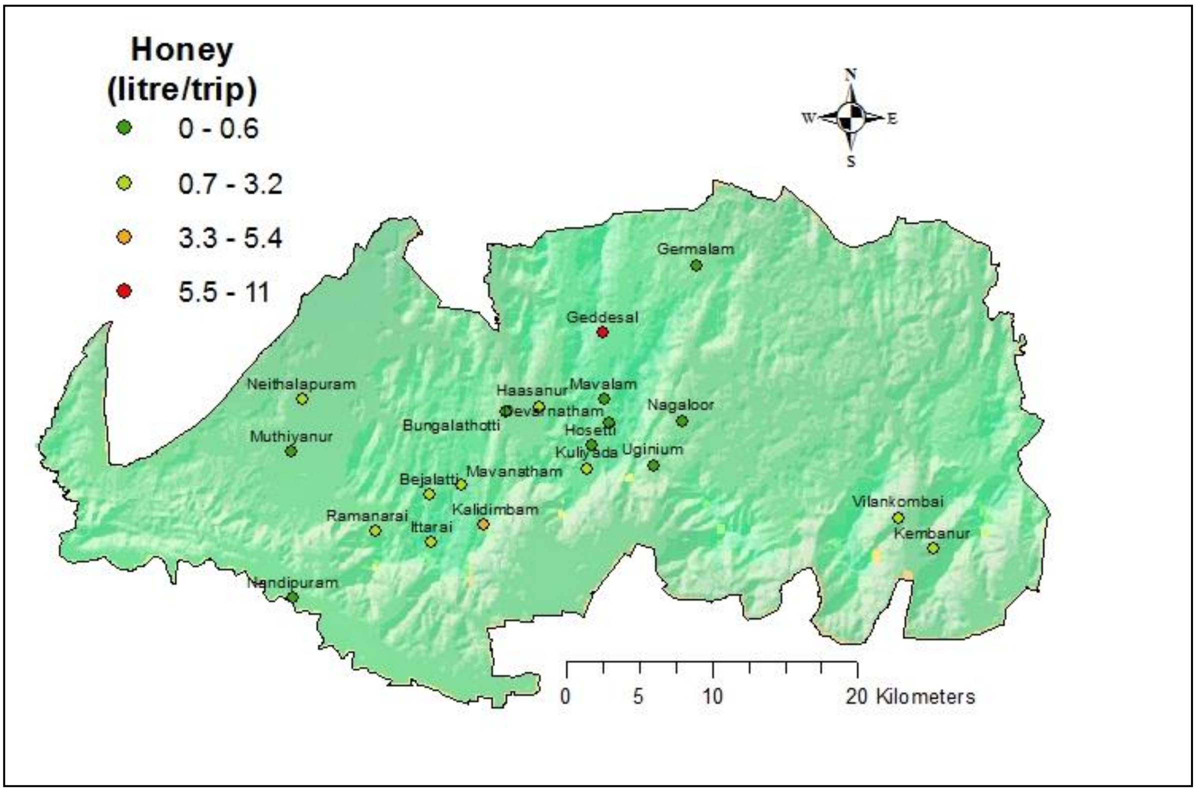
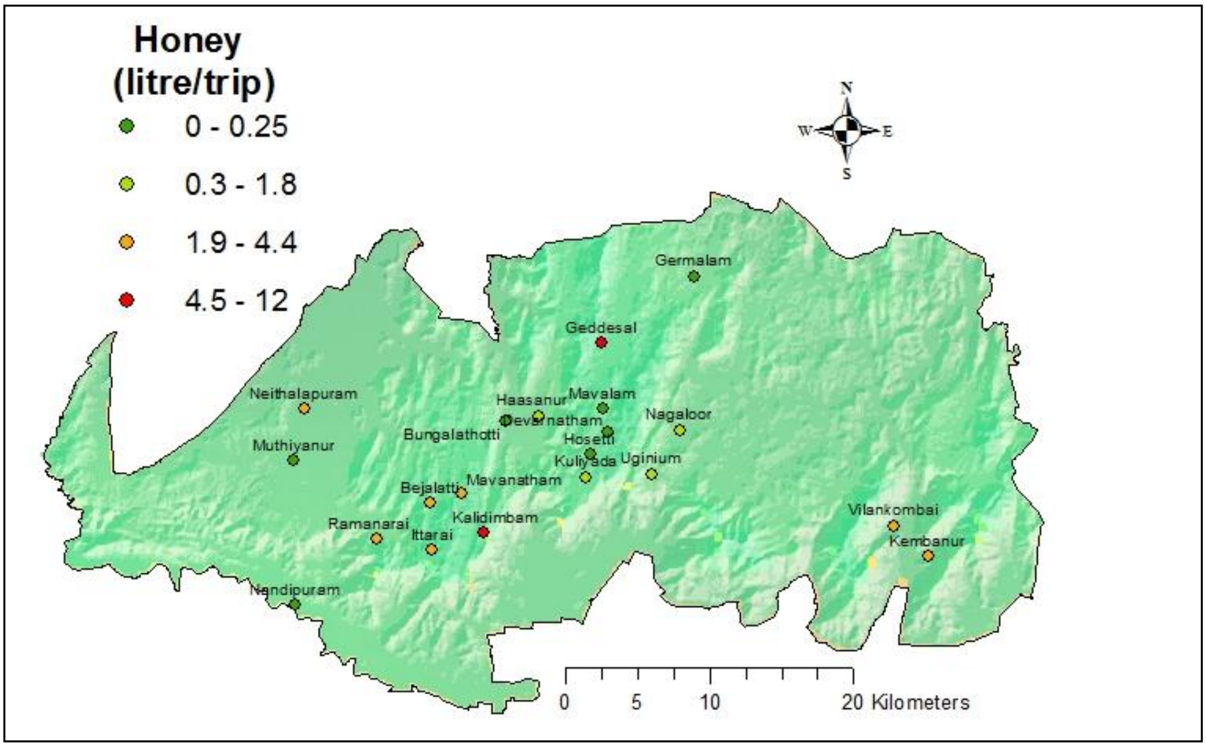


Figure 4.26: Quantity of honey extracted/HH/trip in the Sathyamangalam landscape (10-y ago)



Chapter 5

Non timber forest products extracted in the Sathyamangalam landscape

Introduction

Southern Asia has a long history of human use of forest products (Bawa and Godoy 1993). In India, for example, an estimated 160 million people live in and along the periphery of forests. A large number of these people rely upon nontimber forest products (NTFPs) for their subsistence and cash income (NCHSE 1987). As implicit in the term, NTFPs include all biological materials, except timber, extracted for human use. Some have even used the term to encompass service functions rendered by forestlands. The products include fuel wood, charcoal, honey, resin, spices, and raw materials for handicrafts from rattan, vines, bamboo, grass, and wildlife products such as bones and skins for rituals and ornamental purposes. Service functions include grazing, watershed protection, provision and management of wildlife habitats, and tourism. In recent years the collection of NTFPs is being increasingly driven by commercial demands from a much wider market. There has been much debate on the sustainability of this extraction for the long-term ecological integrity of forests. Sustainable harvest could be defined as the level of harvest that does not impair the ability of the harvested population to replace itself (Hall and Bawa 1993). Sustainable harvest of renewable natural resources such as NTFPs can, in principle, contribute to the economic well-being of the forest people and involve them in conservation of biodiversity (Uma Shankar et al. 1996). Decisions on whether or not to permit NTFP extraction would depend on a variety of considerations, including its importance to the local economy, possibility of alternative sources of income to the people, ecological impacts of NTFP extractions, and legal status of the forests (protected areas versus other categories) (Narendran et al. 2001).

Objectives

1. What are the differences in NTFP species collected across the different villages in the Sathyamangalam landscape.

2. Are there significant trends in the extraction of NTFPs collected in the Sathyamangalam landscape.

Methods

Below we present the data gathered by the Sathyamangalam forest department, this is computed from records maintained in the local office of the forest departments. We examine the trends in NTFPs, especially the dominant NTFPs collected over time. Records of the NTFPs collected from the Sathyamangalam landscape are maintained from 2003 to 2009 for 13 of the 20 villages.

Statistical Analysis

Statistical analysis of trends in NTFP extractions (data obtained from the forest department). Linear regressions were carried out to assess significant trends in NTFPs extracted over time. All analysis was conducted in the statistical software R (R-Project 2006).

Results

Bungalathotti and Bejalatti

In Bungalathotti and Bejalatti, none of the species showed significant changes in extractions over time (Fig 5.1 and 5.2).

Geddesal

There is a significant declining trend in the extraction of *Terminalia chebula* ($F_{1,5}$=30.1, R^2=0.85, p=0.002), other species did not reveal any significant changes over time (Fig. 5.3).

Ittarai

In Ittarai, none of the species showed significant changes in the extractions of species (Fig. 5.4).

Kalidimbam

In Kalidimbam, none of the species showed significant changes in the extractions of species (Fig. 5.5).

Kuliyada

There is a significant declining trend in the extraction of *Phyllanthus emblica* ($F_{1,5}$=12.2, R^2=0.7, p=0.01), however, *Phoenix loureiroi* and *Terminalia chebula* did not reveal any significant changes over time (Fig. 5.6).

Kembanur

There is a significant declining trend in the extraction of *Phoenix loureiroi* ($F_{1,5}$=9.6, R^2=0.65, p=0.02), in the extraction of *Phyllanthus emblica* ($F_{1,5}$=5.8, R^2=0.53, p=0.06), in the extraction of *Terminalia chebula* ($F_{1,5}$=51, R^2=0.9, p=0.001), and in the extraction of *Azadirachta indica* ($F_{1,5}$=8.07, R^2=0.6, p=0.03) (Fig. 5.7).

Mavanatham

There is a significant declining trend in the extraction of *Phoenix loureiroi* ($F_{1,5}$=14.4, R^2=0.74, p=0.01) and in the extraction of *Phyllanthus emblica* ($F_{1,5}$=9.46, R^2=0.65, p=0.02) (Fig. 5.8).

Nagaloor

There is a significant declining trend in the extraction of *Phoenix loureiroi*, ($F_{1,5}$=33.06, R^2=0.86, p=0.002), and in the extraction of *Phyllanthus emblica* ($F_{1,5}$=28.23, R^2=0.84, p=0.003), other species revealed no significant changes in extractions over time (Fig. 5.9).

Nandipuram

In Nandipuram, none of the species showed significant changes in the extractions of species (Fig. 5.10).

Ramaranai

There is a significant increasing trend in extraction of *Phoenix loureiroi* ($F_{1,5}$=14.7, R^2=0.74, p=0.01); also an increasing trend in the extraction of *Phyllanthus emblica* ($F_{1,5}$=10.3, R^2=0.67, p=0.02), and no trend in the extraction of *Terminalia chebula* (Fig. 5.11).

Uginium

There is a significant declining trend in the extraction of *Phoenix loureiroi* ($F_{1,5}$=33.4, R^2=0.86, p=0.002), and in the extraction of *Phyllanthus emblica* ($F_{1,5}$=48.8, R^2=0.9, p=0.001), other species revealed no significant changes in extractions over time (Fig. 5.12).

Vilankombai

There is a significant declining trend in the extraction of *Phyllanthus emblica* ($F_{1,5}$=9.09, R^2=0.64, p=0.03), in the extraction of *Sapindus trifoliate* ($F_{1,5}$=17.05, R^2=0.77, p=0.009), in the extraction of *Terminalia chebula* ($F_{1,5}$=8.8, R^2=0.63, p=0.03), in the extraction of *Azadirachta indica* ($F_{1,5}$=16.3, R^2=0.76, P=0.009), and in the extraction of *Pongamia pinnata* ($F_{1,5}$=9.1, R^2=0.64, p=0.03) (Fig. 5.13).

Discussion

Except for the village Ramaranai, all other villages in the Sathyamangalam landscape revealed significant declines in the extraction of NTFPs. Dominant NTFPs such as *Phyllanthus emblica*, *Phoenix loureiroi* and *Terminalia chebula* whose extraction quantities run into several thousands of kilograms each year show a declining trend in most villages. Whether this is related to ecological sustainability in terms of the declines of yields due to plant survival, regeneration, and recruitment patterns (Murali et al. 1996) needs further research.

In the Biligiri Rangan hills the fruit (*Phyllanthus emblica*) yield per tree varies among forest types, with the deciduous and evergreen forests yielding significantly more fruits per tree than the thorn forests and montane forests of lower stature. Fruit yield per hectare, is a function of tree density/unit area and production potential of the average sized tree, it was highest in deciduous forest and lowest in montane forest, the difference between the two being approximately 28 fold (Uma Shankar et al. 1996).

Whether such a negative trend in the extraction of these NTFPs is an indication of sustainable harvests or not is difficult to answer at present, but certainly such long-term records give us an idea of the ecological cycles or patterns in seed production. Data on such aspects, combined with longterm monitoring of the demography of plant populations, are crucial in understanding the sustainability or otherwise in the extraction of these NTFPs.

References

Bawa, K. S., and R. Godoy. 1993. Introduction to case studies from South Asia. *Economic Botany* 47:248–250.

Hall, P., and K. S. Bawa. 1993. Methods to assess the impact of extraction of non-timber forest products on plant populations. *Economic Botany* 47:234–247.

Murali, K. S., U. Shankar, R. R.Shanker, K. N. Ganeshaiah, and K. S. Bawa. 1996 Extraction of non-timber forest products in the forests of Biligiri Rangan Hills, India. 2. Impact of NTFP extraction on regeneration, population structure, and species composition. *Economic Botany* **50**:252–269

NCHSE (National Centre for Human Settlements and Environment). 1987. Documentation on forest and rights. Volume 1. National Centre for Human Settlements and Environment, New Delhi.

Narendran, K., Indu K. Murthy, Suresh, H.S., Dattaraja, H.S., Ravindranath, N.H., and Sukumar, R. 2001. Non timber forest product extraction, utilisation and valuation: A case study from the Nilgiri Biosphere Reserve, Southern India. *Economic Botany* 55(4): 528-538.

Uma Shankar, K. S. Murali, R. Uma Shaanker, K. N. Ganeshaiah, and K. S. Bawa. 1996. Extraction of non-timber forest products in the forests of Biligiri Rangan Hills, India. 3. Productivity, extraction and prospects of sustainable harvest of Amla, *Phyllanthus emblica* (Euphorbiaceae). *Economic Botany* 50:270–279.

Figure 5.1: Temporal pattern of NTFPs extracted in Bungalathotti

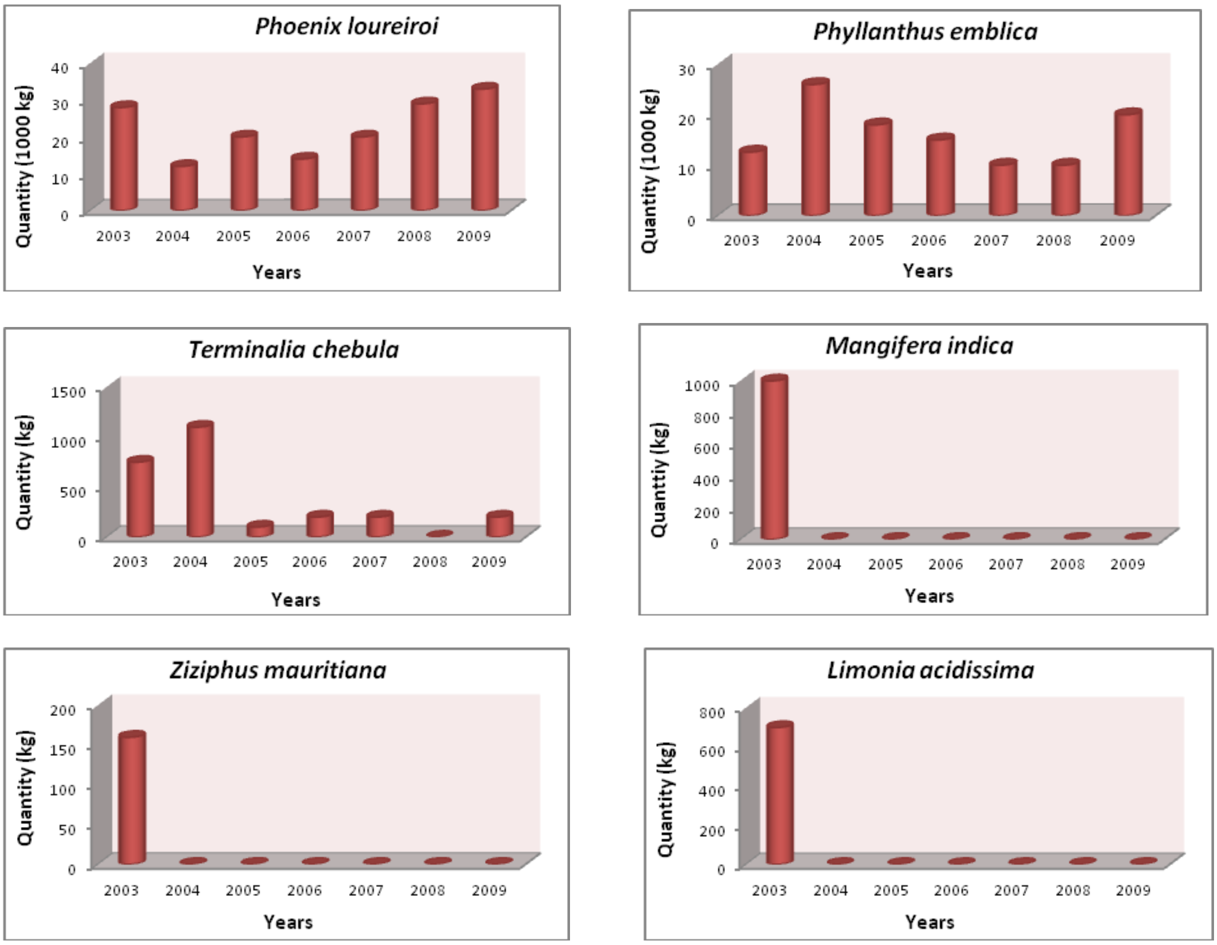


Figure 5.2: Temporal pattern of NTFPs extracted in Bejalatti

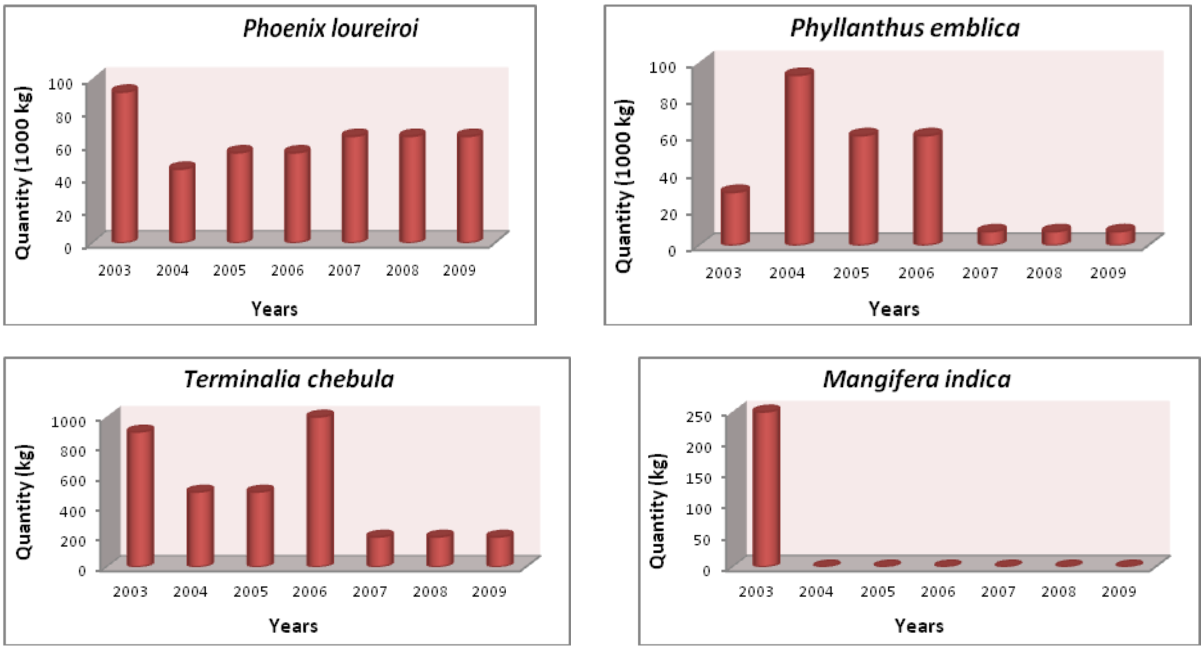


Figure 5.3: Temporal pattern of NTFPs extracted in Geddesal

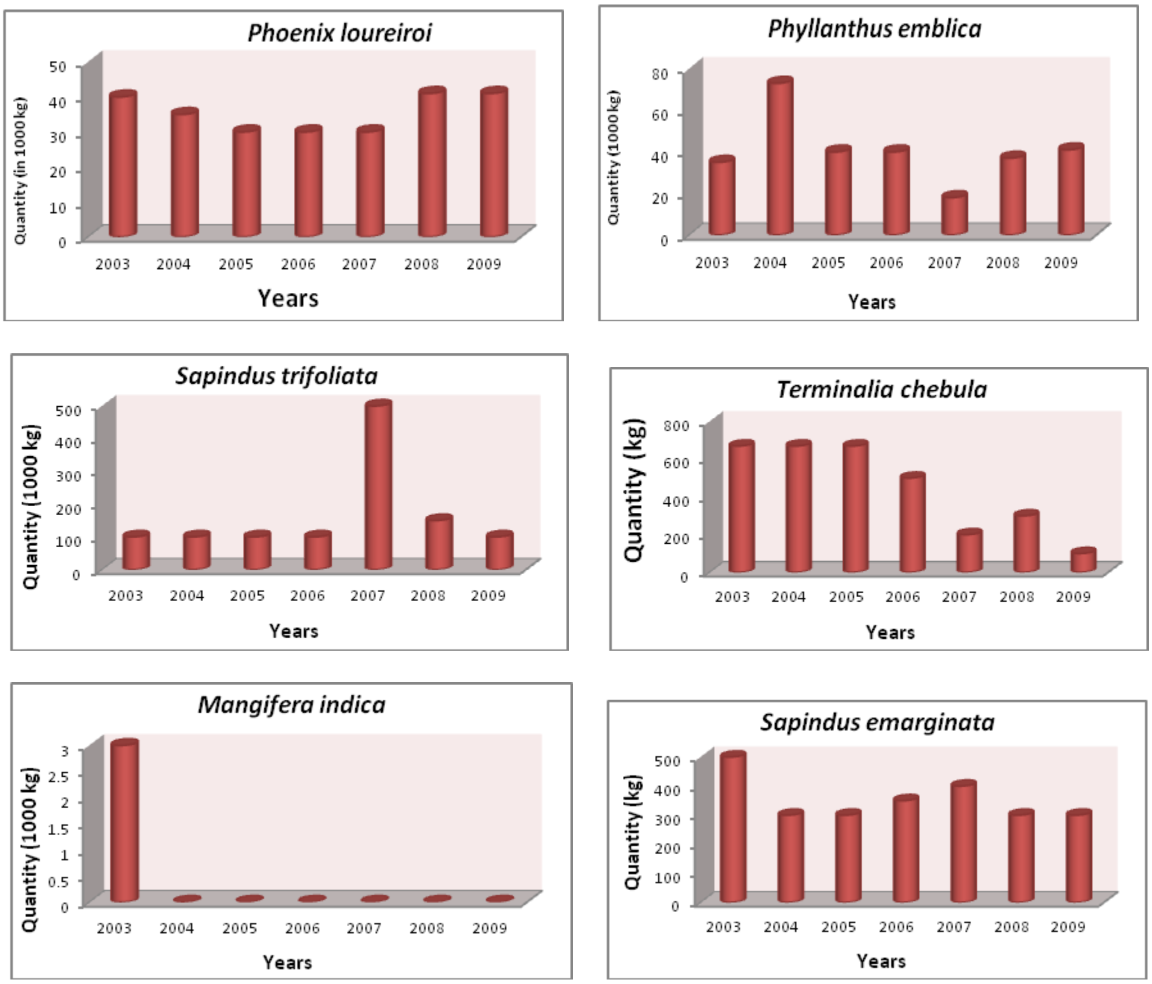


Figure 5.4: Temporal pattern of NTFPs extracted in Ittarai

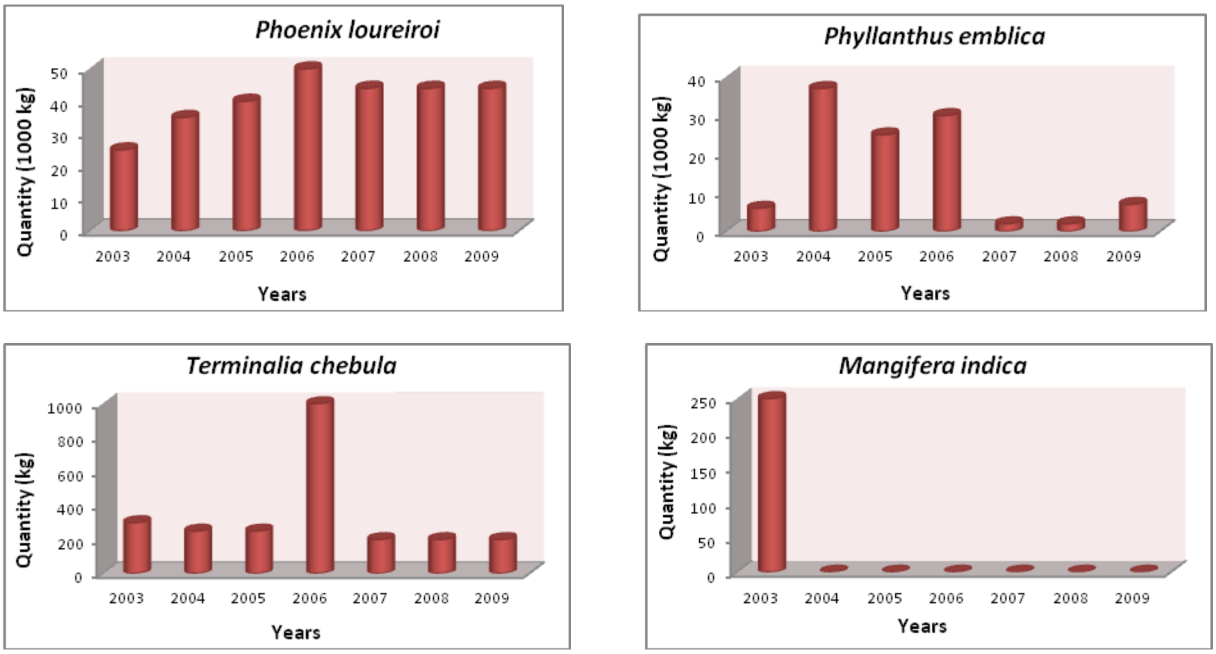


Figure 5.5: Temporal pattern of NTFPs extracted in Kalidimbam

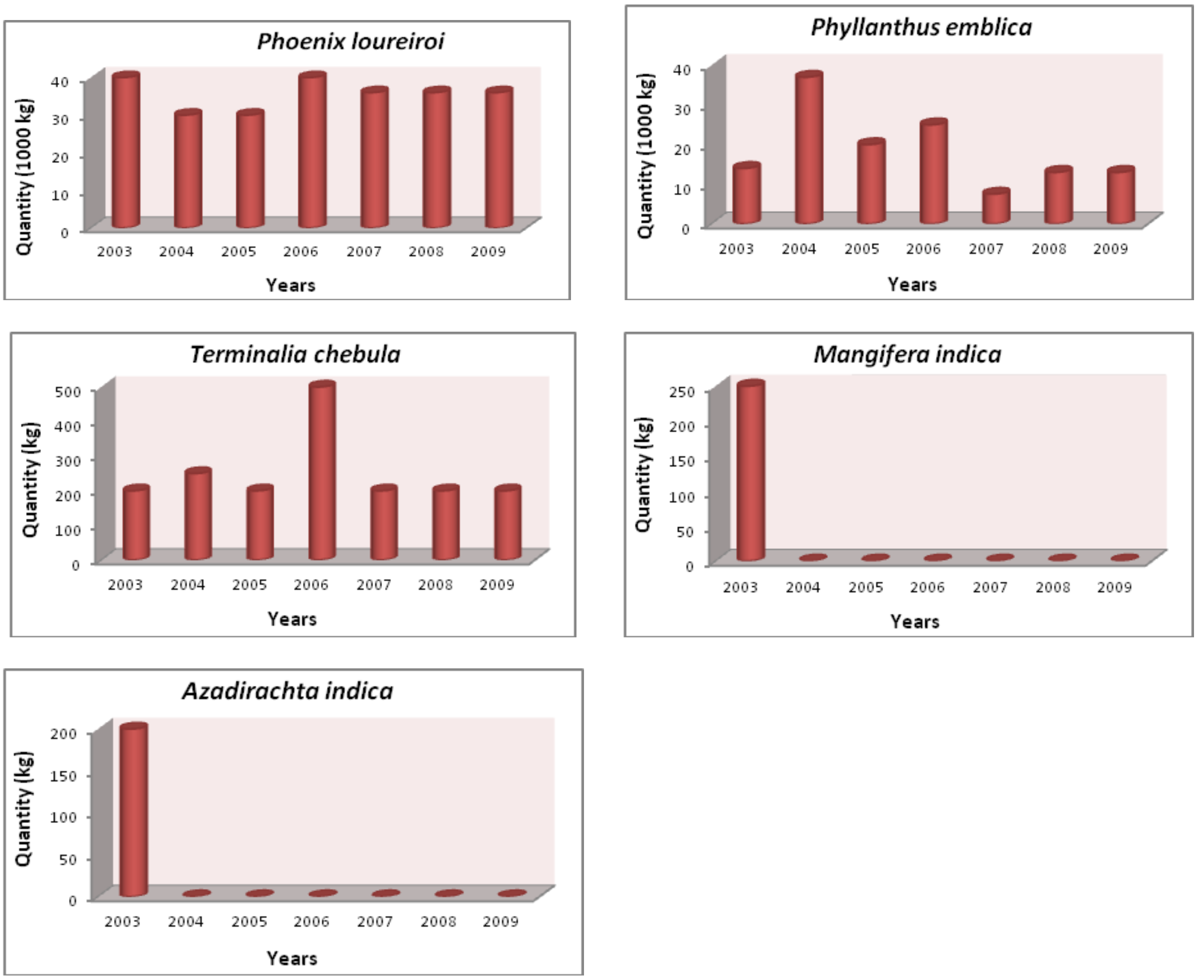


Figure 5.6: Temporal pattern of NTFPs extracted in Kuliyada

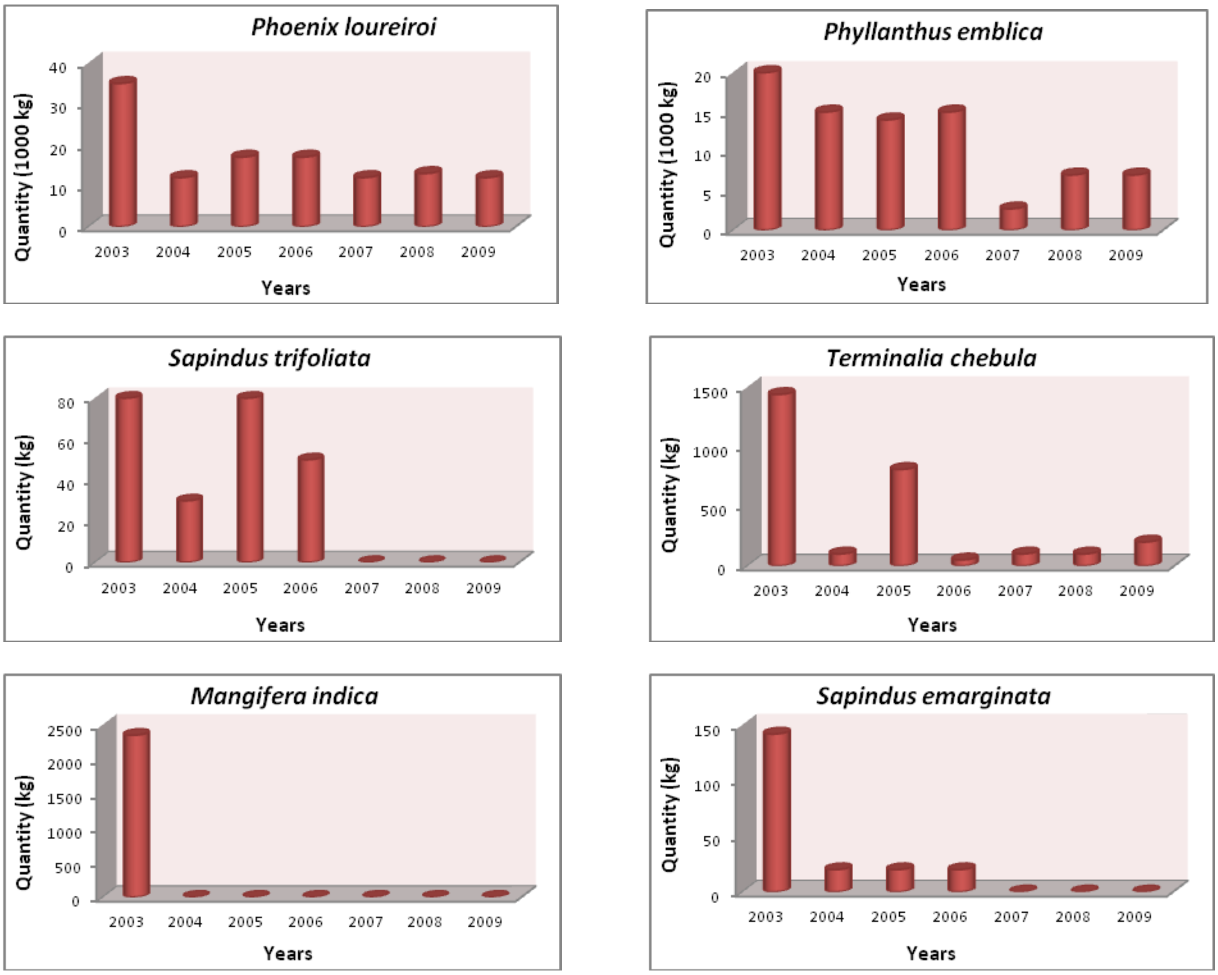


Figure 5.7: Temporal pattern of NTFPs extracted in Kembanur

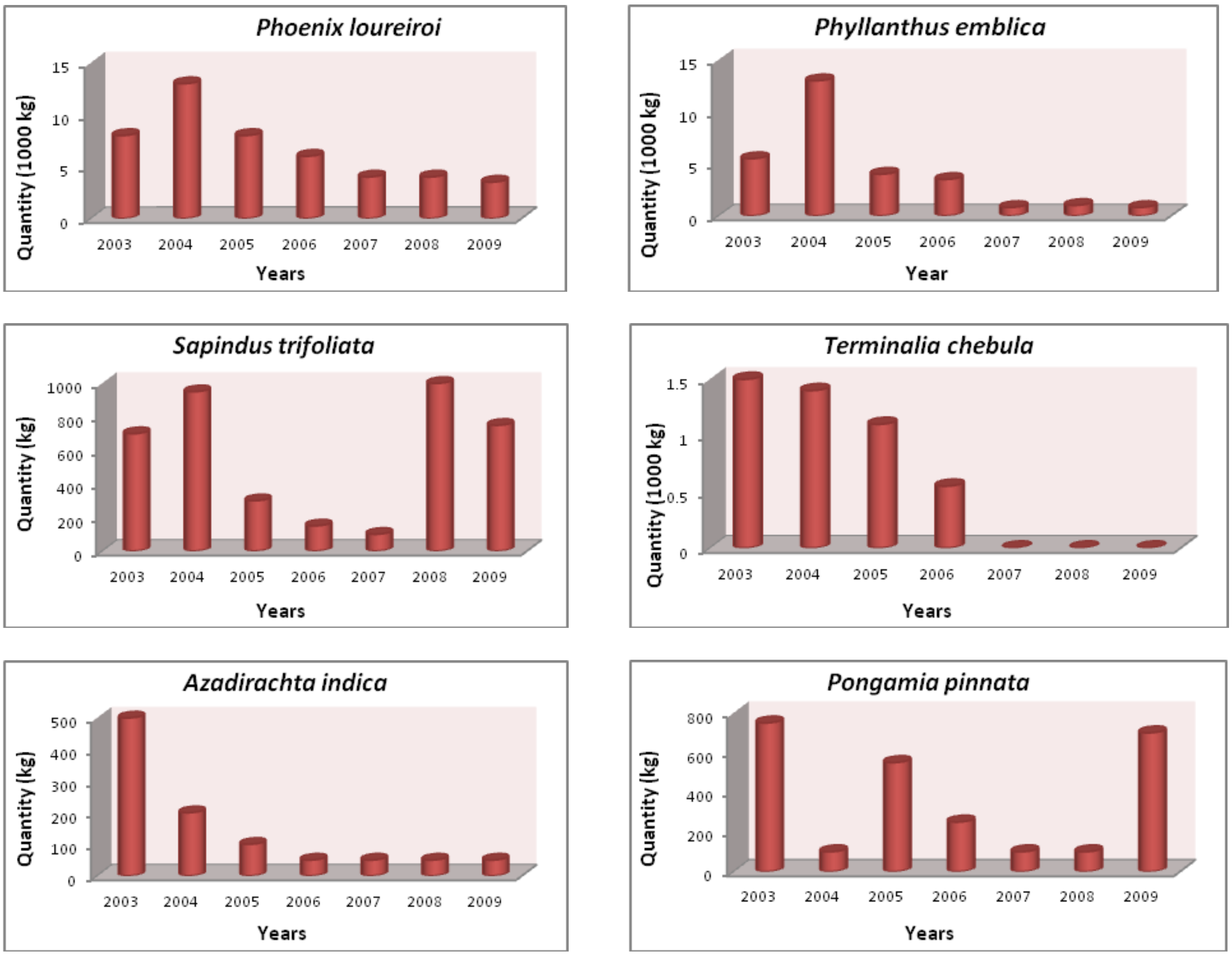


Figure 5.8: Temporal pattern of NTFPs extracted in Mavanatham

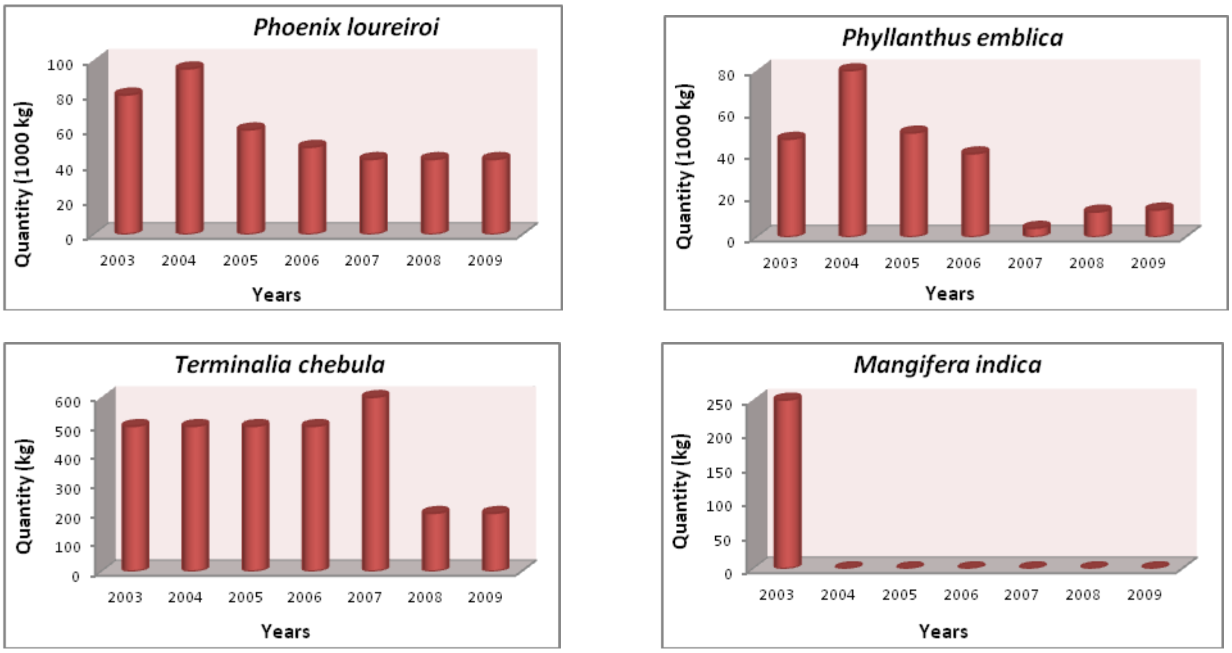


Figure 5.9: Temporal pattern of NTFPs extracted in Nagaloor

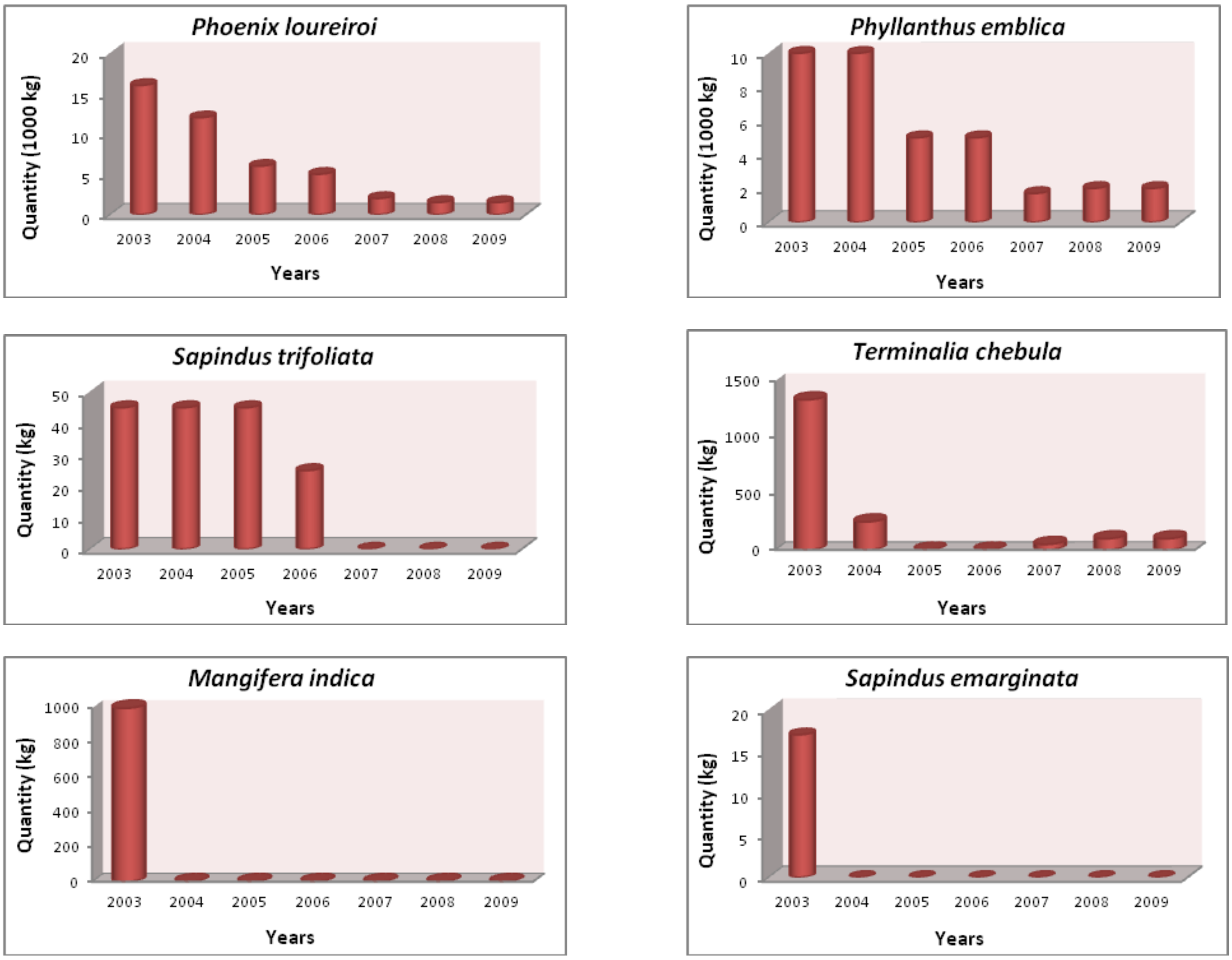


Figure 5.10: Temporal pattern of NTFPs extracted in Nandipuram

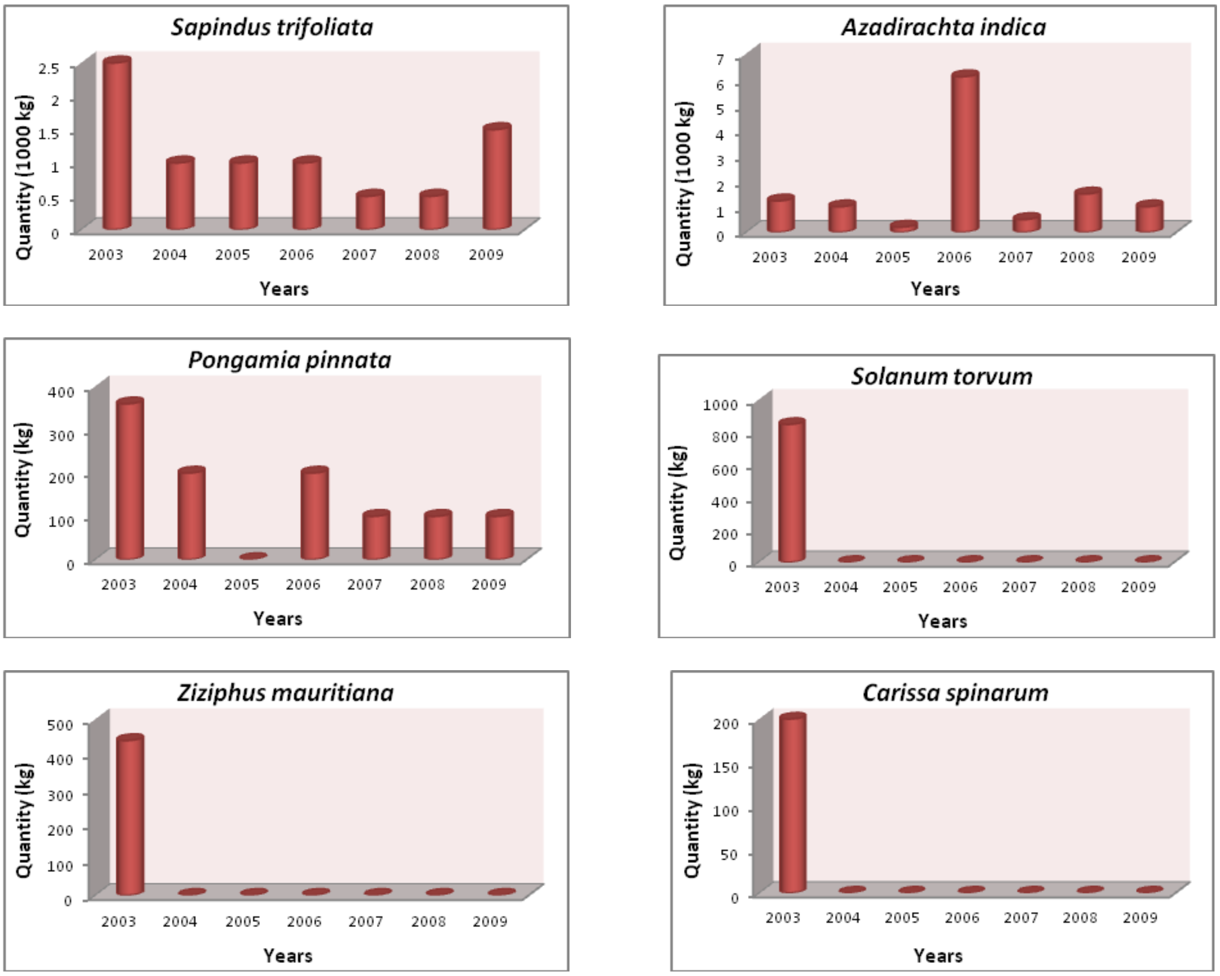


Figure 5.11: Temporal pattern of NTFPs extracted in Ramaranai

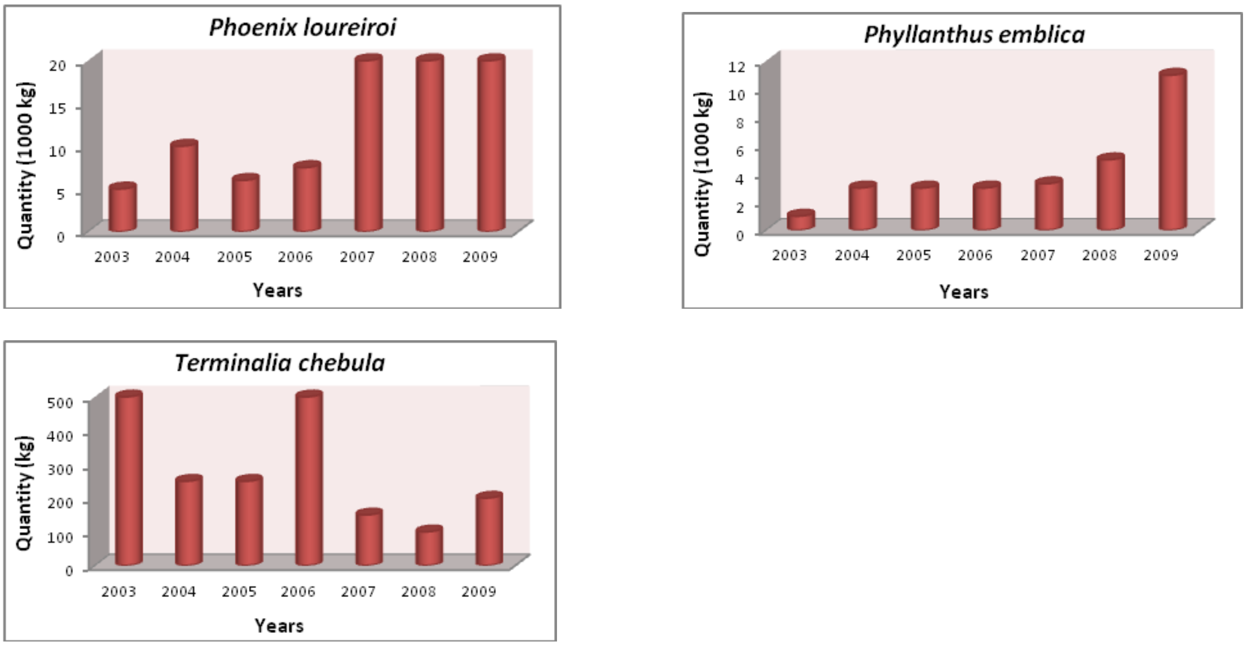


Figure 5.12: Temporal pattern of NTFPs extracted in Uginium

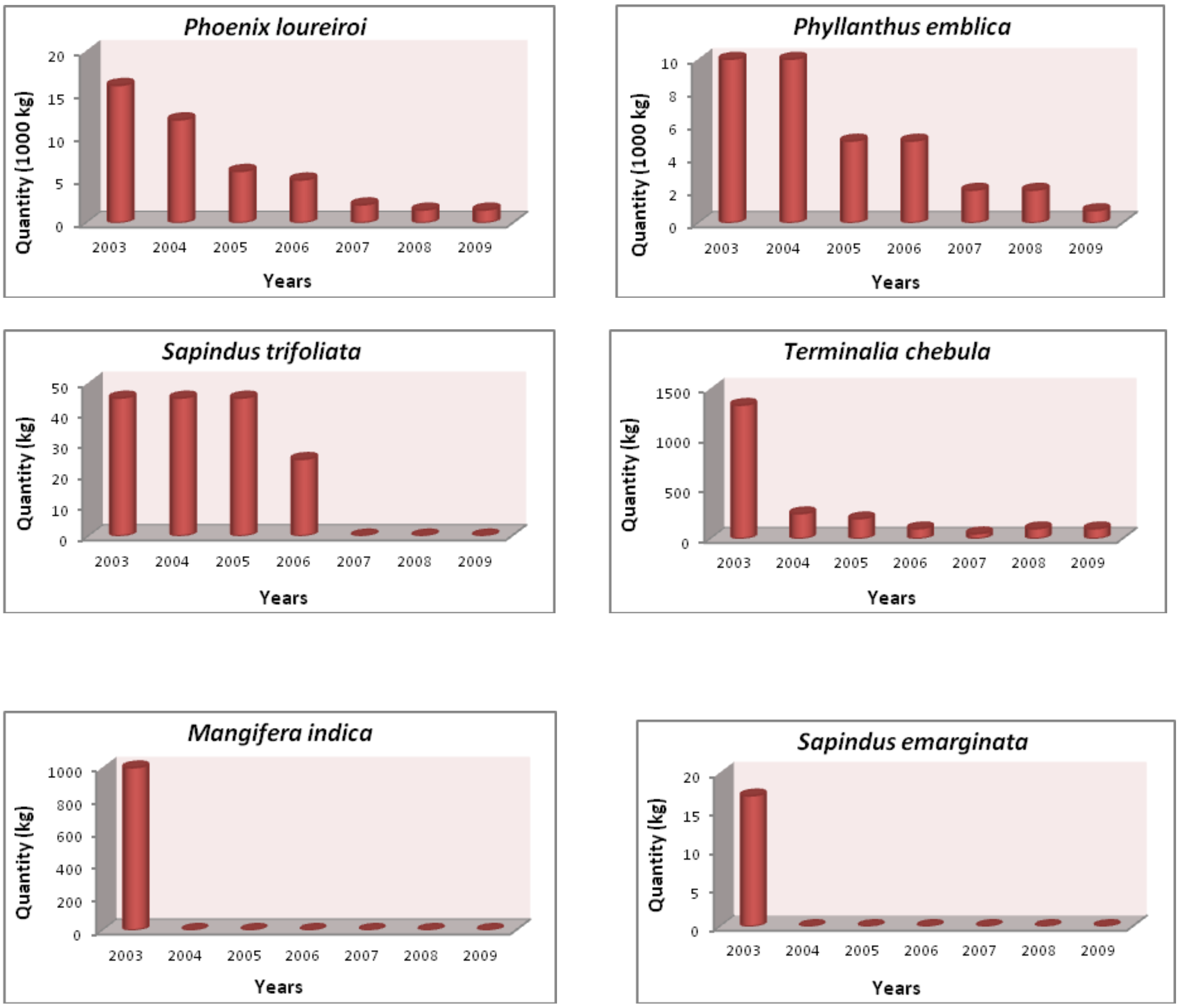
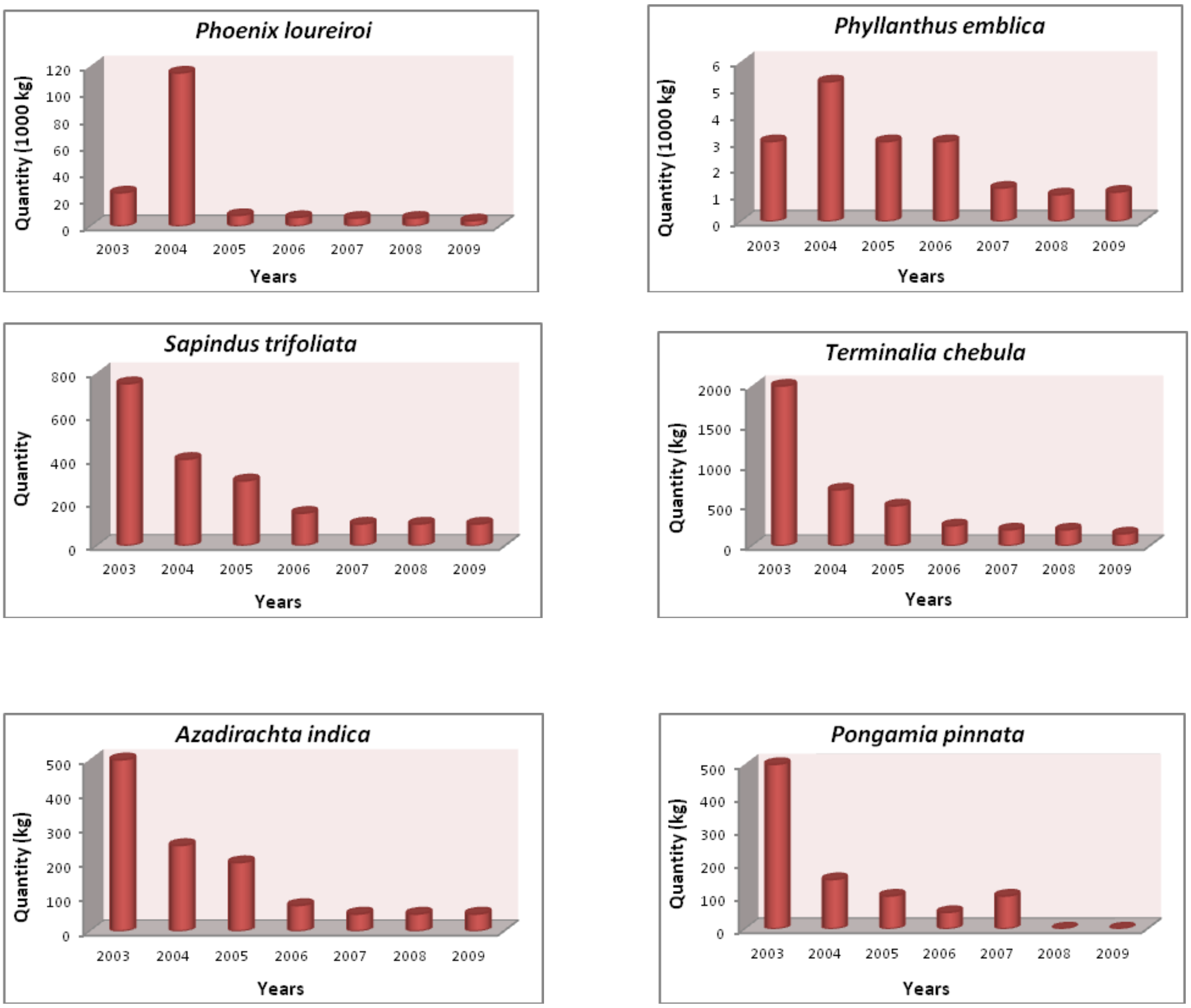


Figure 5.13: Temporal pattern of NTFPs extracted in Vilankombai



Chapter 6

Forest Management Plan

The Sathyamangalam landscape supports several ecosystem services, these include watershed services (maintaining water quality, regulating water flow); it will be extremely useful to adopt a watershed approach to conservation. Identifying the major basins and sub-basins in the Sathyamangalam landscape would be an appropriate strategy for conservation in the area. Understanding the hydrological characteristics of the landscape would be useful in future management programs. Several rainfall stations have been established by the forest department in the landscape, augmenting the number of stations and systematically collecting information would be important for both management and future research.

The landscape harbours high elevation grasslands and evergreen forest patches, steps must be taken to conserve these two unique ecosystems. Apart from contributing to the watershed services, these two ecosystems could harbour rich biodiversity of all taxa. Recent studies in the landscape indicate that the landscape could be holding several tigers and also Asian elephants. Also, the Sathyamangalam landscape is a critical connecting link for the migration of species between the Western Ghats and the Eastern Ghats. The Sathyamangalam landscape is critically located, with the BRT tiger reserve in Karnataka to the north, and the Mudumalai tiger reserve and Bandipur tiger reserve to the west. Adopting a landscape scale planning approach would enhance the conservation outcomes for the whole region. Further, the carbon sequestration potential of the evergreen forests and the deciduous forest could be vital for mitigating the impacts of climate change. Here, it must be pointed out that creating baseline inventories such as the ones established in this report would be useful for new and emerging mechanisms on mitigating climate change such as REDD+.

The socio-economic analyses conducted in this study, provides several important results, one, there is a sizeable human population that is dependent on natural resources of various kinds in the landscape. Food, fibre, and fire wood needs are derived by several village communities in the landscape. Two, important NTFP species such as *Phyllanthus emblica* and *Terminalia chebula* contribute substantially to the local incomes of forest dependent communities. Outlining sustainable extraction practices through people's participation would be important. Establishing participatory governance measures in the landscape to conserve natural resources and manage these resources would be critical for the conservation of biodiversity in the landscape.

Asian Nature Conservation Foundation (ANCF) is a non-profit public charitable trust set up to meet the need for an informed decision- making framework to stem the loss of biological diversity in India and other countries of tropical Asia. The foundation undertakes activities independently as well as in coordination with governmental agencies, research institutions, conservation NGOs and individuals, on matters relation to the conservation of natural resources and biodiversity.

Tamil Nadu Forest Department (TNFD) is the custodian of 22,865 km^2 of forest land and invaluable wildlife in the state of Tamil Nadu. Hence the state has adopted a compelling vision to inspire people to protect wilderness, the ecological diversity and species richness. The Tamil Nadu State Forest Act 1882, the Wildlife Protection Act, 1972, Forest Conservation Act, 1980 and a host of rules formulated under these Acts are being implemented by the Forest Department. Adhering to the best scientific principles and incorporating traditional knowledge, new socio-economically and ecologically sound paradigms for managing forests and wildlife and wildlife have also been incorporated into the managements strategies adopted by the department.

Center for Advanced Spatial and Environmental Research (CASER) is a non-profit charitable trust set up to meet the needs of environmental conservation. The center undertakes activities to alleviate the pressure on natural resources through the application of geospatial and remote sensing techniques. The mission of CASER is to promote principles of sustainable use of natural resources through sound environmental planning.

Tropical forests constitute more than 50% of all forests globally and also support approximately 1 billion of the world's poorest people. Human dimensions of forest degradation in the Sathyamangalam landscape is an important contribution and examines different aspects of forest characteristics, spatial pattern of disturbances and the underlying factors contributing to disturbances in the landscape. The sustainable use of natural resources is critical not only to meet the food, fibre, energy, and income needs of rural communities dependent on forests, but it is also important for maintaining the various environmental services derived from forests.

Chapter one provides an overview of forest dependence in Indian ecosystems, chapter two examines disturbances in the landscape such as grazing, logging, and indicators of disturbance such as invasive species to derive a disturbance index through the use of principal component analysis. Chapter three provides in-depth analyses of forest fires in relation to human settlements in the Sathyamangalam landscape. Chapter four includes detailed analysis of the underlying causes of forest disturbances in the landscape, 20 villages and 400 households were sampled to assess important socio-economic factors of disturbance in the landscape. Chapter five provides trends in the extraction of NTFPs in the landscape. Chapter six makes recommendations to forest managers in the landscape from the findings of our research.

We hope that the current book which contains baseline information on different environmental aspects in the Sathyamangalam landscape will provide an impetus to forest conservation efforts through landscape scale planning.

ANCF
ASIAN NATURE CONSERVATION FOUNDATION

Centre for Advanced Spatial and Environmental Research

ISBN 978-81-909731-6-8
9 788190 973168