DOCTOR OF PHILOSOPHY

Analysis of biodiversity and soil C storage in the south Konkan coast of Maharashtra (India)

Gadekar, Kumarsukhadeo

Award date:
2012

Awarding institution:
Bangor University

ANALYSIS OF BIODIVERSITY AND SOIL C STORAGE IN THE SOUTH KONKAN COAST OF MAHARASHTRA (INDIA)

Kumarsukhadeo Prakash Gadekar

B.Sc. Forestry, (Dr. BSKKV, Dapoli, India)

M. Sc. Forestry, (IGAU, Raipur, India)

A thesis submitted to the Bangor University in candidature for the degree of

Doctor of Philosophy

School of Environment, Natural Resources and Geography

Bangor University

Bangor, Gwynedd,

North Wales, United Kingdom

LL57 2UW

October 2012

Sponsored by

Declaration and Consent

Details of the Work

I hereby agree to deposit the following item in the digital repository maintained by Bangor University and/or in any other repository authorized for use by Bangor University.

Author Name: Kumarsukhadeo Prakash Gadekar, **Student ID:** 500175041

Title: Analysis of biodiversity and soil C storage in the South Konkan coast of Maharashtra (India)

Supervisor and Department: Prof. D. L. Godbold - School of Environment, Natural Resources and Geography.

Funding body: Social Justice and Special Assistance Department Mumbai, Government of Maharashtra state (India)

Qualification/Degree obtained: PhD Forestry

This item is a product of my own research endeavours and is covered by the agreement below in which the item is referred to as "the Work". It is identical in content to that deposited in the Library, subject to point 4 below.

Non-exclusive Rights

Rights granted to the digital repository through this agreement are entirely non-exclusive. I am free to publish the Work in its present version or future versions elsewhere.

I agree that Bangor University may electronically store, copy or translate the Work to any approved medium or format for the purpose of future preservation and accessibility. Bangor University is not under any obligation to reproduce or display the Work in the same formats or resolutions in which it was originally deposited.

Bangor University Digital Repository

I understand that work deposited in the digital repository will be accessible to a wide variety of people and institutions, including automated agents and search engines via the World Wide Web.

I understand that once the Work is deposited, the item and its metadata may be incorporated into public access catalogues or services, national databases of electronic theses and dissertations such as the British Library's EThOS or any service provided by the National Library of Wales.

I understand that the Work may be made available via the National Library of Wales Online Electronic Theses Service under the declared terms and conditions of use (http://www.llgc.org.uk/index.php?id=4676). I agree that as part of this service the National Library of Wales may electronically store, copy or convert the Work to any approved medium or format for the purpose of future preservation and accessibility. The National Library of Wales is not under any obligation to reproduce or display the Work in the same formats or resolutions in which it was originally deposited.

Statement 1:

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree unless as agreed by the University for approved dual awards.

Signed ………………………………………….. (Candidate)

Date / /2012

Statement 2:

This thesis is the result of my own investigations, except where otherwise stated. Where, correction services have been used, the extent and nature of the correction is clearly marked in a footnote(s).

All other sources are acknowledged by footnotes and/or a bibliography.

Signed …………………………………………. (Candidate)

Date / /2012

Statement 3:

I hereby give consent for my thesis, if accepted, to be available for photocopying, for inter-library loan and for electronic repositories, and for the title and summary to be made available to outside organisations.

Signed …………………………………………. (Candidate)

Date / /2012

NB: Candidates on whose behalf a bar on access has been approved by the Academic Registry should use the following version of **Statement 3:**

Statement 3 (bar):

I hereby give consent for my thesis, if accepted, to be available for photocopying, for inter-library loans and for electronic repositories after expiry of a bar on access.

Signed …………………………………………… (Candidate)

Date / /2012

<u>Statement 4</u>:

Choose **<u>one</u>** of the following options

a) I agree to deposit an electronic copy of my thesis (the Work) in the Bangor University (BU) Institutional Digital Repository, the British Library ETHOS system, and/or in any other repository authorized for use by Bangor University and where necessary have gained the required permissions for the use of third party material.	
b) I agree to deposit an electronic copy of my thesis (the Work) in the Bangor University (BU) Institutional Digital Repository, the British Library ETHOS system, and/or in any other repository authorized for use by Bangor University when the approved **bar on access** has been lifted.	
c) I agree to submit my thesis (the Work) electronically via Bangor University's e-submission system, however I **opt-out** of the electronic deposit to the Bangor University (BU) Institutional Digital Repository, the British Library ETHOS system, and/or in any other repository authorized for use by Bangor University, due to lack of permissions for use of third party material.	

Options B should only be used if a bar on access has been approved by the University.

In addition to the above, I also agree to the following:

1. That I am the author or have the authority of the author(s) to make this agreement and do hereby give Bangor University the right to make available the Work in the way described above.

2. That the electronic copy of the Work deposited in the digital repository and covered by this agreement, is identical in content to the paper copy of the Work deposited in the Bangor University Library, subject to point 4 below.

3. That I have exercised reasonable care to ensure that the Work is original and, to the best of my knowledge, does not breach any laws – including those relating to defamation, libel and copyright.

4. That I have, in instances where the intellectual property of other authors or copyright holders is included in the Work, and where appropriate, gained explicit permission for the inclusion of that material in the Work, and in the electronic form of the Work as accessed through the open access digital repository, *or* that I have identified and removed that material for which adequate and appropriate permission has not been obtained and which will be inaccessible via the digital repository.

5. That Bangor University does not hold any obligation to take legal action on behalf of the Depositor, or other rights holders, in the event of a breach of intellectual property rights, or any other right, in the material deposited.

6. That I will indemnify and keep indemnified Bangor University and the National Library of Wales from and against any loss, liability, claim or damage, including without limitation any related legal fees and court costs (on a full indemnity bases), related to any breach by myself of any term of this agreement.

Signature: ……………………………………………………

Date / /2012

Dedication

A dedication to my beloved father and mother

Acknowledgement

I would like to thank my supervisor Prof. Douglas L. Godbold who has offered much precious time, expertise, suggestions, support, guidance, useful criticism and constructive comments, without which, I would not have completed this thesis. I wish to owe many thanks to co-supervisors Dr. R. M. Brook, Prof. David L. Jones and Dr. Morag McDonald for invaluable time and guidance. I acknowledge Bangor University for giving an opportunity to undertake PhD and warm welcome, great logistical support and assistance during course of study. This PhD was made possible through scholarship provided by the Social Justice and Special Assistance Department, Government of Maharashtra (India). I am deeply grateful to School of Environment, Natural Resources and Geography for funding part of the tuition fees to Bangor University, which make possible to submit thesis in stipulated time. I wish to thank all professors, staff and alumni's of Dr. BSKKV, Dapoli for their love, support and encouragement from beginning of the course. Particular heartfelt thanks go to Mr. Sharad Pawar (Hon'ble Union Minister for Agriculture, Government of India, Hon'ble MLA Mr. Ramesh Thorat and Mr. Amol Khatal for inspirations, encouragement and huge moral support. I am also thankful to Maelor Forest Nurseries Ltd. Whitchurch, United Kingdom for providing part time job opportunity. I acknowledge Mr Tchato Guy Tchabet an expert in Cartography, Topography and Geographical Information System (GIS)/ Senior Forestry and Wildlife Technician for helping me all the maps related to study site.

I would like to thank Dr. Christine Cahalan for consistent guidance, inspirations and support throughout my Ph.D. I acknowledge Dr. James Gibbons for his help in vegetation and bird data analysis, without him I would not have command in use of Distance 6.2 release 2 and EstimateS 8.2.0 software applications. Thanks to Gorden and Jonathan Roberts for practical assistance in laboratories. I thank the Department of Agro-Meteorology, Dr. BSKKV Dapoli for providing the meteorological data prevailing in the Ratnagiri district. I would like to thank the college of Forestry and Agricultural Chemistry and Soil Science Department, Dr. BSKKV Dapoli for access to equipment's required for field work. I am also thankful to DFO, forest sub-division Chiplun for the necessary permission and providing access to working plan of Chiplun forest sub-division. I am thankful to FSI for providing the forest cover map of the study area.

From the bottom of heart, I would like to acknowledge my father Mr. Prakash Gadekar, mother Mrs. Chandrabhaga Gadekar, brothers Imam and Arun for their immense love, inspirations, encouragement, moral and financial support throughout my life, without them I would not reach to this success. I am very thankful to my maternal uncles Balasaheb Sonavane, Dyanadev Thawal, Sopan Thawal and Balu Thawal, Raichand Pote, Dipak Gadekar, Laxman Gadekar, aunties Hirabai Sonavane, Laxmibai Thawal, Nalini Thawal, Gangubai Pote and Nirmala Thawal. I am very grateful to my brothers-in-law Navnath Gadre, Santosh Abnave; sisters Nilima, Sarika, Maya, Nikahat; Sangita, Pooja, brothers Vijay Gaikwad, Naresh, Vishal Pote, Vikas Pote, Pravin Sonavane, Nilesh, Pratahmesh, Sagar, Vishal, and friends Ahmed Iftekhar, Hemant Rajput, Nadeem Rehman, Abdul Waheed, Kiran Sarate, Satish Meena, Snehal Kadam, Prashant Chavan, Sachin Lengrekar, Nitin Jagdale, Bapu Temgire and Hrishikesh Gaykar for constant support, encouragement and spiritual guidance during the course of study.

I would like to thank my wife Rohinee for her huge love, patience, considerations, assurance, encouragement and moral support, without which I could not have gone through. Many thanks to my beautiful daughter's Shravanee and Arya and handsome son's Sarthak and Arnavfor love and their presence, providing an incentive to finish so that we could have more time together. In addition, I owe my heartfelt thanks to my extended family and friends for their encouragement, love and moral support. I am very grateful to peoples of Jaitapur and surrounding villages for their love, support and assistance during my stay. Finally, I wish to thank everyone who helped me directly or indirectly throughout the course of study period.

Abstract

This thesis presents an analysis of floral diversity, soil C carbon storage and bird diversity in the south Konkan coast of the Western Ghats of India. The objectives of the investigation were to study structure, composition, distribution, richness and diversity of vegetation under different land-use types, to determine soil organic carbon content and to determine species composition, richness and diversity of birds under different land-use types.

For the investigation, agricultural, forest, casuarina plantation, grassland, mango plantation, homegarden and mangrove sites were selected randomly over a 460 km^2 area. At the forest, casuarina, homegardens and mangrove sites quadrate sampling technique was used for phyto-sociological analysis. Soil organic matter was determined by the weight loss-on-ignition method on soils collected as selected sites. A point transect survey method based on distance sampling was used to study seasonal variation in bird species richness and diversity in different land-use types. The sample based rarefaction curves were computed using EstimateS 8.2.0 and Eco-sim version free software applications. The bird data was analyzed using Distance 6.2 release 2 software.

Floristic analysis revealed that the study area is home for 407 plant species belonging to different 104 families. The most dominating families are Fabaceae, Cucurbitaceae, Euphorbiaceae, Malvaceae, Apocynacaeae, Asteraceae, Caesalpiniaceae, Convolvulaceae, Poaceae, Acanthaceae, Mimosaceae, Rubiaceae, Verbenaceae and Rhizophoraceae. The high species richness was recorded in the forest followed by homegardens and casuarina plantation, while it was lowest in the mangrove vegetation. The highest Shannon-Weaver index of diversity was recorded for the homegardens > forests > casuarina plantation > mangrove vegetation. The highest value of species evenness and Simpson's index of diversity was recorded for the forests and lowest in the casuarina monoculture. The highest total C storage up to 50 cm depth was found in forest soils > mango plantation > mangrove > agricultural land soils > casuarina monoculture soils. The study revealed that the top 30 cm layer contains about 61-69% of the total C stock. SOC content decreased vertically with increase soil depth. SOC content showed significant positive correlation with soil moisture content and soil salinity, and significant negative correlation with soil pH and bulk density. In a total of 4796 encounters, 9348 individual birds belonging to 114 species and 51 families were detected from seven habitats in two seasons during the study period. The highest species richness was observed in the monsoon season. Overall 72% bird species were common in the both seasons. The most dominating families are Accipitridae, Columbidae, Hirundinidae, Muscicapidae, Ardeidae, Corvidae, Cuculidae and Sturnidae. In the dry season the highest species richness and Shannon-Weaver diversity index was observed in the forest land. In the monsoon, season the highest species richness and Shannon-Weaver diversity index was observed in the grassland

The research findings on floral analysis of different land-use types suggest that the region is ecologically and ethno-botanically rich. The wide variety of floral and avian species indicates the high species richness and diversity in the study area. The region is prone to drastic anthropogenic land-use changes such as deforestation, conversion to agriculture, industrialization (especially, nuclear power generation), shrimp farming, construction works and chira mining. This study provides a basis for developing measures for the conservation and management of natural resources in south Konkan coast of Maharashtra. The present study conclude that land clearing, land breaking, nuclear power project installation will affect the floral and faunal biodiversity as well as carbon balance. Therefore, the study suggests that the nuclear power project should not be started on the site for future environmental health and safety, public health and security and to avoid future hazards of loss of biodiversity in the south Konkan coast of Maharashtra state.

Table of contents

List of figures:

List of tables:

Abbreviation

%	:	Percentage/ per cent
˚C	:	Degree Celsius
<	:	Less than
>	:	Greater than
1-D	:	Simpson’s index of diversity
A	:	Abundance
AAAS	:	American Association for the Advancement of Science
AES	:	Agro ecological situation
ANOVA	:	*Analysis of Variance*
BA	:	Basal area
BNHS	:	Bombay Natural History Society
BSH	:	Bright sunshine hours
C	:	Carbon
CBD	:	Convention on Biological Diversity
CBFM	:	Community-Based Forest Management
Cd	:	Concentration of dominance
CFA	:	Commonwealth Forestry Association
CFOD	:	College of Forestry, Dapoli
Cm	:	Centimeter
CO_2	:	Carbon dioxide
CV	:	Co-variance
D	:	Simpson’s index of dominance
Dbh	:	Diameter at breast height
DR BSKKV	:	Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli (India)
E	:	Species evenness
e.g.	:	For example
EDR	:	Effective detection radius
EIA	:	Environment impact assessment
ENVIS	:	Environmental Information System, India
ER	:	Encounter rate
et al.,	:	and others
EVP	:	Evaporation

F	:	Frequency
FAO	:	Food and Agriculture Organization of the United Nations
Fig.	:	Figure
FOI	:	Flowers of India
FRI	:	Forest Research Institute
FSI	:	Forest Survey of India
G	:	Gram
g (r)	:	Detection function
Gbh	:	Girth at breast height
GHG	:	Green House Gas
GPS	:	Global Positioning System
Gt	:	*Giga tones*
H’	:	Shannon Weaver index
Ha	:	Hectare
Hr	:	Hour
HSD	:	*Honestly Significant Difference*
i.e.	:	That is
IEA	:	International Energy Agency
IPCC	:	Intergovernmental Panel on Climate Change
IUCN	:	International Union for Conservation of Nature
IVI	:	Importance value index
IWPA	:	The Indian Wildlife (Protection) Act, 1972
J	:	Jaccard's similarity index
JNPP	:	Jaitapur Nuclear Power Plant
Kg	:	Kilogram
Km	:	Kilometre
Ln	:	Natural logarithm
LOI	:	Loss-on-Ignition
M	:	Meter
MCDS	:	Multiple-Covariate Distance Sampling
MEA	:	Millennium Ecosystem Assessment
Mm	:	Millimeter
MMF	:	Mangroves for the Future
ms/cm	:	*Millisiemens/centimetre*

MSL	:	Mean sea level
Mt	:	*Megatons*
MWe	:	Megawatt electric
N	:	Total number of individuals in community
NEA	:	Nuclear Energy Agency
NEERI	:	National Environmental Engineering Research Institute, Nagpur
NGO's	:	Non-governmental organizations
NH	:	National highway
NPCIL	:	Nuclear Power Corporation of India Limited
OECD	:	Organization for Economic Co-operation and Development
PDF	:	Probability density function
PET	:	Potential Evapo-transpiration
Pg	:	*Petagram*
pH	:	*Hydrogen in concentration*
Ppm	:	Parts per million
R	:	Radius
RA	:	Relative abundance
RBA	:	Relative basal area
RD	:	Relative density
RETs	:	Renewable Energies Transfer System
RF	:	Relative frequency
SE±	:	Standard error
Sob_s	:	Number of species observed
SOC	:	Soil organic carbon
SOM	:	Soil organic matter
spp.	:	Species
T	:	Tones
Viz.,	:	Namely
WS	:	Wind speed
Π	:	Pi a rational number (3.14)

1 INTRODUCTION

There is an alarming threat to life supporting systems on planet earth due to rapid declining of diversity and complexity of living organisms. The desire to stop the current effects of the biodiversity loss has been a prime incentive or challenge for ecologists. Wilson (1999) and Frank (2005) argued that we are facing the sixth extinction crisis since the beginning of the Palaeozoic era (means early geological period in which fish and insects appeared on earth). The problem is acute, especially in tropical regions, which encompasses 15 biodiversity hotspots of the world's 35 biodiversity hotspots (Williams *et al*., 2011; Frank and Habel, 2011). During last few decades, the tropical ecosystems were severely affected by the anthropogenic disturbances such as large-scale deforestation resulting in fragmentation of habitats and loss of rich biodiversity (Stoms and Estes, 1993; Baccini *et al*., 2012).

Recently climate change, biodiversity conservation, maintenance of ecosystem services, and the carbon storage and sequestration of the ecosystems have received much attention internationally (Turner *et al*., 2007; Gullison *et al*., 2007; Butchart *et al*., 2010; Strassburg *et al*., 2010; Frank and Habel, 2011). Solomon *et al*. (2009) described that the carbon dioxide emissions are responsible for irreversible climate change. Greer *et al*., (2008) and Montzka *et al*., (2011) believe that over the past century the rapid increase in greenhouse gases within the atmosphere due to combustion of fossil fuels causing unprecedented changes to the earth's climate. The experts agreed that if the warming trend continues, climate change is inevitable (National Research Council, 2002; National Centre for Atmospheric Research, 2005; Greer *et al*., 2008). At the global scale, surface temperature increased by almost 1^0C during the last century. The increase is attributed largely to anthropogenic greenhouse gas emissions (IPCC, 2007; Keenlyside and Ba, 2010; Smol, 2012). The Fourth Assessment Report of the Intergovernmental Panel on Climate

Change (IPCC) published in 2007 has labelled climate change as ‘unequivocal’ (Lemos and Rood, 2010). Land-use and forest activities are intricately linked with biogeochemical cycles. An inappropriate land-use, deforestation, biomass burning, shifting cultivation, wild fires and conversion of forest area into non-forest uses are primarily responsible for disturbing biodiversity and nutrient budgets in tropical forests.

1.1 Background

Biodiversity is the total variety of life form on earth and it is generally defined as the diversity of life in all its forms (plants, animals, fishes, invertebrates, fungi, bacteria and so on) and at all levels of organisms (genes, species, communities, ecosystems and so on) (Heywood, 1995; Hunter, 1996; Gaston, 2000; Wallace, 2007; Miller *et.al.*, 2009) and the ecological processes of which they are part (Stattersfield *et.al*., 1998). The concept of biodiversity has become an ecological paradigm and the cornerstone of conservation biology. In many areas of the world biodiversity is being reduced just by humans through changes in land cover and land-use, pollution, invasion of exotic species and possibly climate change (Kappelle *et al*., 1999). Many researchers (Parmesan and Yohe, 2003; Root *et al*., 2003) have shown evidence that climate change over the past 30 years (approximately) has produced numerous shifts in the distribution and abundance of species. About nineteen scientists assessed extinction risk for a sample region in Europe, Africa, South America, North America and Australia that covers some 20% of the earth’s terrestrial surface (Thomas *et al*., 2004). Conservationists assumed that the probability of extinction of species shows power law relationship with the geographical range. This prediction is based on climate change scenario for 2050 that at least 15-40% species of the study region and taxa will be effectively “committed to extinction” in just half a century due to habitat loss (Thomas *et al*., 2004; Rahbek and Colwell, 2011; Thomas and Williamson, 2012). The above estimate suggests the importance of urgent implementation of technologies to decrease the greenhouse gas emissions and strategies for biodiversity conservation and carbon sequestration.

1.2 Land-use and biodiversity in changing climate

Recently, it has been reported that human induced land-use changes increasingly threatened tropical forest biodiversity where species diversity and human pressures together influenced natural environment (Gibson *et al*., 2011). This changes influence species composition, structure and functions of tropical tree communities but status is still unknown and remains a gap in developing conservation plans for tropical biodiversity. There are only few, if any, terrestrial ecosystems unaffected by human activities. In some of the most bio-diverse regions of the world the land conversion is still progressing at alarming rate. Conversion of land cover or natural forest land to other land-uses for human purpose is among the major drivers of the terrestrial ecosystem transformation (Turner *et al*., 1990; Lambin *et al*., 1999 and 2003). Sala *et al*., (2000) revealed that land-use and land cover changes are so pervasive when aggregated globally. It significantly affect key aspects of the earth system functioning and directly influence biodiversity worldwide. The land-use and land cover changes contribute to local and regional climate change (Chase *et al*., 1999) and global climate change (Houghton *et al*., 1999). Habitat loss and fragmentation have major negative impacts on biodiversity. As biodiversity loss is one of the greatest challenges facing society, constituting a global problem with economic, biological, societal and ethical consequences (Van Kooten *et.al*., 2000; Harris, 2004, Sanchez-Hernandez *et al*., 2007), there is considerable interest in mapping and monitoring specific habitats of high conservation value (Turner *et al*., 1998; Pullin *et al*., 2004; Breininger *et al*., 2006; Sanchez-Hernandez *et al*., 2007).

Land-use changes are associated with changes in local and global climate, carbon cycling, loss of biodiversity and water cycling. Since the emergence and spread of the agriculture, it is often quoted that 25-50% of worlds tropical forest has been converted to other land-use, although studies are limited (Pimm and Raven, 2000; Ball, 2001; Houghton, 2003; MEA, 2005; Lewis, 2006). It is true that modern and intensive agriculture is often a threat to biodiversity. However, the biodiversity rich areas of the humid tropical forest are not suitable for intensive agriculture because of the undulating topography and poor soils (Huston, 1980; Bawa, 2007).

1.3 Distribution of the tropical forests of world and India

The tropics form a belt either side of the equator bounded by lines of latitude. Latitude 23.45°N marks the tropic of Cancer and 23.45°S marks the tropic of Capricorn (Allaby, 2006). A simple definition of tropical forest used by United Nations Food and Agriculture Organization (FAO, 2001) is to couple the definition of 'forest': 'land with a tree canopy cover of more than 10%, more than 5m (meters) tall, and covering an area of more than 0.5 ha (100m x 100m)', with the definition of tropical', i.e. between the tropics of Cancer and Capricorn. This includes a very diverse array of forest types, including moist or rain forests, mangroves, montane forests, dry forest and wooded savannah systems (Lewis, 2006).

Thomas *et al*., (2004) stated that a high proportion of the world's species reside in tropical forests, where future estimated rate of species extinction will be 4% by 2050. Tropical forests are one among the most rich and complex terrestrial ecosystems. These account one third of terrestrial primary productivity and contribute significantly to the soil carbon sink (Field *et al*., 1998; Philips *et al*., 1998; Brookshire, 2012). It has been reviewed that the tropical forests cover only 7% of earths land surface, but harbour more than half of the world's life forms (Wilson, 1988; Sagar *et al*., 2003; Pragasan and Parthasarathy, 2010). Deng *et al*., (2008) reported that the tropical forests play an important role in conserving global biodiversity and maintaining the functions of the earth's ecosystems. The tropical forest ecosystems are valuable for the intrinsic value of the species inhibiting them and provide society with functional ecosystem services, such as carbon sequestration, water cycling and scenic beauty (Daily, 1997; Koellner *et al*, 2010). Further, this is evident at a time when our knowledge of structure and functional dynamics of tropical forests is woefully inadequate.

1.4 Floral diversity and conservation

India is endowed with diverse physiographic, edaphic and climatic conditions that manifested in a great variety of forest, flora and fauna (Ashutosh *et al*., 2010). Among the 35 biodiversity hotspots of the world, India hosts the Eastern Himalayas and the Western Ghats biodiversity hotspots (Myers *et al*., 2000; Mittermeier *et al*., 2004; Das *et al*., 2006; Mehta *et al*., 2008; Hanson *et al*., 2008; Frank and Habel, 2011). The Eastern Himalayas comprises the northern part of the India, Nepal and Bhutan (Ge *et al*., 2005). The Western Ghats represents one of the best non-equatorial tropical forests (Giriraj *et al*., 2009). The Western Ghats covers 160,000-km^2 area (Das *et al*., 2006) of western part of peninsular India and is a series of hill ranges along with the narrow coastal strip running from north-south direction (Daniels *et al*., 1995) along Arabian Sea. The Western Ghats extends from Tapi (21° N) to Kanniyakumari (8° N) (Joshi and Janarthanam, 2004). Due to their proximity to the ocean and through an orographic effect it receives high rainfall. The region has tropical moist deciduous forest and as well as rain forest. The Indian portion of the Western Ghats is home to 250 species of orchids, of which 100 are endemic and 150 species of grasses. The Western Ghats also act as the gene bank of mycorrhizal fungi (13,000 spp.) as well (Behera, 2010). Recently the exploitation of land and forest resources by humans along with hunting and trapping for food and sport has led to the extinction of many species in India. Increased encroachment by human beings in natural ecosystems, land-use change, deforestation, industrialization and global warming would leads to threat to this region. Nearly about 4000 (27%) of the total plant species in India have been recorded in the Western Ghats (Nayar, 1996). This area hosts the highest number of endemic species (Pascal, 1988; Ramesh *et al*., 1991), however species richness and endemism not uniformly distributed along the Western Ghats (Pascal *et al*., 2004).

The studies in the Western Ghats have been focused on assessing biodiversity in various land-use types. The hotspot is home for variety of plant formations and has high species richness and endemism. The favourable climatic conditions with high rainfall, dry season and high humidity are responsible for high species diversity and endemism (Pascal, 1988; Ramesh *et al*., 1991; Pascal *et al*., 2004). Reddy *et al*., (2008) reviewed that the primary forest of Western Ghats and Eastern Ghats are disappearing at alarming rate due to anthropogenic activities and replaced by forest containing inferior species or their land-use patterns changed (Bahuguna,1999). Daniels *et al*., (1995) reviewed that there have been a few estimates of biodiversity losses on the Western Ghats (Nair and Daniel, 1986) and evidence of disappearance of some plant species from the region (Daniels *et al*., 1990).

1.5 Soil properties, SOC storage under changing climate

SOC investigation and analysis of soil properties are essential for soil quality assessment and C cycling predictions. This could be an important asset for the politicians, regulators, agency employees and policy makers at state and regional level planning (Amichev and Galbraith, 2004). Soil conditions can be determined by soil carbon levels and may reflect duration and intensity of past land-use management (Collard and Zammit, 2006). Land-use change and deforestation have historically been, and are currently, net sources the main greenhouse gases to the atmosphere (Schimel, 1995; Denman *et al*., 2007; Galford *et al*., 2010). Forests are influenced by natural and human causes, including harvesting, over-harvesting and degradation, large-scale occurrence of wildfires, pest and disease outbreaks, land-use change and industrialization. These disturbances generally cause forests to become net sources of CO_2 because the rate of net primary productivity is exceeded by total respiration or oxidation of plants and soil organic matter. The present role of land-use and forestry in the global carbon cycle is not only a function of present land-use, but also of past use and disturbances.

The various studies reported that the land-use conversion has been a significant impact on the global carbon cycle through changes in rate of accumulation, change in soil properties, and turnover of soil carbon, soil erosion and vegetation biomass (Richter *et al*., 1999; Fang *et al*., 2001; Lal, 2002; Zhang *et al*., 2010). Land-use changes causes perturbation of the ecosystems and depletes the soil organic carbon stocks, particularly during conversion of forest to agricultural ecosystems (Howard *et al*., 1995; Guo, 2002; Cerri *et al*., 2003; Lal, 2005; Cochran *et al.*, 2007). Similarly, the conversion of forest to agriculture in humid tropics resulted in reduction in ecosystem carbon storage due to removal of aboveground biomass and a gradual reduction in soil organic carbon (Noordwijk *et al*, 1997).

Measuring changes in soil organic carbon can assist in soil fertility management, determining levels of inputs required to maintain required soil carbon levels and active sequestration of carbon in the soil (Kamoni *et al*., 2007). It has been has stated that the term 'carbon sequestration' is used to describe any increase in SOC content resulted by a change in land management, with an assumption that the increased SOC storage increase possibility of slowing climate change (Powlson *et al*., 2011). Powlson *et al*., (2011) assumed that converting land from annual cropping to forest, grassland or perennial crops will reduce C from atmospheric CO_2 and genuinely contribute to mitigate climate change.

1.6 Faunal diversity

The humid tropical/ moist forests of the Western Ghats are most diverse, most productive and most threatened of biological communities (Daniels *et al*., 1995). The region shows high species diversity as well as high levels of endemism. Nearly 77% of the amphibians and 62% of the reptile species found here are found nowhere else. The endemic amphibian species are found in the lower altitudinal range of 0-1000 m (Daniels, 1992). The faunal diversity of the region includes 146 species of amphibians (116 or 80 % are endemic); 259 of reptiles (161 or 62 % endemic); 528 of birds (7.5 % endemic); and 140 of mammals (38 or 27 % endemic). Total number of terrestrial vertebrate species stands at 1,073 (355 or 33 % endemic), and of vascular plant species at 4,780 (2,180 or 45 % endemic).

Newton (1995) and Urfi *et al*., (2005) stated that the birds are ideal bio-indicators and useful models for studying a variety of environmental problems. Birds occur in most habitats throughout the world and are ecologically versatile to environmental change (Bibby *et al*., 1992, Demey, 2006; Urfi, 2010). Gregory and Strien (2010) reported that an extreme degree of habitat alteration has contributed to the disappearance of many bird species. The increased requirement of food production demands of the growing human population, increased over exploitation of natural resources and land-use change have led to land degradation, which in turn negatively affects bird species richness (Misana, 2003). The most of researchers argued that the avian communities have been recognized as indicators of overall biodiversity and environmental decline or recovery (Nohr and Jorgensen, 1997; Canterbury *et al*., 2000; Chase, 2000; Soini, 2006). Many studies have shown that bird community composition depends on vegetation composition (Terborgh *et al*., 1990; Wiens, 1992), however understanding of how vegetation determines bird community composition in tropical regions, is still limited (Thinh, 2006).

It has been stated that the Indian subcontinent hosts diverse avifauna with 1300 bird species (Grimmett *et al*. 1999; Ali *et al*., 2011). Many researchers stated that Indian subcontinent is known for diverse and rich bird species whose taxonomy, distribution and their general habitats characteristics are well documented in India (Jerdon, 1862-1964; Bates and Lowther, 1952; Ali and Ripley, 1983; Chettri, 2001). In a number of bird counting exercises undertaken in India, there has been a focus on endangered birds, wetland birds, and birds found in conservationally significant terrestrial habitats (Urfi *et al*., 2005). Avian studies on the southern Western Ghats have been sporadic (Praveen and Nameer, 2009). However, there appears to be no studies on bird diversity analysis in the Konkan coast of Western Ghats.

1.7 Biodiversity loss and conservation measures

There are number of well-known major threats to the future of biodiversity, such as habitat conversion, environmental toxification, climate change, biological invasions and direct overexploitation of organisms, among others. The dramatic biodiversity loss has been recognized in the past 100 years (Walker and Steffen, 1996), which has raised numerous concerns, including the possibility that the function of the earth's ecosystem might be threatened by biodiversity loss (Ehrlich and Ehrlich, 1981; Schulze and Mooney, 1993).

Humans are now behaving in ways reminiscent of a spoiled teenager. Ehrlich and Pringle (2008) said that narcissistic and presupposing our own immortality, humans mistreat the ecosystems that produced us and support us, mindless of the consequences. The state of the biodiversity today is a reflection of that abuse, but the reflection is hazy because humans know neither the total number of populations or species nor how many have gone extinct. Many researchers opinioned that land-use change may deteriorate ecosystems, eliminate species locally, decline natural habitats and ecosystem function, thus collectively it affecting biodiversity and provision of ecosystem services (Priess *et al*., 2007; Turner *et al*., 2007; Ricketts *et al*., 2004 and 2008; Steffan-Dewenter and Westphal, 2008; Lavorel *et al*., 2007; Martinez *et al*., 2009).

The rapid loss of biodiversity in tropical forests is recognized as one of the serious environmental problems all over the world (Hare *et al*., 1997; Pragasan and Parthasarathy, 2010). Bawa *et al*., (2007) stated that the biodiversity of the Western Ghats has been under threat due to habitat loss and deforestation. Some biologist suggest that continuing biodiversity and ecosystem services loss urgently requires techniques to rapidly assess and monitor in biodiversity and ecosystem services (Balvanera *et al*., 2001; Menon and Bawa, 1997; Margules and Pressy, 2000; Ramesh *et al*., 1997; Stork and Samays, 1995; Krishnaswamy *et al*., 2009. The biodiversity conservation efforts at global scale have potential to deliver ecosystem services, but the benefits of the biodiversity conservation and ecosystem services cannot be identified unless the ecosystem services can be quantified, valued and their area of production is mapped (Naidoo *et al*., 2008). The data on biomass and forest productivity are scarce in many important tropical forests. Many researchers reviewed the annual loss of millions of hectares of tropical forests and changes within intact forests over recent decades (Lewis, 2006). It is stated that the rapid conversion and destruction of tropical forest has led to an unprecedented decline in biodiversity and disruption of ecosystem services (Dierick and Holscher, 2009; Pragasan and Parthasarathy, 2010). Lamb *et al*., (2005) stated that the historical losses in tropical forest cover and biodiversity is associated with current rate of deforestation.

1.8 Energy scenario, crises and options in India

In Indian context, the energy security and sustainable development are the prime issues to ensure countries economic growth and human development (Atmanand *et al*., 2009). The energy is the main driver for any economy to grow with rapid pace. Many developing countries like India are under pressure to mitigate greenhouse gas emissions. India is the largest democracy with an estimated population of about 1.04 billion and is on a road to rapid economic growth (Grover and Chandra, 2006); and energy consumption growth rate is with 8-10% (Tashimo and Matsui, 2008). Near about 72 million households in rural India do not have access to electricity and primarily depend on traditional sources of energy (IEA, 2007; Urban *et al*., 2009). With a rapid increase in economic activities and population the electrical energy requirement in India will reach an estimated value of 5081 billion kWh in the year 2045 (Mallah and Bansal, 2010). In spite of the rapid electrical capacity growth, there is huge gap between demand and supply.

A number of renewable energy technologies (RETs) like wind energy, solar energy, biogas and hydro energy are established in India. The country ranks fourth in the world in terms of wind energy. Bhattacharya and Jana (2009) stated that India hosts the world's largest "small scale gasifier programme" and second largest biogas program. In spite of many successes the growth of renewable energy is limited. As per as the projected demand and future source of energy is concern the Government of India developing a strategy for growth of electricity generation from both clean coal and nuclear technologies.

IEA (2008) as well as Lee and Chiu (2010) suggested that nuclear energy is a substitute source of secure, cheap and non-GHG-emitting energy supply. It offers opportunities for diversifying energy supply and ensuring long term security (Bertel, 2005). Wolde-Rufael and Menyah (2010) reviewed that many researchers believe nuclear energy is one of the solution to global warming and energy security as it a virtually carbon free source of energy (Elliot, 2007; Fergusan, 2007). The econometric evidence by Menyah and Wolde-Rufael (2010) suggest that nuclear energy consumption can help to mitigate CO_2 emissions.

On other hand Lee *et al*., (2007) reviewed in his article that even nuclear energy able to make considerable contribution to solving the global environmental problems; its environmental burden is still controversial because of the possible danger of radioactive waste and nuclear accidents (Williams, 2001). NEA (2002) opinioned that in OECD countries the possible danger of nuclear energy are largely recognized more than its strengths in coping with climate changes. Despite its controversial reputation, Jain (2004), Whitman (2007) and Abu-Khader (2009) in their publication described nuclear energy as one of the options providing safe, environmentally benign, reliable and economically competitive energy with coal-thermal energy and implied that it will emerge as one of the cheapest sources of electricity.

The history of nuclear power in India is not new. The Nuclear power is the fourth largest source of electricity in India after thermal, hydro and renewable source of electricity. The country has 17 nuclear power plants in operation and other 12 plants planned to generate energy in coming decades (Mallah and Bansal, (2009 and 2010); Mallah, 2011). Now India is the threshold of large expansion of its nuclear power programme. Further expansion of nuclear power generation capacity to over 20,000 MWe by 2020 is planned (Koley *et al*., 2006).

The construction of numerous nuclear power plant and uranium mines across the country could have significant environmental, health and social impact (Ramana and Rao, 2010). However, a case study on evaluation and assessment of 25 years radioactivity data at Tarapur Nuclear Power plant site indicated that there is no accumulation of radionuclides in either the terrestrial or aquatic environments (Rao *et al*., 2010). There is still controversy among many scientists regarding the economics of the nuclear energy. Ramana (2005) studied energy economics in India and his result showed that for realistic of discount rate, electricity from coal based thermal power stations is cheaper than nuclear.

1.9 Proposed site of Jaitapur Nuclear Power Plant (JNPP)

The Konkan coastal belt of Maharashtra state as previously stated is an area assumed to have high biodiversity where most of the agricultural fields are located around homesteads settlements. The agriculture system as in many rural areas in India is basically slash-and-burn agriculture. The tree lopping and harvesting shrubs, herbaceous and grass vegetation from forest is common practice related with the slash-and-burn. The wood from forest is good source of energy or fossil fuel. Electricity shortage is a major problem in the Maharashtra state, where in some rural area power outage continue for more than sixteen hours, and the Government is constructing a number of electricity generation projects to meet the power deficit. Maharashtra state has proposed to use the Konkan coast as a site for both hydroelectric projects and nuclear power plants.

The Nuclear Power Corporation of India Limited (NPCIL) with AREVA, France is establishing the biggest ever (10,000 MWe capacity) nuclear power plant at Jaitapur in Maharashtra State. The central Indian government has granted license to construct light-water reactors at Jaitapur. The project has been approved by the High Court stating that *"The nuclear power project stands higher footing than biodiversity and public opposition as it is going to supply power to millions of peoples"*. The project is part of India's national program for the development of 40,000 megawatts of nuclear power capacity, by the year 2020.

The Government of India and Maharashtra state government are the planners in relation to national level energy station projects. Accordingly Jaitapur is one of the four possible sites suggested for 10000MWe nuclear power plants by a national level survey in 2005. Jaitapur of Rajapur Tahsil in the Maharashtra state is a typical Konkan village with no polluting industry, mainly because of the remoteness of these areas. People depend mainly on fishing and agriculture for their livelihoods. The area also has good mangrove vegetation that is also responsible for the rich fishery resources. Mango orchards with internationally famous ‘Ratnagiri Alphanso’ variety are common.

1.10 Objectives of the thesis

The quantitative and qualitative information on land-use, C storage, soil properties, vegetation and avifaunal change is highly limited in tropical moist deciduous forests of the central Konkan coast region. The study area persists as fragments and there is special interest in understanding the land-use structure, C storage and soil properties, floristic and faunistic composition. Further, little information is available on soil properties and C storage; structure, composition, diversity and species richness of vegetation; faunal diversity, richness and distribution; ecosystem services functioning and also landscape processes. Therefore, the present study has been undertaken with three major objectives:

1. To determine the floristic structure, composition, species richness and species diversity in tropical moist deciduous forest of the South Konkan Coast region of Maharashtra.
2. To determine Soil C storage under different land-use types in south Konkan coast of Maharashtra (India)
3. To determine the seasonal structure, composition, species richness and species diversity of avifauna at different land-use types in the South Konkan Coast of Maharashtra state.
4. To contribute land-use planning and management knowledge for high biodiversity areas with emphasis on forest nature and ecology linked to soils C storage.

2 DESCRIPTION OF THE STUDY SITE

India is one of the 17 mega-diverse countries of the world. Despite a high population (17% of world's population) and biotic pressure (18% of the world's cattle) and pressure of economic development, India is one of the few developing countries where the forest and tree cover continues to increase (Krishna, 2008-2009; CFA, 2010). Being a part of tropical forest zone of the world India has 69.09 million ha (21.02% of total geographical area), of which 77.94% are tropical moist deciduous forest, tropical dry deciduous forest, tropical wet evergreen forest and tropical thorn forest (FSI, 2009).

Maharashtra is the third largest state by area in India, and has 16.5% forest cover (see Table: 2.1) of the total geographical area of the state (FSI, 2009). Geographically, historically and politically the state has been divided into five main regions; Vidharbha, Marathwada, Khandesh and northern Maharashtra, Western Maharashtra and Konkan region. The state forest is grouped in to six major forest types (according to Champion and Seth, 1968) tropical dry deciduous forest (57.4%), tropical moist deciduous forest (29.8%), tropical semi-evergreen forest (7.7%), tropical broadleaved hill forest (1.5%), tropical thorn forest (1.0%) and littoral and swamp forest, mangrove forest (0.1%).

The western coastal narrow terrain belt of the Western Ghats range (Sahyadri), popularly known as 'the Konkan Coast', lies along the Arabian Sea, and in the Maharashtra state, and it stretches 720 km in length from Palghar (Thane district) to Phonda (Sindhudurg district). Being a part of the Western Ghats the Konkan coast is recognized as a biodiversity Hotspot area (Arun, 2008; Panigrahy *et al*., 2010). This region covers Mumbai, Mumbai suburban, Thane, Raigad, Ratnagiri and Sindhudurg districts.

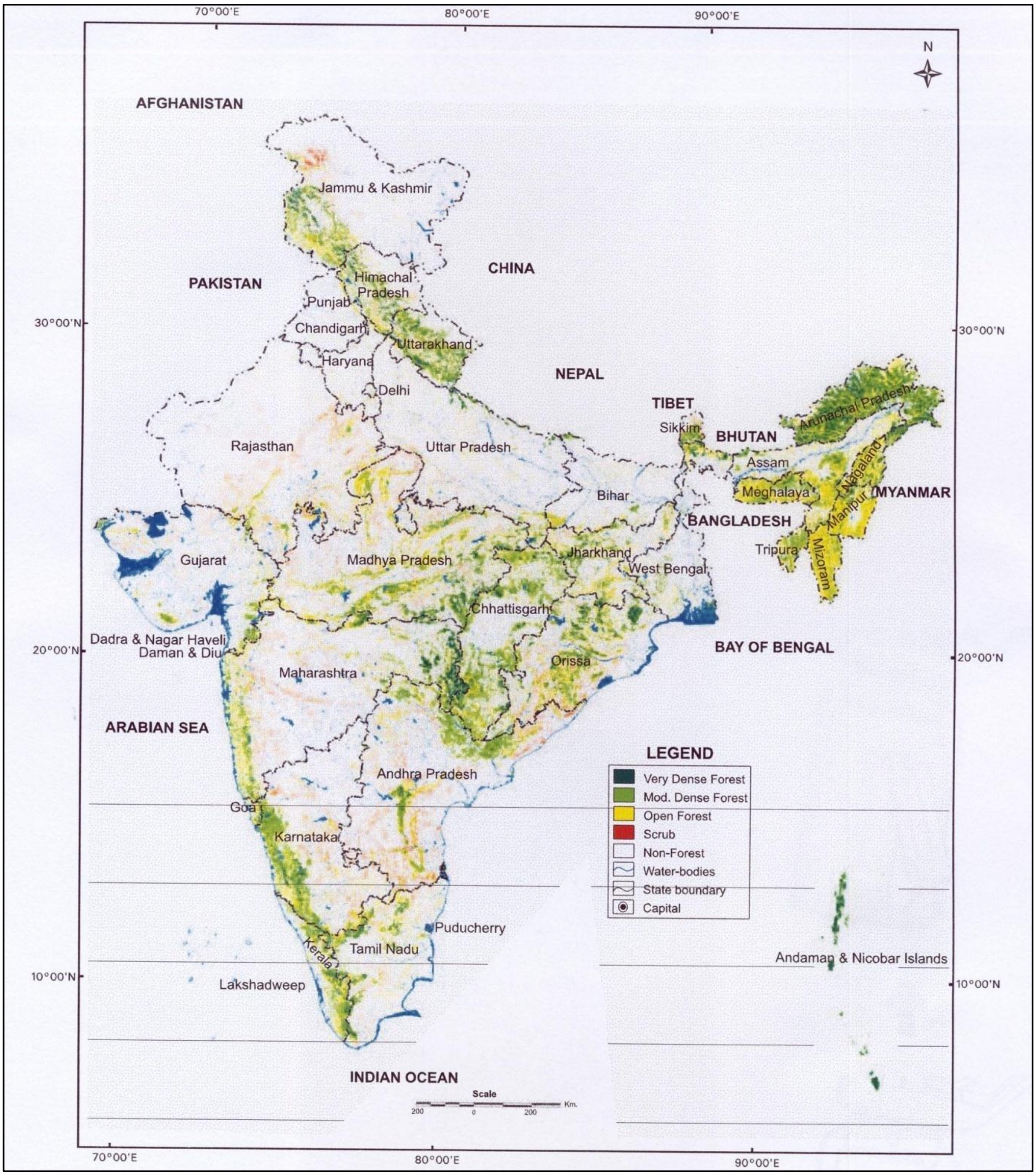


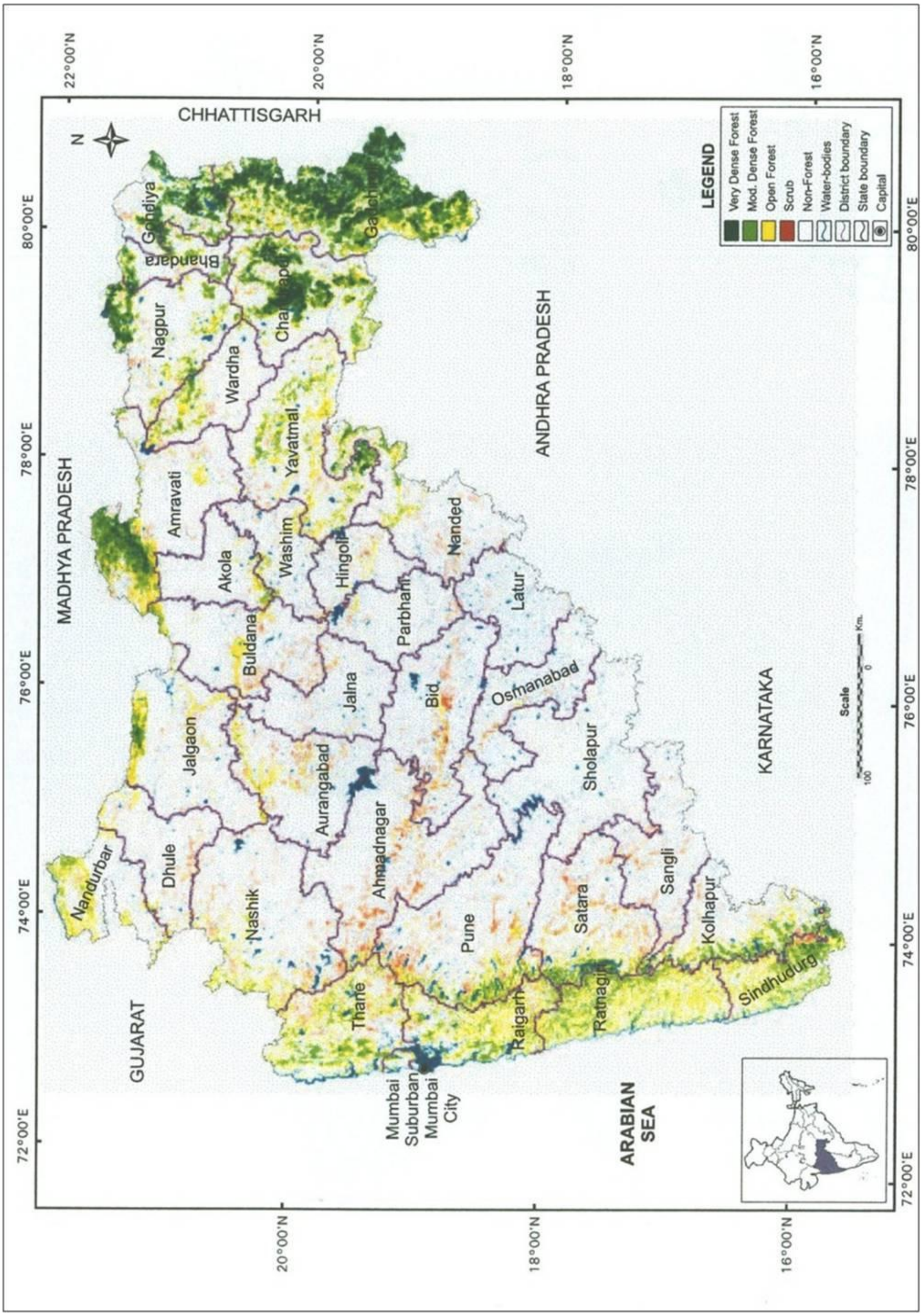
Fig. 2.1: Forest cover map of India showing forest cover (FSI, 2009)

Table 2.1: Status of forest cover of India, Maharashtra state and Ratnagiri district (Source: FSI, 2009)

	India		Maharashtra state		Ratnagiri district	
Class	Area (km^2)	% of geographical area	Area (km^2)	% of geographical area	Area (km^2)	% of geographical area
Forest cover						
Very dense forest	83,510	2.54	8,739	2.84	33	0.40
Moderately dense forest	319,012	9.71	20.834	6.77	1911	23.28
Open forest	288,377	8.77	21,077	6.85	2255	27.48
Total forest cover*	690,899	21.02	50,650	16.46	4199	51.16
Non-forest area						
Scrub	41,525	1.26	4,157	1.35	2	0.024
Non-forest area**	2,554,839	77.72	202,256	65.73	4007	48.82
Total geographical area	3,287,263	100.00	307,713	100.00	8208	100.00

* Includes 4,639 km2 under mangrove forest and ** Excludes scrubs and includes water bodies

Fig. 2.2: Forest cover map of the Maharashtra state (FSI, 2009)



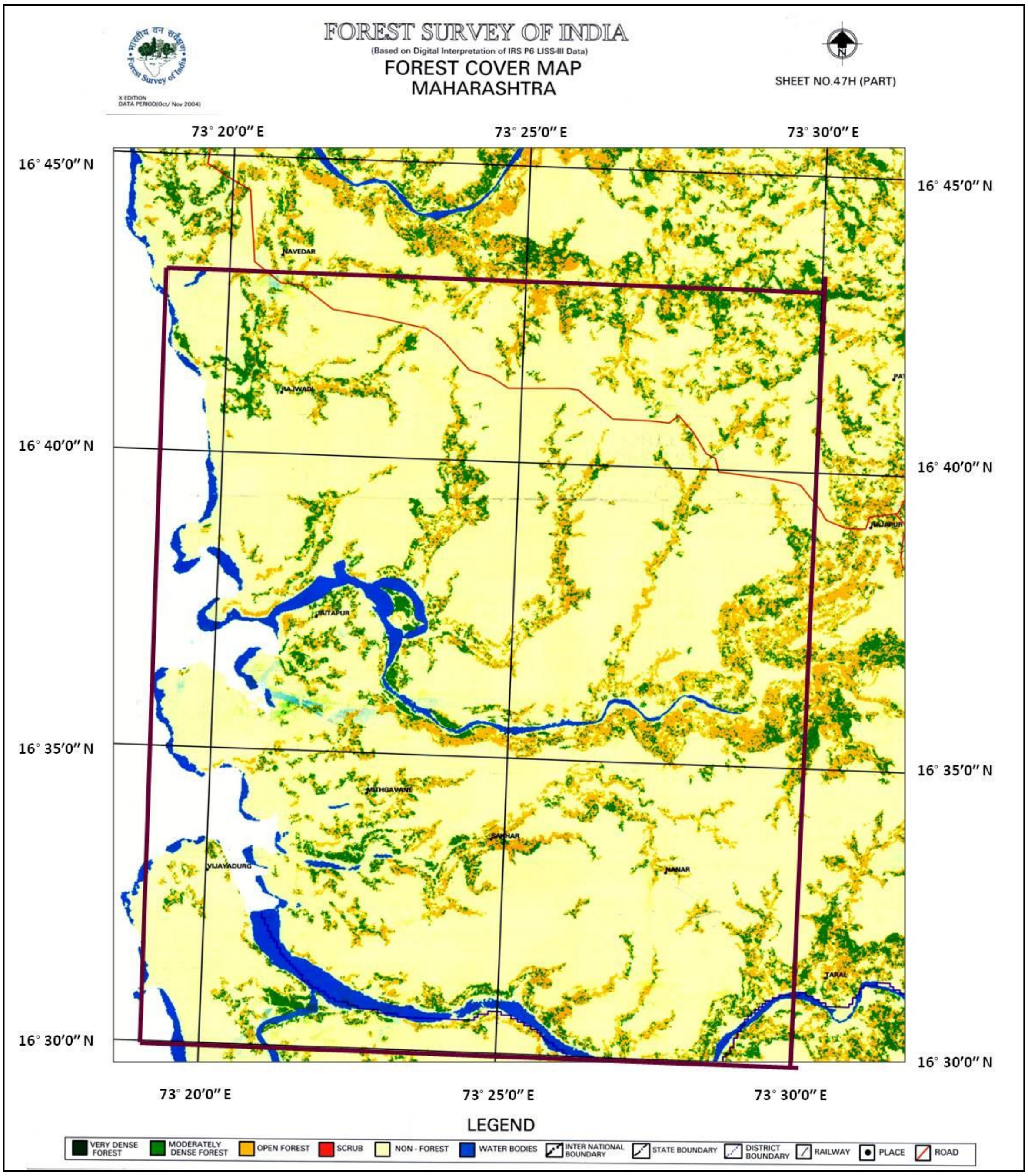


Fig. 2.3: Forest cover map of the study site (FSI, based on digital interpretation of IRS P6 LISS- Data, Part of sheet number 47H)

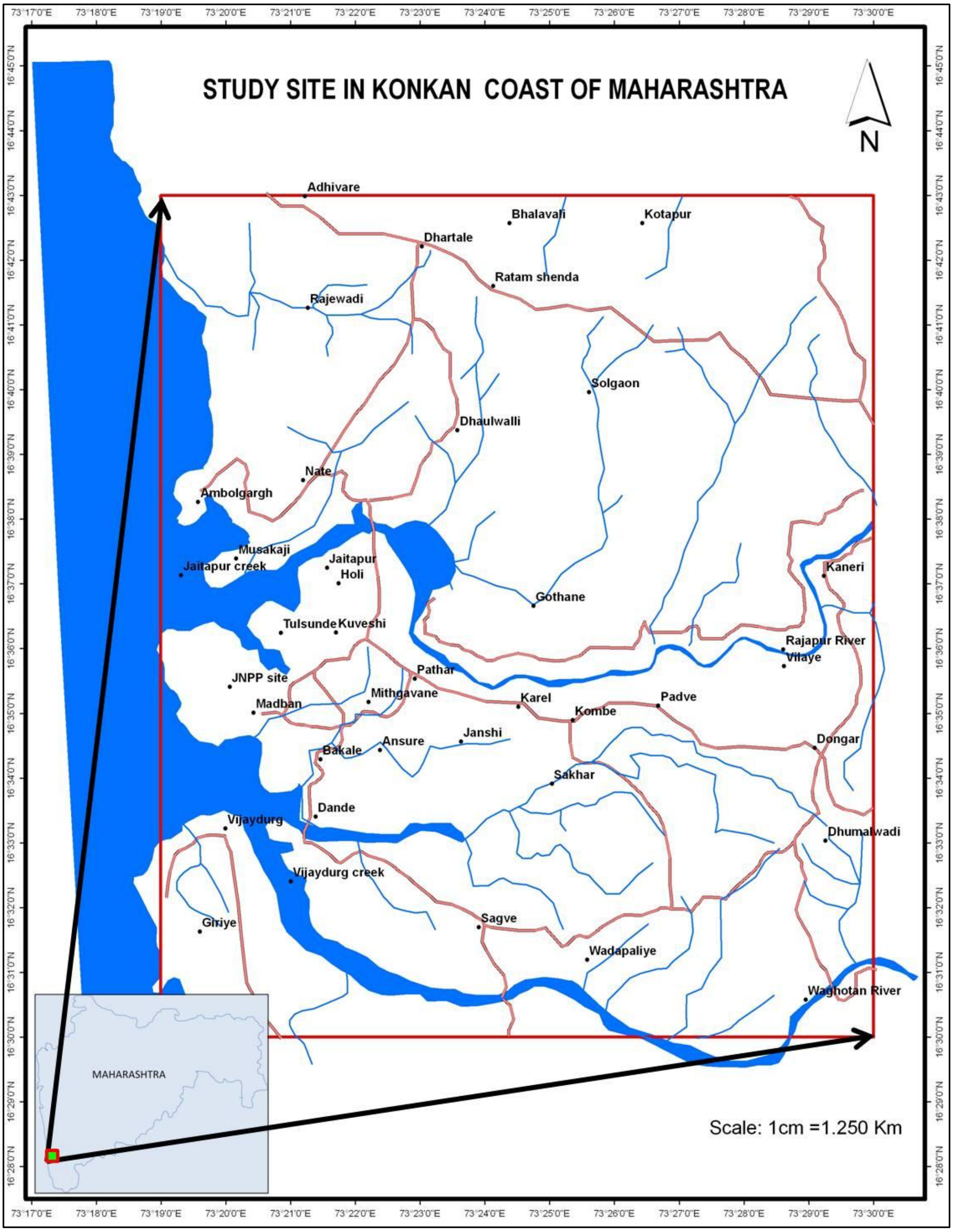


Fig. 2.4: Map showing the location of the study site in the Konkan coast of Maharashtra state.

Geographical coordinates: 16° 30' to 16° 43' N latitudes and 73° 19' to 73° 30' E longitudes

Ratnagiri is the second largest district of the state in respect to forest cover, which has 51.2% forest cover of states geographical area (see Table: 2.1) (FSI, 2009). Being a coastal district the climate is humid tropical and the forest types (Table 2.2) occurring in the region are grouped in to 5 major types (Champion and Seth, 1968; Takalkar, 2002)

Table 2.2: Major forest types of the study area

Sr. no.	**Code**	**Forest type**
1.	3B/C2	Southern moist mixed deciduous forest
2.	8A/C2	Western sub-tropical hill forest
3.	4E/RS1	Tropical riparian fringing forest
4.	4B/TS1	Tidal swamp forest and mangrove scrub
5.	4B/TS2	Tidal swamp and mangrove forest

2.1 Geographical location and physiographic characteristics of the study site

The study area (Geographical coordinates: 16° 30' to 16° 43' N latitudes and 73° 19' to 73° 30' E longitudes) is situated on "the Konkan coast" of the Western Ghats. Ground elevations within the site range from 0 to 225 meter above mean sea level. It covers an area approximately 460 km^2 (19.5 km east west and 25.5 km north south) land excluding water bodies in Rajapur Taluka of Ratnagiri district in the Maharashtra state (Fig. 2.1, to 2.4)

2.2 Study site selection and background

Recently the Konkan coastal strip is in the news for many reasons, such as natural disasters like cyclones, tsunamis, earthquakes, deforestation and establishment of power generation projects. The narrow coastal strip is targeted for power generation. There are both around 12 different thermal and nuclear power stations (about 16,606 MWe) that in functioning, proposed or in different stages of construction across this narrow coastal strip

(Table. 2.3 and Fig. 2.5) About 938.03 ha (692.3 ha for project and 245.7 ha for the residential complex) area is required for the proposed super mega nuclear power plant of 10,000 MWe capacity at Jaitapur (Nuclear Power Corporation of India Limited, 2006-07; Menon, 2010). Arun (2008) described this site as ecologically sensitive area with rich biodiversity and argued that the project is against the environment, people and their livelihoods in the name of development. Arun (2008) reviewed that the Konkan region harbours diverse and sensitive ecosystems ranging from tropical evergreen forest to estuaries, mangroves and even corals.

Table 2.3: List of the thermal and nuclear power stations

Sr.	**Project/station**	**Location**	**District**	**Capacity MW**
1.	Finolex Industries	Ranapar	Ratnagiri	43
2.	Indo-Bharat Power Konkan Ltd.	Waral, Mashala	Raigad	450
3.	Indo-Bharat Power Konkan Ltd.	Dhakar, Ajagaon	Sindhidurg	1050
4.	JSW Energy	Jaigad	Ratnagiri	1200
5.	Maharashtra Energy	Shahapur	Thane	4000
6.	NTPC	Dabhol	Ratnagiri	2100
7.	Pioneer Gas Power	Bhagad	Raigad	115
8.	Relience Infra	Dahanu	Mumbai	1200
9.	Tata Power Company	Trombay	Mumbai	250
10.	Urban Energy Generation	Vangani, Tarfe Panvel	Raigad	2100
11.	Urban Energy Generation	Kondagaon, Roha	Raigad	2100
12.	Urban Energy Generation	Dronagiri	Navi Mumbai	2000
13.	Jaitapur Nuclear Power	Madban, Jaitapur	Ratnagiri	10,000
Total generation capacity from 13 project along Konkan coast				**26608**

Fig. 2.5

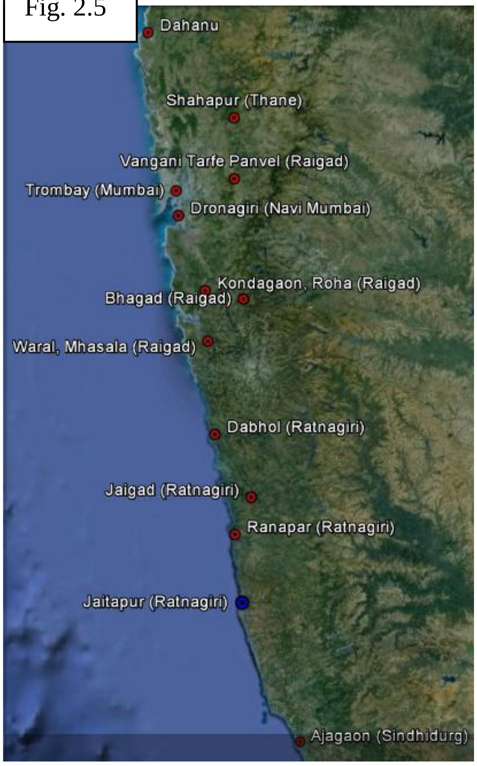


Fig. 2.5: Map showing location of the thermal and nuclear power stations along Konkan coast of Maharashtra.

The Konkan region presents a microcosm of the most imposing and extremely threatened topographic, floristic and faunistic features of the globally recognized Western Ghats biodiversity hotspot (Gaonkar, 1996) and is among area with highest conservation value (Khoshoo, 1994). The National Environmental Engineering Research Institute (NEERI, 2010) submitted the comprehensive Environment Impact Assessment (EIA) report for Proposed Nuclear Power Project at Jaitapur but Konkan Bachav Samiti and many other NGO'S argued that the report is unsatisfactory and unscientific document (The Hindu, 2010). The assessment of biodiversity at that site was carried out by college of Forestry, Dr. BSKKV, Dapoli. The NEERI declared that the proposed site of Jaitapur Nuclear Power Plant and surrounding area is rich in marine and terrestrial biodiversity and claimed that there is no impact on terrestrial and marine environment or life as radioactive releases from the project are "expected to be insignificant".

The topography of the area comprises of undulating laterite terrain with steep edges towards the sea at several places. The laterite tops often does not allow the growth of trees and grasslands are the climax vegetation. This is often mistaken for barren land because of the absence of tall trees, and this is one of the reasons why more and more industries are being proposed in this area. The tremendous scale at which these plants are proposed within a small stretch of highly ecologically sensitive area would appear to have little concern for the immediate environment.

I selected the study site to assess the variation in floral and faunal structure, composition and diversity under different land-uses. A very little ecological work beyond description has been carried out in Konkan coast and I am here to investigate vegetation and avifaunal structure, composition, distribution and diversity. There are many special interest of habitat, which has a big environmental conservation values. It is crucial need to understand the ecosystem services and biodiversity in order to minimize future environmental impacts on human and entire ecosystems.

The EIA report by NEERI declared that site (938.03 ha) selected for Jitapur Nuclear Power Plant is a rocky, waste and barren land with no have habitation and vegetation, and conversion of this land will not have any impact on flora, fauna, human livelihood and consequently on entire ecology. But topographical map, forest cover map shows that the proposed area and surrounding area is a mixture of agriculture land, forest land, mangrove forest, grassland, Kevda beaches, the casuarina plantations, commercial mango plantations and of course human settlement (Fig. 2.6). I made the preliminary recognizance survey of the area and agreed with the opinion of Arun (2008) that the area is ecologically sensitive.

2.3 Sampling framework

The base map of the study area was prepared from survey of India toposheet and forest cover map sheet number 47H on 1:50000 scale. 1km x 1km square grids were laid down over covering a total area approximately 460 km^2 and identified different land-use types at each grid intercept point location such as agricultural land, forest land, mangrove forest, homestead gardens, casuarina plantations, grasslands and mango plantations. The soil, vegetation, avifaunal and soil sampling were carried out at randomly selected points all over the study area under different land-use types using base map and GPS unit. The method used to selection of random points followed by Panse and Sukhatme (1985). The detail on sampling method, data collection and data analysis protocols for soil, vegetation and avifauna is given in respective chapters.

Fig. 2.6: Showing different land-use types in the study area

Agricultural land (Rice crop)

Casuarina plantations

Forest land at coast side

Forest land at east side of study area

Grass land in the monsoon season

Grass land in the dry season

Homestead gardens (Monsoon season)

Homestead gardens (Dry season)

Mango plantations

Mangrove

Kevda plantations

Mangrove habitat for Flying foxes

2.4 Climate of the study area

In general, the study area experiences tropical monsoon, warm, humid or maritime climate throughout the year, with plentiful and irregular rainfall during the monsoon, oppressive weather in the hot months, and high humidity throughout the year. Climatic conditions in the study are strongly influenced by its geographical conditions. The area consist three major seasons viz., summer, rainy, and winter. Summer season from March to May followed by south-west monsoon season from June to September, October and

November form the post monsoon or the retreating monsoon season. Thus area shows two distinct seasons, the rainy season from June to November and remaining six months considered as the summer (dry) season. The period from December to February is the winter season. Meteorological data from the Agricultural University at Dapoli are shown in Fig. 2.7., 2.8., 2.9, and 2.10. This had been taken as representative of the conditions prevailing in the Ratnagiri district.

The weather data 1999-2010 shows that the average annual rainfall in the district is 3531 mm. However, Fig. 2.7 clearly shows that there is variation in annual rainfall and rainy days. Generally, the monsoon rain arrives at the Konkan coast in the first week of the June. The highest amount rainfall occurs in July and nearly 91 per cent of rainfall is occurs in four months i.e., June to September (Fig. 2.7). The concentration of rainfall during four months coupled with lateritic soils has imposed restrictions on availability of irrigation facilities and drinking water in summer season. There are some post monsoons or the retreating rains in October and November. Number of rainy days varies from 83 to 113 days (Fig. 2.8). The climate of the area is humid and the relative humidity seldom goes below 50%. The relative humidity ranges from 64.4 to 94.9 (Fig. 2.9). Also the mean annual bright sunshine hours measurements range from 6.3 hours day $^{-1}$ to 7.0 hours $^{-1}$ (Fig. 2.9).

Being a coastal zone, variation in the temperature during the day and throughout the season is not large. The mean annual temperature of the study area is about 24.9°C, which begins to increase in March to May. Maximum temperature at the coast rarely goes beyond 38.5°C and in the interior; it seldom crosses 40°C owing to proximity to the sea. The minimum and maximum temperatures vary between 17.0°C to 31.6°C (Fig. 2.8).

The winds are very strong and blow from west or south west during the monsoon period. The average annual wind speed ranges from 4.1 to 5.2 km/hour (Fig. 2.10). In the recent years the Konkan coast is victim of the strong and most devastating cyclones. The winds are generally moderate during the period of October to December but sometimes strong and blow from directions between North East and South East to South West and North West. In next three months from January to March, wind continues to be moderate and predominantly blows from North to South and East to West directions. In April, there is slight strengthening of wind with variable directions. After May, there is further strengthening of wind and blows from South West to North East and North West to South East. The data in Fig. 2.10 shows that the mean monthly potential Evapo-transpiration (PET) ranges from 3.9 mm to 5.0 mm.

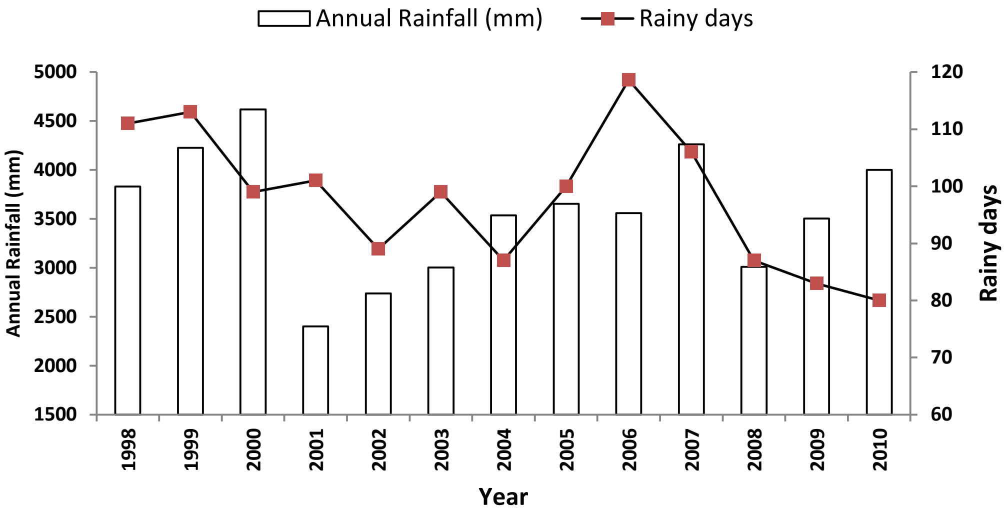


Fig. 2.7: Distribution of annual rainfall (mm) and rainy days at study site (1998-2010)

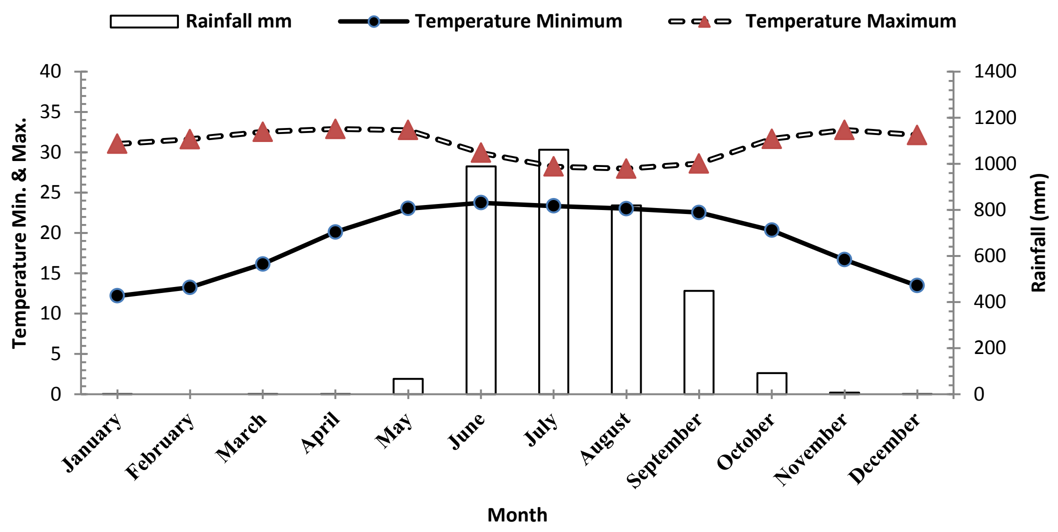


Fig. 2.8: Patterns in monthly distribution of rainfall (mm), the maximum and minimum temperatures (°C) at study site, based on 12 years of data (1998-2010)

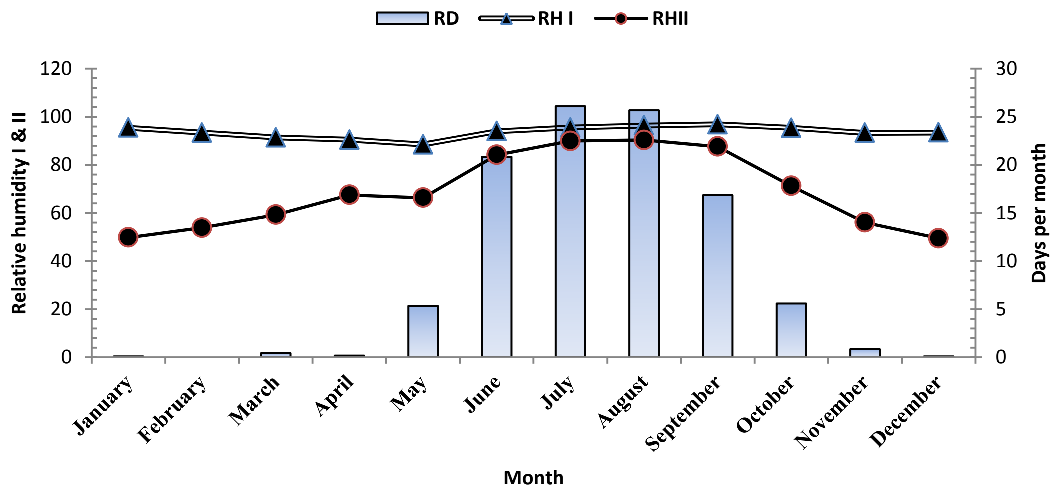


Fig. 2.9: Patterns in monthly distribution of rainy days and relative humidity I and II at study site, based on 13 years of data (1998-2010)

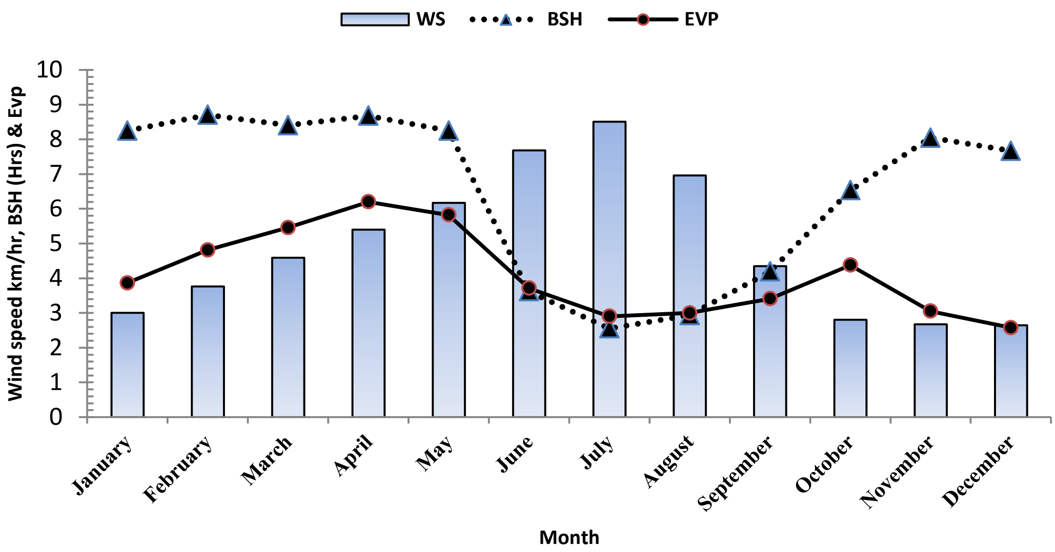


Fig. 2.10: Patterns in monthly distribution of wind speed (km/hr), bright sunshine hours per days and potential evaporation at study site, based on 13 years of data (1998-2010)

2.5 Geology

Considering the physical features, the area has three distinct geological formations as hilly area of Sahyadri and its offshoots Plateau surface and irregularly indented submergent type of coastline. The study area is endowed with variety of rocks of different ages. The rocks in and around the study area belonging to different lithostratigraphic units namely Precambrian crystalline (Deccan trap basalt), the Deccan volcanic (represented by ballistic flows capped by laterite), Consolidated sediments (beach rocks) and unconsolidated sediments (recent sandstone along the coast) (Anon, 1976; Takalkar, 2002).

The coastal bays of Vijaydurg, Rajapur (Jaitapur), Ambolgarh and Wada Vetye in the study area are characterized by an arcuate shape, sandy beaches, mangrove vegetation and partially protected from wind (Gujar *et al*., 2009). The Rajapur River and Waghotan River are the two important rivers in the area and the extensive area between these two rivers is characterized Deccan trap basalt, quartzite, Deccan volcanic capped with laterite and sandstones. The estuaries of these rivers are almost filled with recent sediments (sands) along coast. Krishnan and Roy (1945), Roy (1958), Chari *et al*., (1975), Siddiquie *et al*., (1979), Gujar *et al*., (1988, 2004, 2009 and 2010) reviewed that the onshore and offshore occurrence of heavy mineral placers enriched in Ilmenite and magnetite along the Konkan coast, central west coast of India has been known for a long time.

The black sands on the beaches of the Ratnagiri district, Konkan coast are derived from the weathering of Deccan Trap Basalts (Roy, 1958; Krishnan and Roy, 1945). Earlier studies on detritus heavy mineral assemblage concluded that near shore sediments of the study site are diverse and polycyclic in nature. The assemblage comprised of garnet and kyanite along with other accessory minerals like epidote, olivine and rutile (Gujar, 2009).

2.6 Soils

Knowledge of the soil physical and chemical properties in the study area is limited. The predominant soils in the area are lateritic, which vary in colour from bright red to brownish red, owing to the preponderance of hydrated iron oxides. They are always acidic and fairly well supplied with nitrogen and organic matter. They are porous, non-retentive of moisture and are found all over the area.

Soils were grouped into three class's viz., lateritic, Coastal Alluviums and Salt lands. Lateritic soils, which are predominant in the district, vary in colour from bright red to brownish red owing to the preponderance of hydrated iron oxides and are suitable for rice cultivation. These soils have various names that are identified with their location. Those situated at higher elevations are usually known as mal, while soils those at slightly lower elevations are called kuryat soils. Varkas Soils are situated on the slopes of the hills and are partly eroded, yellowish red and poor in fertility. Further, they are shallow in depth and coarse in texture. Cashew nut and mangos grows in plenty in this area. On the mountain tops are the perennial forests, here the soils are rich in humus as they are protected from erosion. Homestead Garden Soils are usually of mixed origin, varying from yellow-red to brown, and are located in the basins at the bottom of the hill ranges. These soils are light, easily workable, well drained and fertile that is why crops like Areca nut and Coconut often seen growing well in homestead gardens.

The coastal strips in study area are covered with Coastal Alluvium soils of recent deposits and are locally known as *pulanwat.* They are deep sandy loams, and cocoanut gardens and areca nut gardens thrive well in them. Paddy is also taken here to some extent. Due to the inundation of the sea, a part of the coastal soils has become salty. They are locally known by several names like *khar, khajan, kharvat,* etc.

2.7 Agro-ecological situation

Ratnagiri district belongs to coastal agro-ecological zone of India. The study area is heterogeneous in respect of topography, rainfall, temperature, soils, agricultural conditions and resource endowment. There are some variations in land-use pattern, dominant crops, irrigation facilities available, fishing activity, forestry, etc. Therefore, for planning, classifying the area into more homogeneous agro ecological zones is worthwhile for identifying common resource base and common needs. Ratnagiri district is divided into six agro-ecological zones as AES-I to AES-VI. The study area belongs to South Coastal Zone (AES- II), which covers representative villages like Nate, Sakhari Nate, Sagve, Mithgavane, Madban and Jaitapur. Principle agricultural crop cultivated in the study area is paddy.

Paddy is grown extensively during rainy season (June-October) Pulse crops like horsegram, blackgram and small-fruited dolichos are also taken in this season. Most of the agricultural fields remain uncultivated during summer season due to unavailability of water for irrigation. Being proximity to the sea and terrain mountain area, it is not possible to store water. However, the slopes of the Terrain Mountains are covered with dense to open forest vegetation. The plains of the coast are covered with grass and shrub vegetation.

Being part of Western Ghats biodiversity hotspot, it often has high biodiversity conservation value.

2.8 Land-use structure and habitat diversity

The landscape matrix in which the study area immersed is composed of predominantly of seven land-use types: (1) agricultural land, (2) commercial mango plantations, (3) coastal casuarina plantations, (4) grasslands (5) mangrove forest, (6) homegardens and (7) interspersed by small to large forest fragments (Fig. 2.4). However, the information on the composition, structure, distribution pattern and diversity of these plants in the pastureland, the mangrove forest and the forest fragments is scarce.

Different vegetation types occur in the study area. According to Champion and Seth (1968), the forests of study area are classified in to four major forest types' viz., (1) Southern moist mixed tropical deciduous forest ($3B/C_2$) and (2) Tidal swamp forest, Mangrove forest ($4B/TS_2$). The forest in Lanja Forest Range of Rajapur Tahsil occurs on 295.3 ha area in 37 blocks, which is the only forest area under Government forest department jurisdiction, and out of this forest area 133.66 ha forest occur in Holi, Janshi, Juve-Jaitapur, Ansure, Devache Gothane, Madban, Mithgavane, Dhaulwalli and Pangari Khurd villages (Takalkar, 2002) of the study area. The forest is grouped as unclassified forest. Thus as per above documentary evidences of forest department 45.26% of total government forest of Lanja Forest Range falls in the study area. Remaining forest area of the study area is private owned forest. The forest occurs in patches and mostly dense forest seen on hill slopes. The forest ecosystem is rich in endemic woody trees, shrubs, herbs and liana species (Takalkar, 2002).

The study area has approximately 30 km coast boundary and harbours variety of fish species. The small and large-scale fishing is done in the study area. Major fishing areas are Jaitapur, Ambolgadh, Nate, Madban, Vijaydurg bays of Arabian Sea, respective creeks, Rajapur River and Waghotan River. The most commonly occurring fish species are *Aetomylaeus maculates*, *Megalops cyprinoides*, *Chirocentrus dorab*, *Harpodon nehereus*, *Plotosus anguillaris*, *Osteogeneiosus militaris*, *Muraenosox talabonoides, Sillago sihama*, *Atropus atropus, Chorinemus lysan, Lutianus roseus, Rhabdosargus sarha, Pampus orgentus*, and *Cybium commersoni* etc

Beside this every village in the studied area is electrified. Modes of transportation in study area are by road and sea. Nevertheless, most of the transport is by road, and very limited by sea. The nearest railways station is at Rajapur. Newly constructed coastal highway NH-153 passes through the study area, which is helping in development of economic and social situation of the region.

2.9 Threats to Konkan coast over time

The Konkan region is blessed with spectacular natural beauty along with rich biodiversity as well as agro-biodiversity. The Konkan region harbours diverse and sensitive ecosystems ranging from tropical evergreen forests to estuaries, mangroves and even corals. The Konkan region presents a microcosm of the most imposing and extremely threatened topographic, floristic, and faunistic features of the Western Ghats (Gaonkar, 1996) and is among areas with highest conservation value (Khoshoo, 1994). The undulating terrain along the sea coast although sharply raises from the sea at most places, it also has beautiful silver sand beaches and protected natural harbours spotting its coastline at several places. The conversion of the Western Ghats forest in to agriculture and monoculture plantations coupled with hydroelectric projects, mining, urbanization, illegal tree felling have resulted in change in landscape and loss of biodiversity (Menon and Bawa, 1997; Ramesh *et al*., 2010). The primary forests in Konkan region of the Western Ghats are disappearing at an expeditious rate due to anthropogenic activities and special attention needed in conservation and management of the ecosystems. Therefore, both quantitative as well as qualitative information on land-use patterns and vegetation status are necessary for formulating useful policies for timber harvesting, conserving biodiversity, estimating carbon sequestration rate, combating environmental hazards and sustainable management of the resources.

The study area is also endowed with rich mangrove vegetation diversity along coast, estuaries and creeks. However, the majority of the mangrove forest or creek ecosystem of the Konkan region has vanished or under tremendous pressure due to anthropogenic pressure, urbanization and industrialization in recent years. The common mangrove plant species growing in locality are *Bruguiera gymnorhiza, Sonneratia caseolaris, Avicennia officinalis, Rhizophora mucronata, Excoecaria agallocha, Avicennia marina, Aegiceras corniculatum, Rhizophora apicalata* etc. Shrub *Acanthus ilicifolius* (L.) grows abundantly everywhere in the mangrove vegetation.

The forest vegetation in Konkan region is recently under threat due to anthropogenic pressure and human activities. The forest provides fuel, food, timber, raw material for slash and burn on agricultural field and so on to the human being. At least 15 small scale sawmills are present in different villages of the study area. Illegal felling by the local peoples for timber and carelessness of the forest department is the major reason deforestation. The forest department in the region seem to be inactive in managing the forests. The laid back attitude among the officers and corruption is the main drawback of the system. As already stated the forests in the zone are publically owned and the officers don't have any sense of responsibility and job is the only priority for them. In the study area, the maximum forest area is on private land and seems that there is no control of forest department. Even the mangroves are not protected. Encroachment by human for shrimp farming, coconut plantation and settlement are the common reasons to decline the mangrove vegetation in the region.

Fig. 2.11: Causes of land-use conversion in the study area.

In recent years the rate of deforestation increased extensively because hectares and hectares of forest land is cleared for mango plantations. Similarly, the homestead gardens are the most important source of livelihood to meet the needs of the people. The crops grown are coconut, cashew nut, mangos, jackfruit, spices, medicinal plants, ornamental plants, vegetables and some crops having importance for live fencing. The small agro based industries like cashew processing; pickle processing and jackfruit processing are situated in the study area. The clean and wide beaches and huge casuarina plantations are key attraction for tourists. These plantations acts as windbreaks and play a protective role as barrier against the sand expansion along coastal line. These are over aged and are under threat from natural calamities like cyclones and tsunamis. No more reforestation work has been carried out on damaged casuarina plantations by forest department. The conservation and restoration of theses protective belt is also a big challenge.

Grasslands are also found in few patches in open areas, hillocks and occasionally occur as under storey in mixed deciduous forests. Majority of grassland patches are occurring on coastal plain area. The biotic interferences coupled with edaphic factors helped in the perpetuation of grassland over extensive areas. The main feature of these grasslands is that number of cattle's depending for the grazing throughout the year. Theses grasslands are habitat for number of birds, mammals, reptiles and microorganisms. A large number of migratory and threatened birds occur on grasslands located on coastal plain area. As per as faunal diversity is concerned different species of mammals, birds, reptiles along with scores of amphibians, insects, nematodes and other microorganisms are endemic to the Konkan region. The some specific locations in mangrove vegetation are habitat for flying foxes. About more than 10,000 flying foxes resides in Juve Jaitapur village, which most interesting habitat location in the study area. The area does not have either any protected area or wildlife sanctuary or national park or reserve or sacred groves. The study area has some untouched mangrove forest patches and Pandanus (Kevda) vegetation along coastal slopes (see photographs of all specific vegetation in Fig.2.6).

Recently the area is under huge anthropogenic pressures like deforestation, wetland conversion for shrimp farming and miscellaneous plantations, chira mines, construction of road, fuel wood, loss of casuarina shelterbelts, a slash and burn agriculture, construction of roads and industrialization (Fig. 2.11).

3 ANALYSIS OF FLORISTIC DIVERSITY AT DIFFERENT LAND-USE TYPES IN SOUTH KONKAN COAST OF MAHARASHTRA (INDIA)

3.1 Introduction

Globally, climate is one of the major components that control species diversity and distribution (Root *et al*., 2007). The literature suggests that climate changes have been considered as prime reason in modifying biodiversity (MEA, 2005). In 2004 Britain's chief scientist, David King sounded a dramatic warning when he identified climate change as a greater risk to the world than terrorism (King, 2004; Root *et al*., 2007). Many studies revealed that forest fragmentation and habitat loss influences forest structure and species composition. Worldwide forests have been fragmented into small patches and ultimately forest structure and species composition have been influenced by this fragmentation and habitat loss (Echeverria *et al*., 2006; Wassie *et al*., 2010). In past, the functional diversity has been seen as the key predicting tree stability, invisibility, resource capture, nutrient cycling and productivity of communities (Manson *et al*., 2003). For many decades, the species area curve and several diversity indices have been used for assessing species richness and diversity (Fisher *et al*., 1943; Shannon, 1948; Simpsons, 1949; Sanders, 1968; Gimaret-Carpentier, 1998). Turner (2010) suggested that ecologist should make a renewed and concerted efforts to understand and anticipate the effects of changing disturbance regimes. Tropical forest ecosystems are home to the majority of species on the earth and are of global importance and interest for many reasons (Hartshorn, 2001).

The Royal Botanic Gardens, Kew together with the Natural History Museum, London and *International Union for Conservation of Nature* determined a global analysis extinction risk for the world's plant, and revealed that the world's plants are as threatened as mammals, with one in five of the world's plant species threatened with extinction (Kew Royal Botanic Gardens, 2010; IUCN, 2010). This is the first time a large-scale true estimate of threatened plant species, which accounts 380,000 plants species, under threat has been carried out.

The primary aim of our investigation was to understand the structure and diversity of vegetation in the South Konkan coast of Maharashtra. The predominant forests types of the region are southern moist mixed tropical deciduous forest and mangrove forest (Champion and Seth, 1968). For the, study of floristic composition, richness and diversity the whole area investigated was divided into different land-use types; forest, homegardens, casuarina plantations and mangroves. Several studies (Bharucha and Shankarnarayan, 1958; Lee, 1989; Daniels *et al*., 1992; Sukumar *et al*., 1992; Jose and Shanmugaratnam, 1993; Jagtap, 1994; Jagtap *et al*., 2001; Kumar *et al*., 1994; Nair and Sreedharan, 1986; Krishnan and Davidar, 1996; Ganesh *et al*., 1996; Azariah *et al*., 1992; Sundarapandian *et al*., 1997., Ghate *et al*., 1998; Chandrashekara and Sankar, 1998; Nair *et al*., 1998; Kadavul, 1999; Bhat *et al*., 2000; Srinivas and Parthasarathy, 2000; Muthuramkumar and Parthasarathy, 2000; Parthasarathy, 1999; John and Nair, 1999; Ayyappan and Parthasarathy, 1999, 2001 and 2004; Ramanujam and Kadamban, 2001; Upadhyay, 2002; Kumar and Nair, 2004, 2006; Davidar *et al*., 2005; Behera and Mishra, 2006; Nair and Kumar, 2006; Peyre *et al*., 2006; Magnussen *et al*., 2006; Mohan *et al.*, 2007; Jagtap and Nagle, 2007; Reddy *et al*., 2008; Kumar, 2009; Saha *et al.*, 2009; Ramesh *et al.*, 2010) on diversity of the forest vegetation, mangroves and homegardens in Western Ghats and Eastern Ghats are documented in literature; however, diversity status of the casuarina monocultures along the coast has not been investigated.

3.2 Review literature

3.2.1 Vegetation dynamics in India and Western Ghats

FAO (2011) reported that India, ranks 4th position in the world among five countries with largest forest area and it has been registered that the forest area increases in last decade. India set a target to cover 33 per cent of its land area with forests and tree cover by 2012. FAO (2011) notified that studies in India indicate an increase in productivity and diversity of vegetation following the introduction of CBFM (Prasad, 1999). India sustains some of the world's most imperilled forest. However, recent studies critically evaluated forest trends in India and argued that native forest are actually being lost, degraded or transformed at an alarming rate (Puyravaud *et al*., 2010).

The floristic spectrum of India comprises more than 30,000 species (excluding fungi), of which the flowering plants or about 1,500 species. Thus, flowering plants are the dominant group representing about 7% of the flowering plant species of the earth. A total of 140 genera and 5285 species are endemic to the country (Kharkwal, 2008; Kumar, 2009; Kharkwal and Rawat, 2010). Biodiversity is intimately not only interconnected with the long-term health and vigour of the biosphere as an indicator of global environment but also as a regulator of ecosystem functioning (Diaz *et al*., 2006). Therefore, conservation of biodiversity at different levels is necessary, as it demands for adopting sustainable land-use practices in different regions. However, land-use transformations are rapid in many parts of India and causing alarming threat to functioning of many ecosystems.

Upadhaya *et al*., (2003) reviewed in his paper that several researchers (Pascal and Pelissier, 1996; Parthasarathy and Karthikeyan, 1997; Ayyappan and Parthasarathy, 1999; Parthsarathy 2001) reported that the Western Ghats is one of the biodiversity rich area in the Indian Subcontinent. Cincotta *et al*., (2000) and Anand *et al*., (2010) recognized that Western Ghats is one of the most densely populated biodiversity hotspot with a mosaic to natural, semi natural and agro-ecosystems in close proximity to one another. The Konkan region of the Western Ghats is well known for sacred groves, which are patches climax vegetation of forest traditionally protected on religious ground by local communities.

3.2.2 Land-use change and floristic diversity

The land-use changes and associated biodiversity losses are the major threats to the world's ecosystems (Vitousek, 1997; Carnery and Matson, 2006). Pragasan and Parthasarathy (2010) reviewed that floristic inventory is critical for conservation and management of forest ecosystems. Plant diversity inventories in tropical forests have mostly been concentrated on tree species than any other component, because tree diversity forms an important aspect of forest ecosystem diversity (Rennols and Laumonier, 2000). Quantifying species diversity on a regional scale is quite challenging because of difficulties in measurement of species abundance and distribution (Koellner *et al*., 2004; Mani and Parthasarathy, 2006). It is argued that the most dramatic changes in tropical forest ecosystem is conversion to some other land-use (Pimm and Raven, 2000; Ball, 2001, Houghton, 2003; Reid *et al*., 2005; Lewis, 2006). Many studies referred the moist tropical forests are characterized by relatively dense and evergreen broadleaf trees with closed canopy usually composed of a high diversity of tree species (Malhi *et al*., 2002, Ter Steege *et al*., 2003). The several researchers revealed that high species richness is one of the characteristic features of the moist tropical forest ecosystem (Parson and Cameron, 1974; Chandrashekara and Ramakrishnan, 1994).

Joshi and Janarthanam (2004) reviewed that a number of studies have been undertaken in Western Ghats and to determine floristic composition and endemism (Nayar, 1996; Mishra and Singh, 2001). However, none of the studies has emphasized the ecology of the endemics under different land-use types. Anitha *et al*., (2010) studied tree species diversity and community composition in tropical forest of Western Ghats and concluded that the structure, function and ecosystem services of tropical forest depends on its species richness, diversity, dominance and patterns of changes in the assemblages of the tree population over time.

Chandrashekara and Ramakrishnan (1994) investigated vegetation dynamics, biomass accumulation and net primary productivity of humid tropical forest of Western Ghats and reported that the fast growing shrubs and secondary tree species were decreased with the gap age. The same trend was observed for rate of nutrient uptake and biomass accumulation. In 2003, Bhuyan *et al*., investigated tree diversity and population structure in disturbed and undisturbed sites in tropical wet forest in Eastern Himalaya and reported lower species richness and diversity in human disturbed than in the undisturbed stand.

3.2.3 Variation in vegetation structure, composition, richness and diversity

Dansereau *et al*., (1968) defines vegetation structure as the organization in space of the individuals that form a stand (and by extension of a vegetation type or plant association) and he states that primary elements of structure are growth form, stratification and coverage. The structural attributes of plant community can be expressed both in qualitative and quantitative characters. The qualitative characters are physiognomy, phenology, stratification, abundance, dispersion, sociability, vitality and life form, whereas quantitative characters include density, frequency, dominance and basal area (Odum, 1983). These quantitative primary variables are used for deriving secondary variables and Importance Value Index (IVI) of a species in a given community. The structural and compositional aspects of vegetation are studied through vegetation analysis (Whittaker, 1972). The most important vegetation characteristics, which may be measured by readily, are size, number and distribution of the species, also it is stated that the almost universal acceptance of the quadrate method has provided a great wealth of data about plant communities in all parts of the world (Curtis and McIntosh, 1950). The ecological importance of species and their organization as plant communities assessed in terms of dominant, co-dominant and suppressed vegetation based on the vegetation analysis (Mishra, 1968; Odum, 1983). The conventional techniques of vegetation analysis help in better understanding of community composition only at stand level.

Krishnan and Davidar (1996) studied shrubs of the Western Ghats and recorded 406 species belonging to 46 families. Of them, they listed 77% shrubs as endemic and 4% as rare and endangered.

3.2.3.1 Species diversity and community composition in the moist deciduous forest

Tropical forest has been studied in India for several decades; however, their ecology is not precisely understood (Hubbell and Foster, 1992; Anitha *et al*., 2010). Ramesh *et al*., (2010) reported abundance of the woody plants in central Western Ghats. They suggested that the area supports a wide array of non-equatorial tropical habitats including moist deciduous forest with moderately rich and diversified floristic formation. Singh and Singh (1991) studied the structure and diversity in mixed dry deciduous forests of Vindhyan region. The basal cover of vegetation varied from 3.8 to 10.4m^2 $ha^{-1}$for trees and 3.1 to 7.8 m^2 $ha^{-1}$for shrubs. Similarly, Shannon and Weiner index and concentration of dominance ranged between 1.93 to 2.18 and 0.18 to 0.38.

Gupta and Shukla (1991) analysed the forest vegetation of Gorakhpur division consisting of mainly Sal plantations. Basal cover of the tree species varied from 52 to 50 m^2 ha^{-1} and 1.2-1.4 m^2 ha^{-1} for shrubs and 0.04 to 0.006 m^2 ha^{-1} for herbs, and density varied from 12.9 to 19.1 for trees, 16.9-20.3 for shrubs and 17 to 46 for herbs. Species diversity index (H) varied from 1.02-1.2 and dominance varied from 0.067- 0.13.

Varghese and Menon (1998) conducted vegetation analysis studies in south moist mixed deciduous forests of Agasthyamalai region of Kerala, India. The stand density, species density and basal area of these forests were 535 trees ha^{-1}, 12 species per 0.1 ha and 26.57 ha^{-1}, respectively. Shannon index of these forests was 1.89, while evenness index was 0.73. *Terminalia paniculata, Pterocarpus masupium* and *Careya arborea* were found as dominant plant association.

Ramanujam and Kadamban (2001) studied the natural vegetation on the southeastern coast of Peninsular India has now been reduced to patches, some of which are preserved as sacred groves. The plant biodiversity and population structure of woody plants (>20 cm girth at breast height; gbh) in two such groves, Oorani and Olagapuram, occurring on the northwest of Pondicherry have been analyzed. The vegetation structure indicated that the Oorani grove was a relic of tropical dry evergreen forest, whereas Olagapuram was reduced to thorny woodland.

Pande *et al*., (2002) studied the vegetation composition, species diversity, distribution pattern and other parameters of vegetation including population structure and regeneration of some tree species in a Western Himalayan forest of Chakrata forest division (Uttaranchal). The density (plant 100 m^{-1}) was 4.51-6.64 for trees, 23.56-41.62 for shrubs and 7280-11920 for herbaceous species, while the range for total basal cover (m^2 100 m^{-2}) was in between 0.332-0.938 for trees, 9.50-18.81 cm^2/100 m for shrubs and 235-323 cm^2/100 m for herbaceous species. The diversity (species richness) was 1-12 for trees, 9-14 for shrubs and 20-23 for herbs. Concentration of dominance (cd) showed reverse trend to diversity that was 0.12 for trees, 0.13-0.15 for shrubs and 0.1 to 0.13 for herbs. Shannon index varied from 0-2.25 for trees, 1.53 to 2.31 for shrubs and 2.41 to 2.69 for herbs.

Pande (2005) studied the ecological status of vegetation in Satpura plateau, M.P. Total density ranged between 46.93-387.5 trees ha^{-1}, 114 to 714.95 shrubs ha^{-1} and 15905 to 102078 herbs ha^{-1}, whereas, the dominance ranged from 9570 to 217333 cm^2 ha^{-1} for trees, 2912 to 32462 cm^2 ha^{-1} for shrubs and 1304 to 218468 cm^2 ha^{-1} for herbs.

Nath *et al.*, (2005) studied that the species composition, diversity and tree population structure in undisturbed, moderately disturbed and highly disturbed stands of the tropical wet evergreen forest in and around Namdapha National Park, Arunachal Pradesh, India. In total 200 plants, belonging to 73 families recorded in three stands. Tree density and basal area showed a declining trend with the increasing disturbance intensity. Species like *Altingia excelsa, Olea dioica, Terminalia chebula, Mesua ferra* and *Shorea assamica* in the undisturbed stand and *Albizia procera* alone in the moderately disturbed stand contributed more than 50% of the total tree density in respective stands.

Negi (2005) studied the vegetation characteristics of Thalke Dhar Reserve forest of Central Himalayas. A total of 53 species (13 spp. of tree, 24 spp. of shrub and 16 spp. of herb) were recorded. The tree density per hectare was 1,010 - 1230 trees ha^{-1} in different compartments. Total basal cover of tree species ranged from 49.39 to 64.74 m^2 ha^{-1} across the compartment. Density of saplings ranged between 690-770 ha^{-1}. The value of diversity ranged from 2.15 to 2.32, 2.53 to 2.67, 2.39 to 3.20 and 3.32 to 3.94 for trees, saplings, seedlings and shrubs, respectively. Beta diversity was 1.42, 1.32, 1.16 and 1.30 for trees, saplings, seedlings and shrub layer, respectively.

Singh *et al*., (2005) compared the diversity and dominance of pure Sal and degraded moist deciduous forest of Achanakmar wild life sanctuary, Chhattisgarh, India. The pure Sal forest was characterized by high tree (1233 stems ha^{-1}) and under storey vegetation densities (1575 stems ha^{-1}) as well as basal cover (tree, 36.36 m^2 ha^{-1}, under storey vegetation 1.85 m^2 ha^{-1}). The degraded moist deciduous forest sites represent the degraded stage with low density of tree and basal cover (633 stems ha^{-1}, basal cover 32.82

m^2 ha^{-1}) and under storey plants (density 918 stems ha^{-1}, basal cover 0.37 m^2 ha^{-1}). The total number of species was high (30 spp.) in pure Sal as compared to degraded moist deciduous forest (919 spp.). The diversity of plants in pure Sal forest was 2.82 (Shannon index), 4.76 (richness index) and 0.99 (equitability index). The diversity of plants was low in degraded forest, the values being 1.99 (Shannon index), 3.48 (Riches index) and 0.78 (Equitability index).

3.2.3.2 Homegarden vegetation dynamics

Homegardens are the traditional agroforestry land-use systems involving deliberate management of multipurpose tree species and shrubs in intimate association with annual and perennial agricultural crops and invariably livestock within the compounds of individual houses (Kumar *et al*., 1994; Fernandes and Nair, 1986; Jose and Shanmugaratnam, 1993; Das and Das, 2005; Kumar and Nair, 2006; Mohan *et al*., 2007). The concept of homegardens, their global distribution and complexity is discussed in detail by Kumar and Nair (2004) and Peyre *et al*., (2006). Worldwide, homegardens have attracted considerable research attention during past three decades (Wojtkowski, 1993, Ceccolini, 2002; Coomes and Ban, 2004). In tropical countries, they provide a diverse and stable supply of socio-economic products and benefits to the families that maintain them (Christanty, 1990). It is believed that species diversity of tropical homegardens is very high (Babu *et al*., 1982; Michon *et al*., 1983; Soemarwoto, 1987; Kumar *et al*., 1994).

Das and Das (2005) studied homegarden biodiversity in Northeast India and revealed that homegardens exhibit high diversity, comprising of 122 tree and shrub species. In Kerala, the home gardens are extensively studied. Kumar *et al*., (1994) reported homegardens in Kerala composed of 127 species with more dominance of the fruit tree. They concluded that floristic diversity was higher in small homegardens than larger size. Some researchers agreed that the homegardens are important sites for *in situ* conservation of plant diversity (Brower and Zar, 1984; Gajaseni and Gajaseni, 1999; Alcorn, 1992; Clarke and Thaman, 1993; Gomez- Pompa, 1996; Johnson, 1972; Smith *et al.*, 1995; Saha *et. al*., 2009).

Kehlenbeck and Maass (2006) argued that the species diversity in homegardens is not static; it varies with time and according to ecological and socio-economic factors and/or characteristics of the homegardens and owners. Beside this, it is assumed that being multi-layered vegetation structure, homegardens serve as an important habitat for wild flora and fauna in these areas (Kehlenbeck *et al*., 2007). Millat-e-Mustafa *et al*., (1996) studied florist structure of traditional homestead in Bangladesh and concluded that the homegarden species richness and diversity vary with size and region. They reported highest diversity between food and fruit producing species, followed by the timber species.

Peyre *et al*., (2006) investigated dynamics of the six different type traditional homegarden structure and function in Kerala (India) and argued that traditional homegardens are subject to different conversion processes linked to socioeconomic changes. Saha *et al.,* (2009) reviewed that the high plant-species diversity of tropical homegardens has been illustrated in a number of reports (Swift and Anderson, 1993; Kumar *et al*., 1994; Mohan *et al*., 2007). Some studies that have estimated the diversity indices from ecological points of view have indicated that plant-diversity indices of homegardens are comparable to those of adjacent forest (Kumar *et al*., 1994; Gajaseni and Gajaseni, 1999; Wezel and Bender, 2003).

3.2.3.3 Structure and composition of Casuarina plantation understory vegetation

The monoculture planting (coastal shelterbelts) of *Casuarina equisetifolia* covered some part of South Konkan coast of Maharashtra state, which grew densely covering most of the beach starting from the high tide line. Few studies have been carried out on analysis of understory vegetation in Casuarina plantation monocultures in India. Pratt (2011) assessed casuarina monocultures in Hawaii National Park (U.S) and reported presence of several seedlings, shrubs, herbaceous species and native creeping grass species.

3.2.3.4 Floristic composition of mangrove forest vegetation

The term 'mangrove refers to an ecological group of hallophypeic plant species as well as to a variety of complex vegetation dominated by these species, found along ocean coastlines throughout the tropics (Upadhyay *et al*., 2002; Komiyama *et al*., 2008, Donato, *et al.*, 2011). Worldwide, mangrove vegetation distributed in 117 countries and comprises of approximately 54-75 species in 41 genera, of which 34 species belonging 29 genera. This includes 33 species from 24 genera and 19 families on west coast of India (Banarjee *et al*., 1989; Singh *et al*., 1990; Deshmukh *et al*., 1994; Sarvanakaumar *et al*., 2002). IUCN (2011_b) declared mangrove as healthy ecosystem proving their value in protecting local communities from cyclones. Several studies reported that the mangrove ecosystems on earth are threatened by global climate change (Valiela *et al*., 2001; Macintosh and Ashton, 2002; Gopal and Chauhan, 2006; Gliman *et al*., 2008).

Banerjee (1989) stated the species diversity is higher in the Indian mangrove forest ecosystem compared to that of Latin America and Africa. He reported 116 species, which includes 59 mangrove species, 47 algae and 10 species of sea grasses. India contributes approximately 3% to the world's mangrove forest area (Upadyay *et al*., 2002). These ecosystems are endowed with rich and diverse living resources that provide forestry and fishery products to a large human population (Kathiresan, 2000). Beside this, Donato *et al*., (2011) reviewed that the areal extent of the mangrove forest has declined by 30-50% over the past half century because of coastal development, aquaculture expansion and over harvesting.

Mangrove ecosystem along the Konkan coast of Maharashtra is becoming prone to the hazards of pollution due to industrialization (Nair *et al*., 1998). Singh (2000) reviewed that the studies on the mangrove structure and composition have been very limited along Indian coast. It is argued that mangroves thrives better in warm and humid regions that receives more rain and are > 04 m above MSL (Ellison, 1989).

Jagtap *et al*., (2001) assessed coastal wetlands in central west coast of Maharashtra and concluded that the mangrove vegetation comprised of 17 species and dominated by *Rhizophora mucronata, Avicennia officinalis, Avicennia marina, Sonneratia alba, Excoecaria agallocha* and *Acanthus illifolius*. Mangrove habitats particularly from Indian subcontinent are deteriorating to great extent (Jagtap and Nagle, 2007). The results proved that mangrove vegetation associated with high leaf production and leaf fall and rapid decomposition of litter (Ramasubramanian, 2006).

Mangroves are commonly characterized by rapid land-use changes such as shrimp farming and agriculture, and industry (AAAS, 1995; Dinesh *et al*., 2004; Hinrichs, 2009). It is concluded that biotic pressure on Indian mangrove biodiversity has been mainly due to land-use changes. In India, along west coast alone, almost 40% of the mangrove area has been converted to agriculture and urban development (Upadhyay, 2002). He also reviewed that FSI data indicate that mangrove forest cover has gained or has remained unchanged since 1995, except Maharashtra state.

3.3 Objectives of the investigation

The present investigation was undertaken to determine the floristic structure, composition, species richness and diversity in tropical moist deciduous forest, homestead gardens, casuarina plantations and the mangrove vegetation of the South Konkan Coast region of Maharashtra state. The proposed nuclear power industry is surrounded by these land-use types and will have future impact; therefore I selected these land-use types for vegetation study.

3.4 Materials and methods

3.4.1 Study site

The study was conducted in the South Konkan Coast of Maharashtra. The detail information about the study site is given in Chapter 2 Description of the study site.

3.4.2 Field method

The vegetation analysis was carried out during 2008-2009. A quadrate sampling technique was used for vegetation analysis of different land-use type in the study area (Tiwari and Singh, 1987; Singh and Singh, 1991).

3.4.3 Sampling scheme, Land-use type selection and layout of quadrates

The base map of the study area was prepared from survey of India toposheet and forest cover map sheet number 47H on 1:50000 scale. A systematic 1km x 1km square grids of 460 points, was randomly superimposed over the survey region and different land-use types or habitats, such as forest land, mangrove forest, homestead gardens, grasslands, and the casuarina plantations were identified at each grid intercept point location.

The work was carried out using a stratified random sampling scheme (Kindt and Coe, 2005) in which the sample universe is subdivided into group of sample units (strata). The strata have more homogeneous vegetation than that of sample universe as whole (Pendleton, 1995; International Commission on Radiation Units and Measurements, 2006). Here we used land-use or habitat types as strata. Stratified sampling ensures that observations are taken in each stratum. The quadrates were placed at randomly selected land-use from a grid (Kindt and Coe, 2005). Within each stratum all over 125 sample points/ quadrates (50, 40, 25 and 10 quadrates in forest land, homegardens, mangroves and the casuarina plantation land-use types, respectively) randomly located by using random numbers Table (Panse and Sukhatme, 1985).

3.4.4 Data collection

Floristic data was collected from a network of 125 quadrates at different land-use types. The methodology adopted in the present study for the characterization of vegetation is depicted in Fig. 3.1 and 3.2. The number of quadrates studied per land-use is shown in Table 3.1 and the sampling point locations are shown in Fig. 3.3. Normally 10m x 10m quadrate size is used to enumerate tree vegetation in many studies (Gadgil, 1996; Laurance *et al*., 1997; Pyke *et al*., 2001; Condit *et al*., 2002; Bhuyan *et al*., 2003; Upadhay *et al*., 2003; Gould *et al*., 2006). The vegetation analysis in forest land, mangrove and the casuarina plantation land-use type has been carried in 10m x 10m quadrate (sample plots). However, within each of the main 10m x 10m quadrates, under-story (shrub and climber) and ground-story (herb) vegetation were scored in 5 x 5 m and 1 x 1m size quadrates, respectively (Chandrashekara and Ramakrishnan, 1994; Nath *et al*., 2005; Khumbongmayum *et al*., 2006; Sheikh *et al*., 2009). However, in the homegarden vegetation at each sampling point 20m x 10m size quadrate was laid down to study tree, shrub and climber and 5m x 5m to enumerate herbaceous vegetation within the 20m x 10m size quadrate.

Table 3.1: The land-use wise distribution of quadrates studied with the size of quadrate for different vegetation components.

Sr.	Land-use types	Quadrates	Quadrate size			
			Tree	Shrub	Climber	Herb
1	Forest land	50	10m x 10m	5m x 5m	5m x 5m	1m x 1m
2	Homegardens	40	20m x 10m	20m x 10m	20m x 10m	5m x 5m
3	Mangroves	25	10m x 10m	5m x 5m	5m x 5m	1m x 1m
4	Casuarina plantation	10	10m x 10m	5m x 5m	5m x 5m	1m x 1m

Within each 10m x 10m (forest land, mangrove and the ccasuarina plantation) square shaped quadrate and 20m x 10m rectangular shaped quadrate (homegardens), each individual tree diameter at breast height (dbh) was measured at 1.37 m (Bhuyan *et al.*, 2003; Nath *et al*., 2005; Khumbongmayum *et al*., 2006). The dbh and height of trees was measured using wooden tree calliper and Ravi's multimeter, respectively.

3.4.5 Plant identification

The plant identification was based on Almedia, (1996-2009); Cooke, (1901-1908); Shrama *et al*., 1996; Singh and Karthikeyan, 2000; Singh *et al*., 2001; Ingalhalikar, (2001 and 2007). We used online database to identify most of the plant species from flowers of India website (FOI, 2005).

3.4.6 Conservation status

The plant species conservation status has been identified by following IUCN Red List of the threatened species (IUCN, 2011a) and further availability of species in world database was done from Species 2000 and ITIS Catalogue of Life (Bisby *et al.*, 2012).

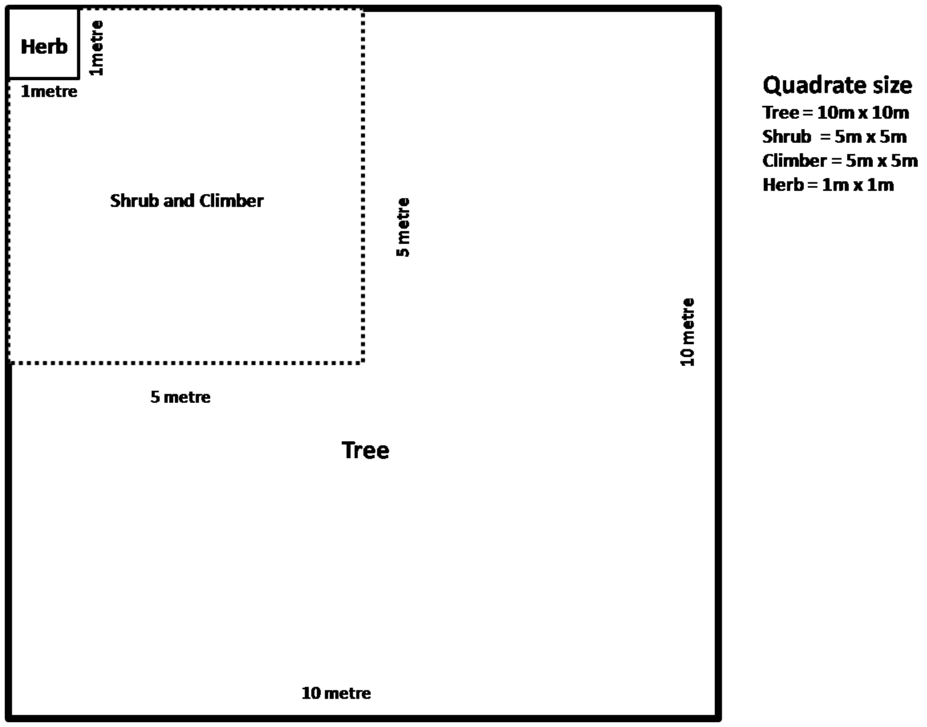


Fig. 3.1: Layout of the tape and the procedure of quadrate sampling for different component in forest land, mangrove and the casuarina plantation land-use types.

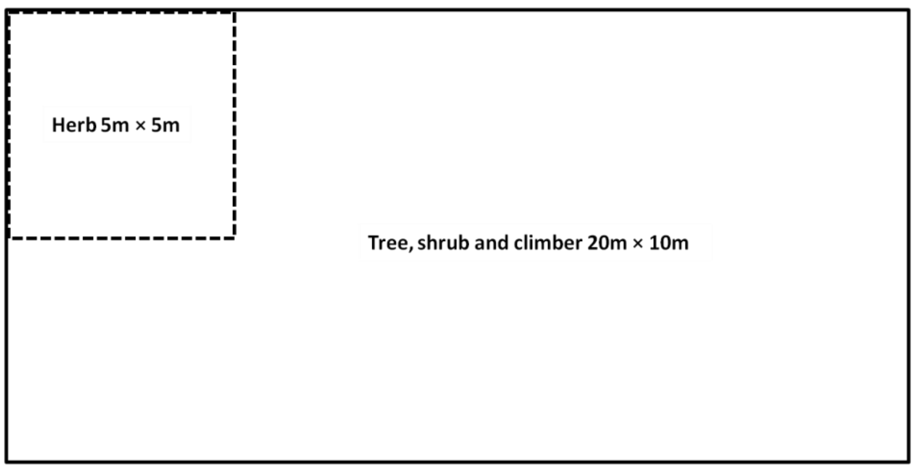


Fig. 3.2: Layout of the tape and the procedure of quadrate sampling for different component in homegarden land-use types.

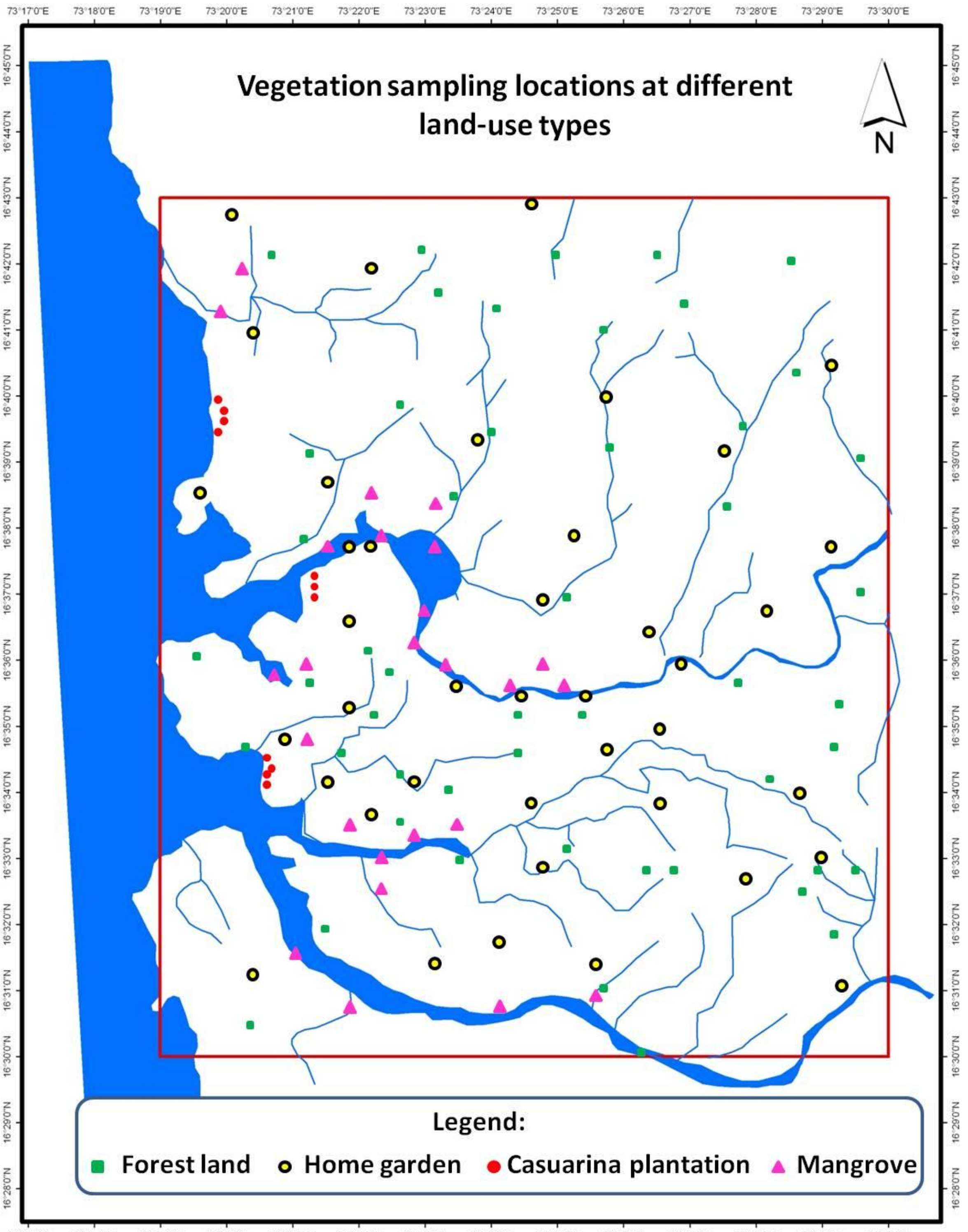


Fig. 3.3: Maps showing the sampling locations at different land-use types

3.5 Data analysis

3.5.1 Quantitative analysis

The data was analysed for vegetation characters such as frequency, density, abundance, basal area and importance value index following the methods of Curtis and McIntosh (1950), Whittaker (1972) and Murty *et al*., (2011). The following formulae are used for calculating structural variables.

3.5.1.1 Frequency, density, abundance and basal area

Frequency is the number of plots / sampling units/ quadrates in which a species is occurs (as %). Thus, frequency of each species is calculated by following formula.

$$\text{Frequency (F)} = \frac{\text{Number of quadrates in which the spp. occured}}{\text{Total number of quadrates studied}} \text{ x } 100$$

After determining the frequency of each species various species were distributed among Raunkiaer's (1934) five frequency classes depending upon their frequency values (Table 3.2).

Density is the number of individuals per unit area (Ralph, 1981_b). It gives an idea of degree of competition in the community. The density was calculated by using following formula. The density per hectare was then calculated for tree species, shrubs, herbs and climber components.

$$\text{Density (D)} = \frac{\text{Total number of individuals of a spp. in all quadrates}}{\text{Total number of quadrates studied}}$$

Abundance is the average number of individuals per quadrates for the quadrates in which it occurs and it was calculated by following formula,

$$\text{Abundance (A)} = \frac{\text{Total number of individual of the spp. in all sampling points}}{\text{Number of sampling units in which the spp. occured}}$$

Table 3.2: Raunkiaer's frequency class Table (Raunkiaer's, 1934)

Range	Raw frequency data	Frequency class
0-20	53	A
21-40	14	B
41-60	9	C
61-80	8	D
81-100	16	E

The basal area of trees was calculated as a sum the cross sectional area of stem at breast height (1.37m) and is calculated by using following formula,

$BA = \pi r^2$ Where, BA = Basal Area, $\boldsymbol{\pi}$ = 3.14 and r = dbh/2.

3.5.1.2 Importance value index (IVI):

The species dominance was quantified by the importance value index. In calculating this index, the percentage values of the relative frequency, relative density and relative dominance are summed up together and this value is designated as the Importance Value Index or IVI of the species (Curtis, 1959; Philips, 1959; Kershaw, 1973; Tiwari and Singh, 1987; Lu *et al*., 1998 Murty *et al*., 2011).

$$\text{IVI} = \text{Relative frequency} + \text{Relative abundance} + \text{Relative density}$$

Where,

$$\text{Relative Density (RD)} = \frac{\text{Total density of the individual spp.}}{\text{Total density of all spp.}} \text{ x } 100$$

$$\text{Relative Frequency (RF)} = \frac{\text{Total frequency of the individual spp.}}{\text{Total frequency of all spp.}} \text{ x } 100$$

$$\text{Relative Abundance (RA)} = \frac{\text{Total abundance of the individual spp.}}{\text{Total abundance of all spp.}} \text{ x } 100$$

$$\text{Relative Basal Area (RBA)} = \frac{\text{Total basal area of the individual spp.}}{\text{Total basal area of all spp.}} \text{ x } 100$$

3.5.2 Species richness and species accumulation curve

Plant species richness was calculated as the total number of species recorded at each land-use type during study period. Rarefaction curves were used to compare species richness among habitats investigated, as there is difference in sampling efforts (Pragasan and Parthasarathy, 2010). The sample based rarefaction curves were computed using EstimateS 8.2.0 a free software application (Colwell, 2009). The expected species accumulation curves (sample-based rarefaction) were based on species abundance data (counts) for each species in each quadrate. We used abundance data for comparing the species composition of the different habitats. Species accumulation curve is the graph of the number of observed species as a function of some measure of sampling effort required to observe them (Colwell *et al*., 2004). Sample based rarefaction curves expressing the expected species richness as a function of the number of sampled quadrates for each land-use were obtained by using the programme EstimateS version 8.2.0. Here we constructed sample based species accumulation curve form empirical species-by–sample abundance matrix using EstimateS 8.2.0 a free software program. Species accumulations curves extrapolate species richness vs. sample size data to an asymptotic of total richness (Soberon and Lorente, 1993, Colwell and Coddington, 1994). Similarly an attempt has been made to use EcoSim Version 7.72 freeware program (Gotelli and Entsminger, 2011) to compute species accumulation curve.

3.5.3 Species diversity

The diversity indices reflect the manner in which abundance is distributed among the different species constituting the population (Gimaret-Carpentier *et al.*, 1998). The protocols for determination of various diversity indices are given as below.

3.5.3.1 The 'Shannon–Weaver' Index of diversity (H'):

We used "Shannon's index" (Shannon and Weaver, 1949; MacArthur, 1965; Odum, 1983; Chandrashekara and Ramakrishnan, 1994; Arias-Gonza´lez, 2011), which referred as most commonly used index to calculate species diversity. The Shannon-Weaver index was calculated by using following expression.

$$H' = -\sum_{i=1}^{n} pi\, ln\, pi$$

Where, pi is the relative proportion of the total sample belonging to the i^{th} species, *n* the number of species and *ln* is natural logarithm (base e). Similarly, we used EstimateS 8.2.0 a free software application (Colwell, 2009) in order to compute Shannon's index and compared against the same indices computed by the Shannon-Weaver index formula.

3.5.3.2 Simpsons Index of Dominance and Simpsons Index of Diversity

The concentration of dominance was measured by Simpson's index of dominance and Simpson's index of diversity (Simpson, 1949; Krebs, 1994 and 1999; Sagar and Sharma, 2012). The Simpson's index value attaches more weight to the abundance of the most common species.

$$\text{Simpson's index of dominance } (\lambda) = \sum_{i=1}^{n} (pi)^2$$

Where, pi is the relative proportion of the total sample belonging to the i^{th} species and *n* the number of species, i.e. $pi = ni/N$

$$\text{Simpsons index of diversity } (1-\lambda) = 1 - \sum_{i=1}^{n} (pi)^2$$

3.5.3.3 Species evenness:

The species diversity was evaluated by species evenness index. We calculated community evenness by the ratio of observed diversity to maximum diversity (Magurran, 1988 and 2004; Metzger and Decamps, 1997). The species evenness index is based on Shannon Weaver Index.

$$E = \frac{H'}{LN\ (n)}$$

Where, H' is bird species diversity (Shannon's index) and *LN (n)* is the maximum possible diversity for given species number *n* (assuming that all species are equally abundant).

3.5.3.4 Sorensen's quantitative index:

The percentage similarity between four land-use types and vegetation components within different land-use types was determined using Sorensen's quantitative index (Sorensen, 1948; Magurran, 1988; Brower *et al.*, 1984; Magurran, 2004).

$$\text{Sorensen's quantitative index } = \frac{2 \times \text{ number of spp. in common}}{\text{Total number of spp.}} \times 100$$

3.5.3.5 Jaccard's similarity index:

To estimate variation in species composition between land-use types, we first calculated Jaccard's similarity index (Magurran, 1988; Brower *et al.*, 1984; Magurran, 2004). The compared similarity indices obtained within and between land-use

$$\text{Jaccard's similarity index} = \frac{a}{a + b + c}$$

Where a, is the number of species common in two land-use types (X and Y), b the number of species observed only in land-use X and c the number of species observed in land-use Y.

3.6 Results

We found 407 plant species from 104 families (135 tree spp. from 49 families, 71 shrub spp. from 31 families, 130 herb spp. from 49 families and 71 climber spp. from 31 families) during the floral analysis (Table 3.3 and Appendix I). The investigation demonstrate that Fabaceae is the most dominant family representing 30 species (7% of total flora) followed by Cucurbitaceae, Euphorbiaceae (16 spp. each), Malvaceae, Apocynacaeae, Asteraceae (14 spp. each), Caesalpiniaceae, Convolvulaceae, (13 spp. each), Poaceae, Acanthaceae (12 spp. each), and Mimosaceae, Rubiaceae, Verbenaceae (10 spp. each). The above 13 families represent 185 species (44%) of flora in the study area. Forty-one families were represented by a single species, while 28 families were represented by five or more than five species, which contributed about 67% (281 spp.) of the flora of the study area.

3.6.1 Vegetation structure and composition

The forest and homegarden land-use types contribute 95% flora of the entire study area and rest of the flora composed of mangrove and associate species. Overall, in the study areas, 268 species were found in forest vegetation, 206 species in homegardens, 26 species in mangrove and 40 species in the casuarina plantation. The details of the land-use wise structure and composition of the floral species are given below.

In forests, 268 plant species were found (64% of total spp.) belonging to 82 families, which was composed of 76 tree species (34 families), 39 shrub species (24 families), 100 herbaceous species (44 families) and 53 climber species (19 families). Overall, the highest number of species was represented by the Fabaceae family (23 spp.) followed by Convolvulaceae (12 spp.), Asteraceae and Euphorbiaceae (11 spp. each) and Acanthaceae (10 spp.). These five families together accounts for 25% species richness of the forest vegetation (Table 3.3 and Appendix I).

For the tree vegetation, the Mimosaceae and Moraceae families accounts for the highest tree number species (6 spp. each) followed by Anacardiaceae, Caesalpiniaceae, Combretaceae, Euphorbiaceae and Rubiaceae (5 spp. each). About 37% of the tree species richness was contributed by members of these seven families. Shrub species richness in forest land-use types was dominated by 18 species (46% of total forest land shrub spp.) belonging to Apocynaceae, Acanthaceae, Euphorbiaceae, Phyllanthaceae, Rubiaceae and Vebenaceae (3 spp. each). The Asteraceae family provides the highest number of herbaceous species (10 spp.) followed by Fabaceae (9), Malvaceae (7), Acanthaceae and Scrophulariaceae (five spp. each). These five families contribute 36% of the species of forest herbaceous flora. Species of the climber type vegetation was found bin 19 families in the forest land-use type. Convolvulaceae was the most dominant family (11 spp.) followed by Fabaceae (nine spp.), Asclepiadaceae (six spp.) and Cucurbitaceae (five spp.). The result indicates that these four families represent 32% climber species in the forests (Appendix I).

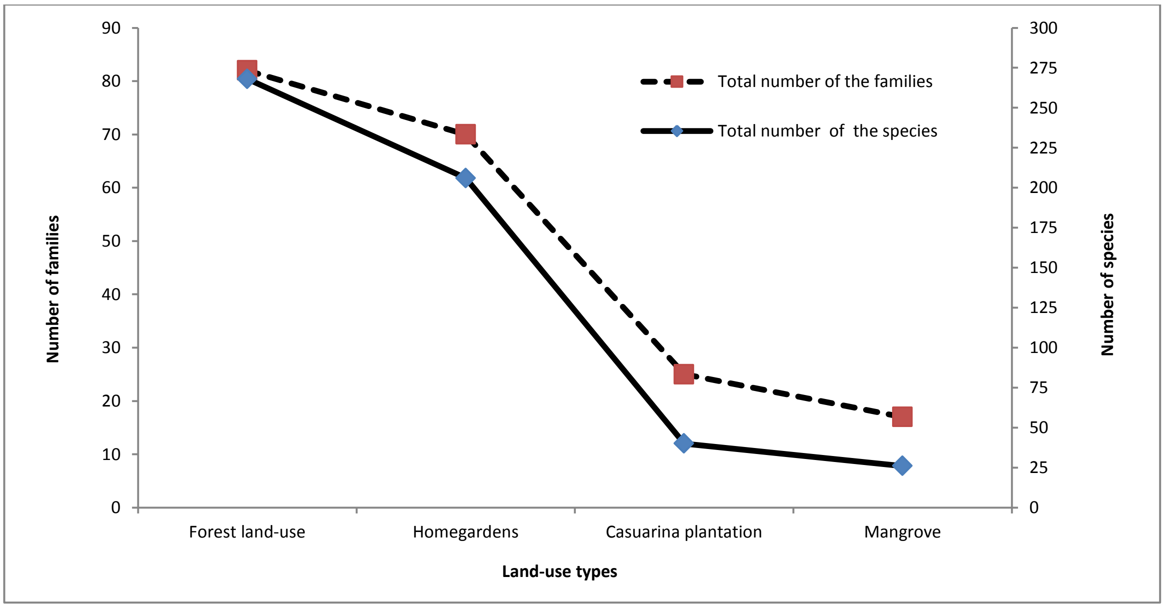


Fig. 3.4: Graph showing number of plant species and number of families at four land-use types in south Konkan coast of Maharashtra.

Next to forest, the highest species richness was recorded in the homegardens. Result of the floristic analysis of the study area showed that the homegardens are the home for 206 plant species (49% of total spp.) belonging to 70 families. The vegetation consists of 88 tree, 48 shrub, 44 herb and 26 climber species. The highest number of species belongs to Fabaceae family (13 spp.) followed by the Apocynaceae and Cucurbitiaceae (11 spp. each), Ceasalpiniaceae (10), Poaceae (9) and Euphorbiaceae, Moraceae and Verbenaceae (8 spp. each). These eight families cover 38% of total richness of the homegarden flora, while 32 families were represented by a single species (Table 3.3).

The tree vegetation accounts for 82 species from 36 families (51% of total families recorded in homegarden), and the highest number of species were belong to family the Moraceae (8) followed by Caesalpiniaceae (7), Rutaceae (6) and Anacardiaceae, Combretaceae and Myrtaceae (5 spp. each). These six families represent about 36% of tree flora of the homegarden. The homegarden flora contained 46 shrub species from 21 families. Venbenaceae was the most dominant family representing 6 species of shrubs in the homegarden flora followed by Apocynaceae and Euphorbiaceae (5 spp. each). The herbaceous vegetation was composed of 44 herb species from 26 families. With the highest number of species belongs to Poaceae (5 spp.) family followed by Fabaceae (4 spp.) and Solanaceae (3 spp.). Withinn the herbaceous vegetation, 26 climber species belonging to 11 families were recorded in the homegarden floristic survey. Eleven species were from the Cucurbitaceae family, which contribute 42% climber species richness of the homegarden land-use type (Appendix I).

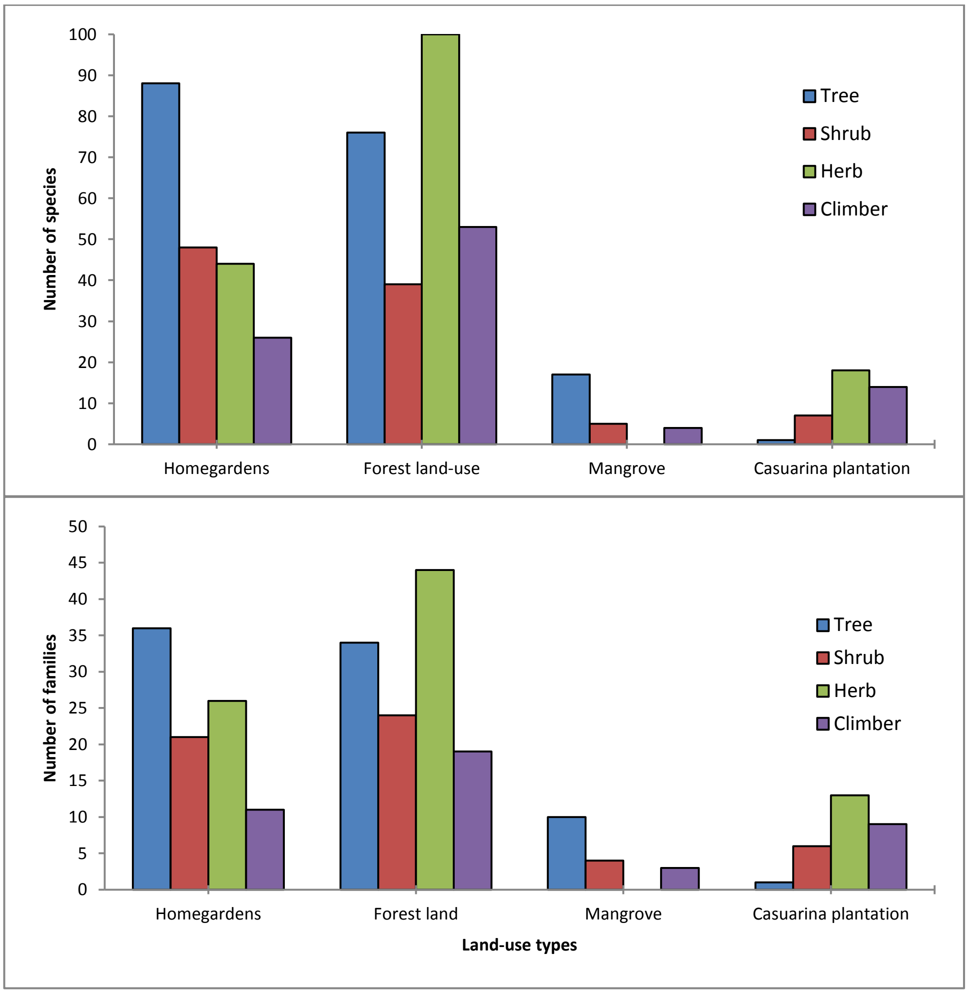


Fig. 3.5 Graph showing number of plant species and number of families at four land-use types in south Konkan coast of Maharashtra.

The mangrove vegetation was composed of 26 mangrove and associate species belonging to 16 families (Table 3.3 and Appendix I). The highest number of plant species belongs to the Rhizophoraceae family (6 spp.) followed by the Fabaceae (3 spp.). These two families contribute 35% of mangrove species richness; however, eleven families were represented by a single species. The mangrove vegetation was composed of 17 tree, 5 shrubs and 4 climber species. The true mangrove species contribute 42% (11 spp.) species richness and rest of the flora consists of mangrove-associated species. The mangrove species belongs to Rhizophoraceae (six spp.), Avicenniaceae (two spp.), and Myrsinaceae, Sonarretiaceae and Acanthaceae (one spp. each).

In the casuarina monoculture plantations in addition to the *Casuarina equisetifolia,* 39 other species were found. These were 7 shrubs, 18 herbs and 13 climber species belonging to 25 families. The plantations contained 10% species of the species found in the whole study area. The family with the largest number of species was the Asclepiadaceae with five species followed by Asteraceae, Convolvulaceae, Fabaceae, Malvaceae and Poaceae with three species each. These six families contribute fifty per cent of the understory flora of the casuarina plantation (Table 3.3 and Appendix I).

3.6.2 Vegetation components, Family and species representation

The component wise floristic structure and composition in different species for the whole study area is given in Table 3.3. The tree species contribute 33% of the total flora of the study area, providing 136 species from 49 families. Moraceae family represents the highest number of species (9 spp.) followed by Mimosaceae (8 spp.), Anacardiaceae, Caesalpiniaceae, Euphorbiaceae (7 spp. each) and Myrtaceae, Combretaceae, Rhizophoraceae, Rubiaceae and Rutaceae (6 spp. each). These ten families account 49% of the tree components. However, about 47% of the families were represented by a single tree species.

Table 3.3: Showing component wise distribution of species and families in the study area

Total number of quadrates studied	Number of species	Number of families	Vegetation components	Number of species	Number of families
125	407	104	Tree	135 (33%)	49 (47%)
			Shrub	71 (17%)	31 (30%)
			Herb	130 (32%)	49 (47%)
			Climber	71 (17%)	22 (21%)

In total, 72 shrub species (18% of the total flora) from 31 families (21% of 104 families) were recorded in the study area. Apocynaceae and Verbenaceae families are the largest families (7 spp. each) followed by Euphorbiaceae (6 spp.), Acanthaceae and Fabaceae (5 spp. each). Among observed shrub species these five families accounts for 39% of the shrub flora. The other important families contributing to the species richness are Caesalpiniaceae, Malvaceae, Oleaceae, Phyllanthaceae, Poaceae and Rubiaceae. Thirteen families were represented by single shrub species, while 14 families were represented by five or more than five species.Overall, 130 herbaceous species (32% of the total flora) from 49 families were recorded in the different land-use types in the study area. Members of the Asteraceae family (12 spp.) contributed the most to the species richness of the herbaceous component followed by Fabaceae (10 spp.), Malvaceae (9 spp.), Poaceae (8 spp.), Acanthaceae (6 spp.) and Araceae, Lamiaceae, Liliaceae and Scrophulariaceae (5 spp. each). These nine families represents 49% (65 spp.) herbaceous flora while 22 families were represented by a single species. Seventy-two climber species (17% of total floral composition) belonging to 22 families were recorded in the forest land-use, mangrove, homegardens and the casuarina plantation sites. Cucurbitiaceae was the most dominant family representing 16 liana species followed by Convolvulaceae (12 spp.), Fabaceae (10 spp.), Aselepidiaceae (6 spp.) and Vitaceae (4 spp.). These five families contribute 66% (48 spp.) of the climber flora of the study area and thirteen families were represented by a single climber species.

3.6.3 Frequency distribution

An attempt has been made to determine uniformity or heterogeneity within the vegetation type. The data on frequency distribution in vegetation at different land-use types is shown Fig. 3.7-3.11. The identified species segregated in to various Raunkiaer's normal frequency classes (Fig. 3.6 - A, B, C, D and E) and found that the species with low frequency values are most numerous. In the forest, homegarden and mangrove land-use types the frequency class A is comparatively high. However, in the casuarina plantation frequency class B showed high number of species. We compared the obtained frequency diagram with Raunkiaer's normal frequency diagram, the curves do not seem to be J shaped, and it suggests that there was no uniformity within these vegetation types.

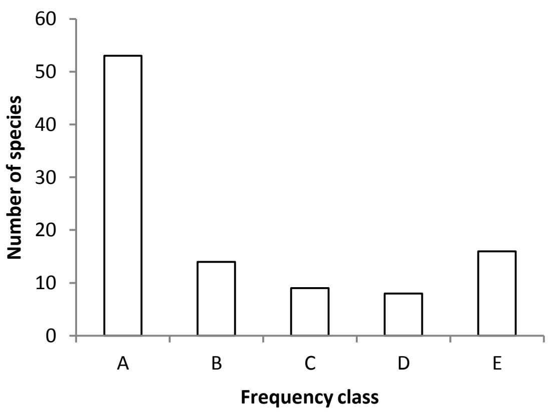


Fig. 3.6: Raunkiaer's normal frequency diagram

Similarly, we determined frequency distribution for tree, shrub, herb and climber flora in each land-use type (Fig. 3.6 to 3.9). Overall results indicate that the largest number of species was recorded in lower frequency class (A). In most of the vegetation component none of the species was observed in frequency class E. Generally, it is observed that the number of the species gradually decreased from frequency class A to D and it never seems to be increase from frequency class D to E. This suggests that the component wise frequency distribution at each land-use type exhibits heterogeneity in vegetation. Theses frequency diagrams does not exhibit J shaped curve.

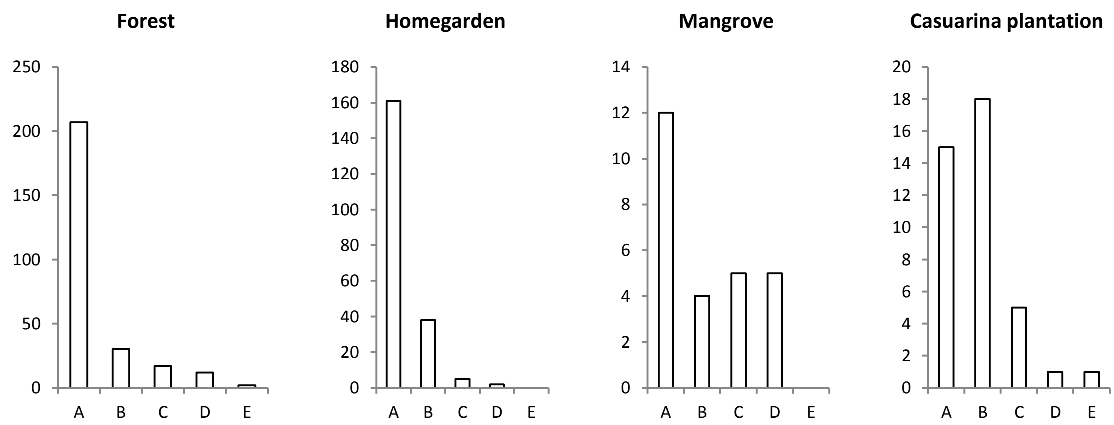


Fig. 3.7: Frequency diagram of different land-use types

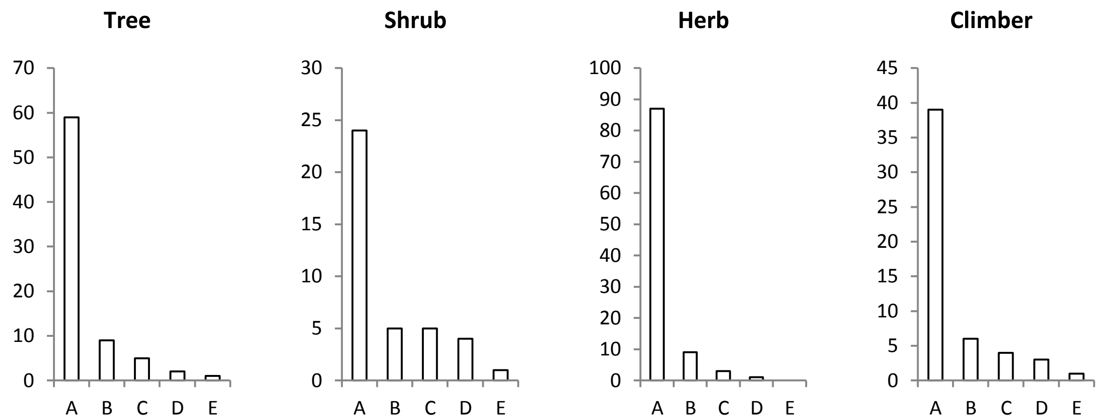


Fig. 3.8: Frequency diagram showing number of species in the forest land-use types

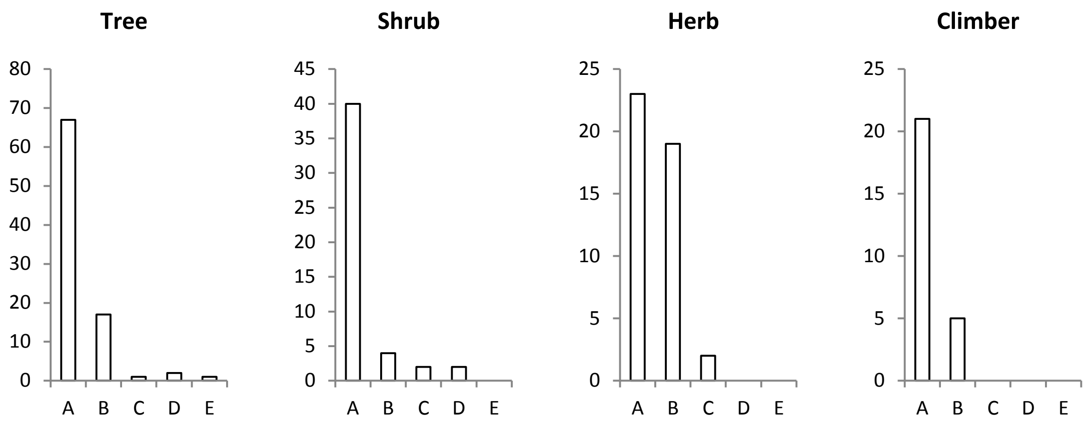


Fig. 3.9: Frequency diagram showing number of species in the homegardens

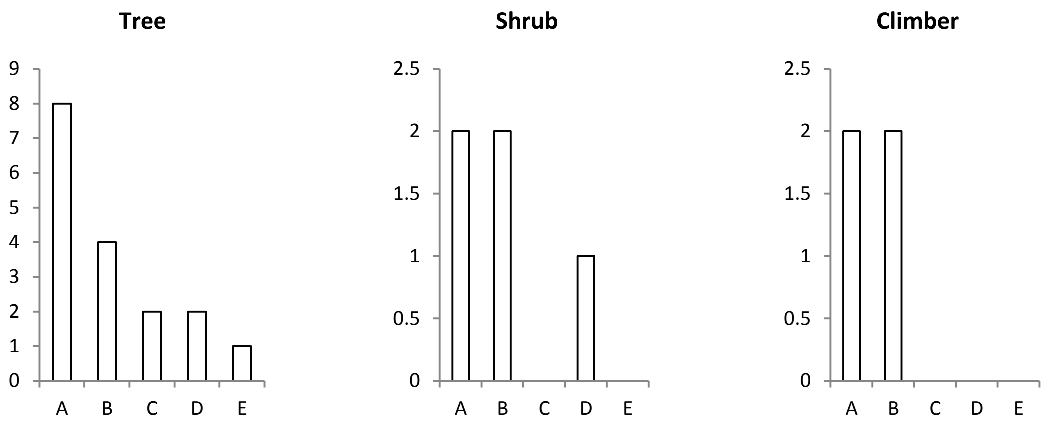


Fig. 3.10: Frequency diagram showing number of species in the mangrove

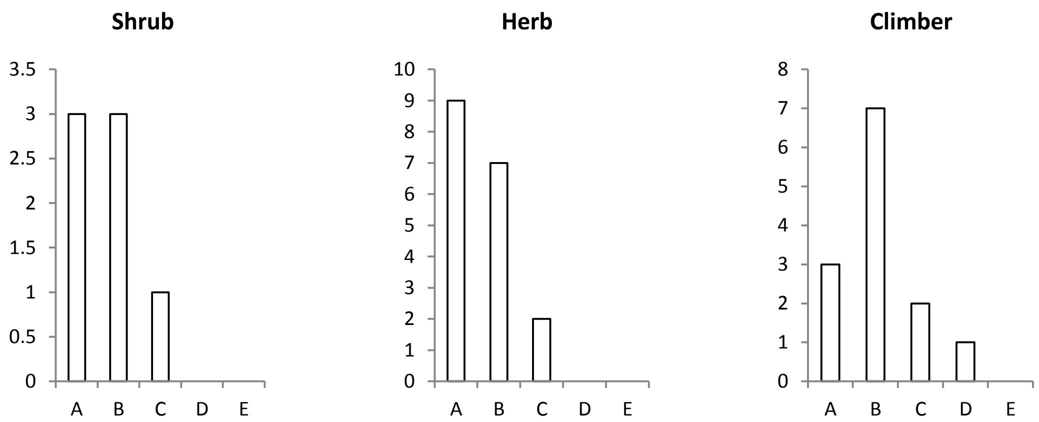


Fig. 3.11: Frequency diagram showing number of species in the casuarina plantation

3.6.4 IUCN conservation status

An attempt has been made to determine the conservation status of the plant species recorded in the study area. Of total 407 plant species recorded in the study area only 36 species were assessed in the IUCN Red List of threatened species; 101 species has not yet been assessed for the IUCN Red List of the Threatened species, but are in the species 2000 and ITIS Catalogue of Life and remaining 270 species has either not yet been assessed for the IUCN Red List, and also are not in the Species 2000 and ITIS Catalogue of Life (Fig. 3.12, 3.13 and Appendix 8.1).

Fig. 3.12 shows that out of 36 species 24 plant species has been grouped under least concern status (Appendix 8.1). Three species such as *Delonix regia* (Hook.) Raf., *Pterocarpus marsupium* L. and *Rotala floribunda* L. are listed under vulnerable category. *Mangifera indica and Myristica fragrans* Houtt., has been listed under data deficient category. However, remaining 7 species are listed under lower risk categories, in which 4 species such as *Wrightia tinctoria* R. Br. (Hook. f.) Pichon., *Calophyllum inophyllum* L., *Woodfordia fruticosa* L., *Picea abies* L. has been listed under lower risk/least concern category; *Catharanthus roseus (L.) G. Don*., has been declared as lower risk/threatened; *Nerium oleander* has been listed under lower risk/ conservation dependent and *Platycladus orientalis* L. has been listed under lower risk/ near threatened category.

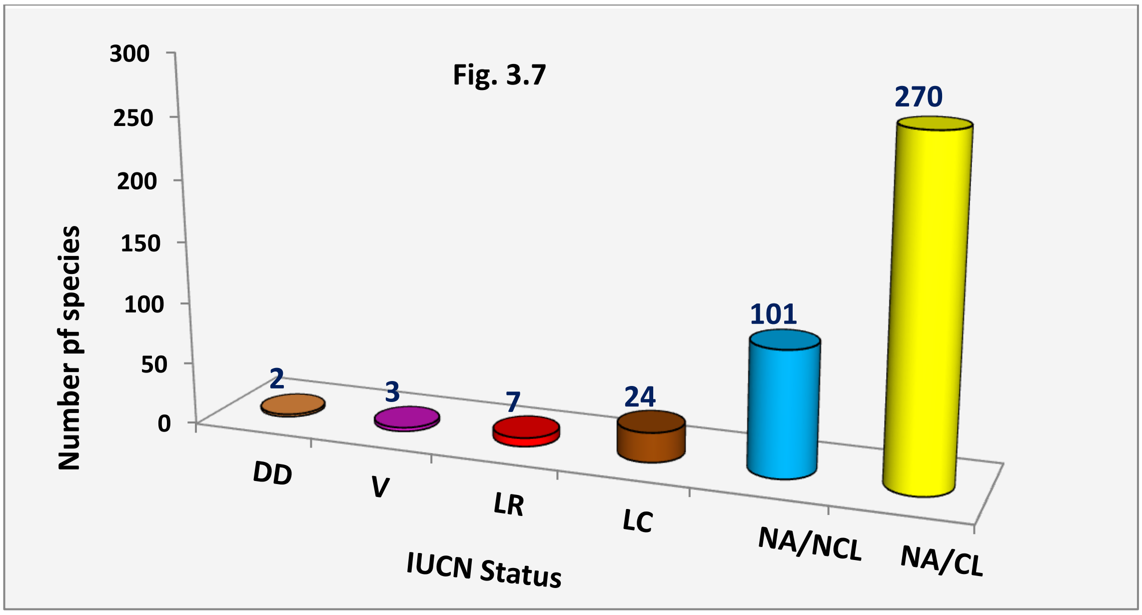


Fig. 3.12: Graph showing number of plant species belonging to different IUCN categories in the south Konkan coast of Maharashtra. NA/CL = Not yet been assessed but listed in the catalogue of Life, NA/NCL = either not yet been assessed and also not listed in the catalogue of life, LC = Least concerned, V = Vulnerable, DD = Data Deficient, LR = Lower risk

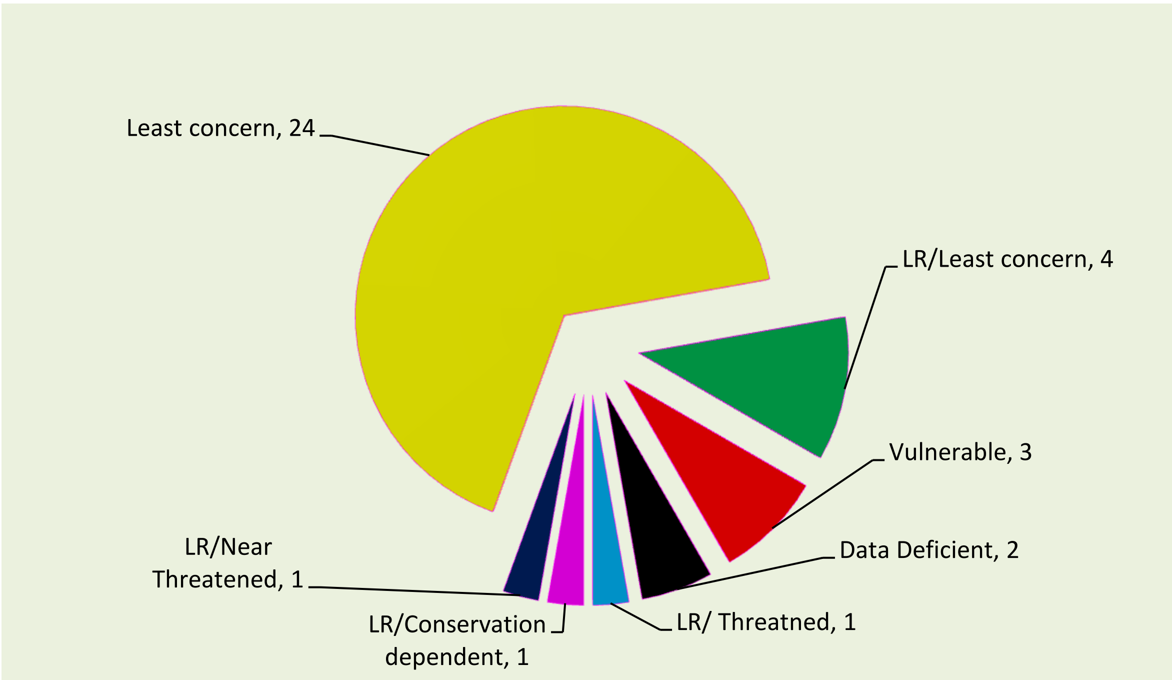


Fig. 3.13: Out of 407 plants only 36 plant species were assessed by IUCN. Pie chart shows numerical distribution of these plants species under different categories.

3.6.5 Plant density ha^{-1}

The data on plant density per hectare are shown in Table 3.4. Overall, the high plant density (36762 plants ha^{-1}) was recorded in forest land-use flowed by the casuarina monocultures (9928 plants ha^{-1}) and homegardens (2286 plants ha^{-1}). However, the lowest density was observed in mangrove vegetation (444 plants ha^{-1}). The result show significant variation in density ha^{-1} for tree, shrub, herb and climber elements in fours and-use types. The highest tree density (264 plants ha^{-1}) was recorded in forest vegetation followed by mangrove (200 plants ha^{-1}) and homegardens (131 plants ha^{-1}).

The high shrub density (1300 plants ha^{-1}) was recorded in forest vegetation followed by mangrove (170 plants ha^{-1}). However, the casuarina plantations and homegardens exhibit similar shrub density (108 and 107 ha^{-1}, respectively). The herb density was highest in forest vegetation (34300 plants ha^{-1}) followed by the casuarina monocultures (9500 plants ha^{-1}) and homegardens (1636 plants ha^{-1}). The highest climber density (898 plants ha^{-1}) was recorded in forest vegetation followed by homegardens (412 plants ha^{-1}). However, it was lowest in mangrove vegetation (74 plants ha^{-1}).

In forest vegetation, the tree species like *Terminalia paniculata, Bridelia retusa* and *Memecylon umbellatum* showed high density (33, 29 and 26 plants ha^{-1}). The most dominant shrubs flora of forest vegetation composed of *Abelmoschus lampus* (199 stem ha^{-1}), *Holarrhena pubescens* (196 plants ha^{-1}), *Leea macrophylla* (175 plants ha^{-1}) and *Carissa congesta* (116 plants ha^{-1}). The estimates of herbaceous density in forest vegetation was contributed by five species (*Cassia tora, Senecio bombayensis, Daedalcanthus roseum, Impatiens tomentosa* and *Euphorbia concanensis* with density 4360, 2780, 2680, 2460 and 2240 plants ha^{-1}). However, the highest climber density was exhibited by *Hemidesmus indicus, Smilax ovalifolia, Dioscorea bulbifera* and *Calycopteris floribunda* (116, 96, 80, 78 plants ha^{-1}, respectively).

In homegardens, the tree density estimates were highest for *Cocos nucifera, Mangifera indica, Dendrocalamus strictus, Psidium guajava, Areca catechu* and *Anacardium occidentale* (18, 10, 8, 6, 5 and 5 plants ha^{-1}). The prominent dense shrub species in homegardens are *Jatropha curcas* (13 plants ha^{-1}) followed by *Musa paradisiaca* (11 plants ha^{-1}), *Hibiscus rosa-sinensis* (8 plants ha^{-1}), *Gliricidia sepium* and *Justicia adhatoda* (7 plants ha^{-1} each). The highest herbaceous flora density in the homegardens was contributed by *Colocasia esculenta, Tagetes erecta, Impatiens oppositifolia, Arachis hypogaea* and *Ananas comosus* (183, 112, 75, 66, and 66 plants ha^{-1}). However, the most dense climber species are *Hemidesmus indicus* (6 plants ha^{-1}), *Trichosanthes cucumerina* (5 plants ha^{-1}), *Piper longum, Piper nigrum* and *Cucumis sativus* (4 plants ha^{-1} each).

The mangrove tree vegetation characterized by high dense species like *Sonneratia caseolaris, Avicennia officinalis, Excoecaria agallocha (L.), Aegiceras corniculatum* and *Rhizophora mucronata* (35, 32, 25, 20 and 19 plants ha^{-1}, respectively). The shrub vegetation in mangrove was dominated by *Acanthus ilicifolius* alone with 196 plants ha^{-1}. While, predominant climber species were *Caesalpinia crista* (L.) followed by *Derris scandens* and *Cryptolepis buchananii* with density 30, 18 and 14 19 plants ha^{-1}, respectively.

The casuarina monoculture characterized with 107 plants ha^{-1} with dominant shrub species like *Calotropis procera* (36 plants ha^{-1}), *Chromolaena odorata* and *Desmodium gangeticum.* The monocultures exhibit high herb density of *Sonchus oleraceus, Sonchus asper* and *Achyranthes aspera* with stem density 2700, 1600 and 900 ha^{-1}. However, the most predominant climbers are *Ipomoea pes-caprae* (104 plants ha^{-1}) and *Hemidesmus indicus* (40 plants ha^{-1}).

Table 3.4: Showing plant density per hectare in four land-use types

Land-use	Density ha^{-1}	Component	Density ha^{-1}
Casuarina plantation	9928	Tree	107
		Shrub	108
		Herb	9500
		Climber	328
Forest land-use	36762	Tree	264
		Shrub	1300
		Herb	34300
		Climber	898
Homegardens	2286	Tree	131
		Shrub	107
		Herb	1636
		Climber	412
Mangrove	444	Tree	200
		Shrub	170
		Herb	-
		Climber	74

3.6.6 Overall dominance and distribution pattern of the plant species

We identified top dominant and rare species assemblage from each land-use type. The data on importance value index (IVI) for tree, shrub, herbaceous and climber component within each land-use type is summarized in Appendix II to V. The result showed that *Cassia tora* is the most dominant plant species with 7.3 IVI value in forest land-use followed by *Abelmoschus lampus* (7.2), *Holarrhena pubescens* (7.2), *Leea macrophylla* (6.8), *Senecio bombayensis* (5.8), *Memocylon umbellatum* (5.3), *Bridelia retusa* (5.2), *Carrisa congesta* (5.1), *Impatiens tomentosa* (4.9) and *Daedalcanthus roseum* (4.8). These ten species accounts for 20% dominance of the forest land-use flora. However, *Trichosanthes nervifolia, Ammannia muliflora, Martynia annua, Oldenlandia corymbosa, Physalis minima*, *Tephrosia tinctoria*, *Impatiens oppositifolia, Sopubia trifida* India *Tephrosia purpurea* are the least dominant species of the forest land-use type (Appendix II). The photographs of the some tree, shrub, herb and climber found in the study area are shown in Appendix XV.

Colocasia esculenta (9.2 IVI) was the most dominant species in homegarden followed by *Cocos nucifer* (8.7), *Mangifera indica* (7.0), *Musa paradisiaca* (6.5), *Tagetes erecta* (6.4), *Jatropha curcas* (6.4), *Oryza sativa* (5.8), *Hibiscus rosa-sinensis* (5.4), *Psidium guajava* (4.8) *and Impatiens oppositifolia* (4.8). The least dominant species are *Magnolia champaca, Ficus elastic*, *Ficus bengalensis, Haldina cordifolia, Mitragyna parvifolia*, *Premna mucronata, Casuarina equisetifolia, Terminalia arjuna, Terminalia paniculata, Artocarpus altilis* and *Pimenta dioica* (Appendix III).

Mangrove vegetation was dominated by mangrove species (IVI with descending order – Appendix IV) such as *Acanthus ilicifolius* (35.7), *Sonneratia caseolaris* (27.8), *Avicennia officinalis* (25.9), *Excoecaria agallocha* (21.6), *Aegiceras corniculatum* (18.8), *Rhizophora mucronata* (18.5), *Bruguiera gymnorrhiza* (16.2), *Avicennia marina* (14.7), *Rhizophora mangle* (14.4) and *Rhizophora apiculata* (13.2). Overall, these species account 69% flora of the mangrove vegetation. While, least dominance was exerted by mangrove associate species like, *Vitex negundo Thespesia populnea, Acacia auriculiformis, Ziziphus mauritiana, Calophyllum inophyllum* and *Cordia dichotoma.*

Sonchus oleraceus, Ipomoea pes-caprae, Sonchus asper, Hemidesmus indicus, Achyranthes aspera, Calotropis procera, and Tylophora dalzellii dominated the casuarina monoculture. However, the least dominance was shown by *Lantana camara, Barleria prionitis, Jatropha curcas, Drimia indiaca, Hibiscus lampus* and *Tacca leontoletaloides* (Appendix V).

3.6.7 Component wise dominance of the plant species at each land-use type

We compared component wise dominance of the species at each land-use type. We identified *Terminalia paniculata* as the most dominant tree species of forest land-use followed by *Bridelia retusa, Memecylon umbellatum, Terminalia elliptica, Ficus benghalensis, Morinda citrifolia* and *Mangifera indica.* However, *Azadirachta indica, Gardinia latifolia, Xantolis tomentosa, Ficus hispida, Erythrina variegate* and *Annona reticulata* are the rare species in forest land-use type. *Abelmoschus lampus* is the most dominant shrub species followed *Holarrhena pubescens, Leea macrophylla, Leea macrophylla, Carissa congesta, Ixora coccinea, Helicteres isora, Microcos paniculata, Lantana camara, Desmodium gangeticum* and *Ziziphus rugosa.* The least dominant shrubs recorded in the forest land-use were *Woodfordia fruticosa, Justicia adhatoda, Barleria involucrata, Mussaenda glabrata, Opuntia elatior, Ensete superbum* and *Osyris quadripartita.* The herbaceous flora of the forest land-use is dominated by *Cassia tora* followed by *Daedalcanthus roseum, Senecio bombayensis, Impatiens tomentosa, Euphorbia concanensis, Urena sinuate, Tacca leontoletaloides* and *Nephrolepis spp.* The less abundant herb species identified are *Fimbristylis littoralis, Physalis minima, Abutilon* *indicum, Tephrosia tinctoria, Impatiens oppositifolia, Sopubia trifida, Mimosa pudica* and *Tephrosia purpurea.* The study revealed that *Hemidesmus indicus* was the most dominant climber species followed by *Smilax ovalifolia, Dioscorea bulbifera, Calycopteris floribunda, Jasminum malabaricum, Tylophora dalzellii* and *Mucuna pruriens.* However, *Dioscorea pentaphylla, Holostemma annulare, Argyreia elliptica, Derris elliptica, Luffa acutangula* and *Trichosanthes nervifolia* are the rare climbers identified in forest land-use type.

The homegarden floristic analysis indicates high diversity in dominance of tree, shrub, herb and climber species. The most dominant tree species in the homegarden land-use type are *Cocos nucifera, Mangifera indica, Dendrocalamus strictus, Psidium guajava, Areca catechu, Anacardium occidentale, Artocarpus heterophyllus, Garcinia indica, Murraya koenigii* and *Tectona grandis.* The low dominance was found for the less frequent tree species like *Magnolia champaca, Ficus elastic, Ficus bengalensis, Haldina cordifolia, Mitragyna parvifolia, Casuarina equisetifolia, Terminalia arjuna, Terminalia paniculata, Artocarpus altilis* and *Pimenta dioica*. The most dominant species in the shrub vegetation were *Jatropha curcas, Musa paradisiaca, Hibiscus rosa-sinensis, Gliricidia sepium, Justicia adhatoda* and *Cajanus cajan. Cassia alata, Acalypha wilkesiana, Lantana camara, Opuntia elatior, Sesbania bispinosa, Microcos paniculata, Clerodendrum chinense* and *Premna mucronata* are the rare shrub species of homegarden. The most dominant herbaceous flora of homegarden constituted with *Colocasia esculenta* followed by *Tagetes erecta, Oryza sativa, Impatiens oppositifolia, Arachis hypogaea* and *Ananas comosus.* However, the species like *Leonotis nepetifolia, Rauvolfia serpentina, Hymenocallis littoralis, Cymbopogon citratus, Maianthemum purpureum* and *Vetiveria zizanioides* are the least dominant herbaceous plant species.

Among the climbers identified in the homegardens *Hemidesmus indicus, Trichosanthes cucumerina, Piper longum, Piper nigrum, Cucumis sativus, Smilax ovalifolia* constitute highest dominance and the species like *Dioscorea bulbifera, Caesalpinia bonduc, Coccinia grandis, Passiflora edulis, Solena amplexicaulis, Dioscoria alata* and *Cryptolepis buchananii* are the rare and the least dominated climbers.

We recorded rich diversity in mangrove, where *Sonneratia caseolaris* is the most prominently occurring mangrove tree species followed by *Avicennia officinalis, Excoecaria agallocha* and *Aegiceras corniculatum.* The mangrove associate species such as *Hibiscus tiliaceus, Ziziphus mauritiana, Calophyllum inophyllum, Acacia auriculiformis* and *Cordia dichotoma* showed low dominance. *Acanthus ilicifolius* is the most dominant mangrove shrub which accounts more than half IVI value. While, *salvadora persica, Vitex negundo, Clerodendrum inerme* and *Crotalaria verrucosa* are the other shrub species identified in mangroves. *Caesalpinia crista and Derris scandens are the dominant* climbers of the mangrove vegetation.

The dense to moderately dense casuarina monocultures were dominated by *Calotropis procera* shrub. The species like *Lantana camara, Barleria prionitis* and *Jatropha curcas* are the least dominant shrubs. We identified *Sonchus oleraceus, Sonchus asper* and *Achyranthes aspera* herb plants are most dominant species; however *Crotolaria verrucosa, Drimia indiaca, Hibiscus lampus* and *Tacca leontoletaloides* are the less dominant herbaceous flora. The climbers of the monocultures were dominated by *Ipomoea pes-caprae* followed by *Hemidesmus indicus, Tylophora dalzellii* and *Cucumis setosus.* However, *Cardiospermum halicacabum, Mucuna pruriens* and *Cocculus hirsutus* are the rare climbers.

3.6.8 Rarefaction and floristic richness in different land-use types

Species accumulation curves for the plant species were estimated for the different land-use types and for tree, shrub, herb and climber components at each land-use type using EstimateS 8.2.0 software. The cumulative number of species encountered with increase in number of quadrates studied was plotted against abundance. The curves obtained approached an asymptotic value within studied quadrates suggests adequate sampling in a particular land-use type. The overall land-use wise comparison of species accumulation curves exhibit variation in species richness in the study area. Fig. 3.14 shows the species accumulation curve showing species richness versus abundance at different land-use types. The high species richness (268 spp.) was observed in forest land-use followed by homegarden (206 spp.) and the Casuarina plantation (40 spp.). The mangrove vegetation showed lowest species richness (26 spp.).

Fig. 3.15 demonstrate land-use wise distribution pattern of species richness. We compared the species accumulation curves for different vegetation components at each land-use type. In forest, it is observed that herbaceous vegetation showed high species richness (100 spp.) followed by tree (76 spp.), climber (53 spp.) and shrub (39 spp.) vegetation. With the exception of the shrub vegetation, none of the curves reaches asymptote. The further rise in the curve indicates chances of discovering new species with increasing sampling efforts or the number of quadrates (Fig. 3.15_a).

The floristic analysis in homegarden indicate that the species richness was highest (88 spp.) for tree vegetation followed by shrub (48 spp.) and (44 spp.), while it was lowest for climber (26 spp.) vegetation. The species accumulation curves for tree, shrub, herb and climber species richness were similar (Fig. 3.15_b). It was observed that after gradual increase in number of species with increase in quadrate number, they reached an asymptotically. The findings indicate that the rarefaction curves for different vegetation component in homegarden land-use type are an asymptotic, which indicates that that sampling was adequate to meet the objectives of the study.

For the mangrove vegetation, the highest number of species was recorded in tree layer (17 spp.) and shrub and climber flora account 5 and 4 species, respectively. However, none of the herbaceous species was enumerated during the mangrove floristic survey. The species accumulation curved showed gradual increase in species number and reached an asymptote with increase in sample number (Fig. 3.15_c).

The Casuarina monoculture plantation showed high herb species richness (18 spp.) followed by climbers (13 spp.) and only seven shrub spp. were recorded. The species accumulation curves for different components of monoculture floristic components are shown in Fig. (3.15_d).

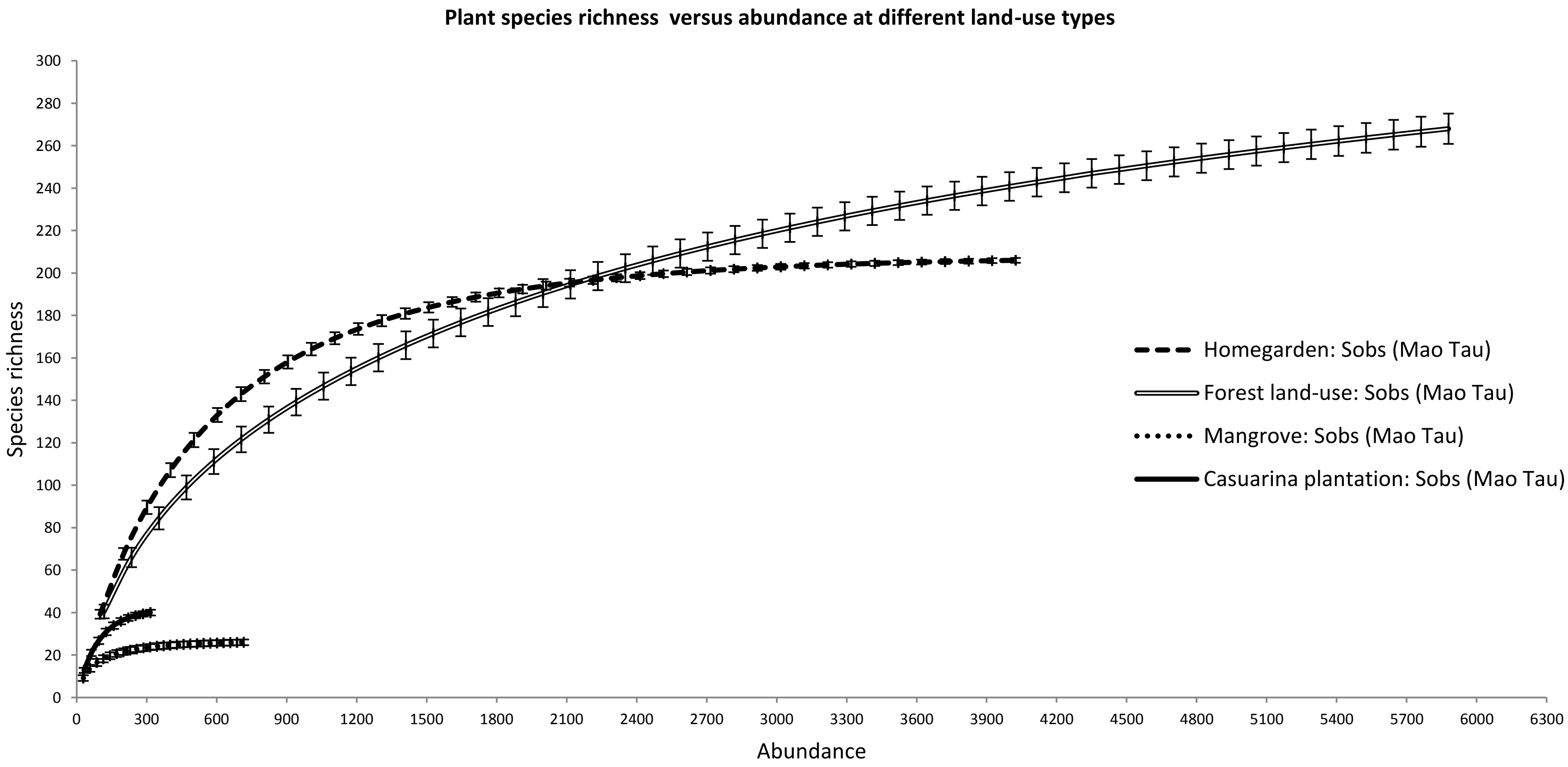


Fig. 3.14: Sample based species accumulation or rarefaction curves (S_{obs}) for the plant species assemblage's verses abundance at different land-use types. Each quadrate along with the curve corresponds to an estimate of mean cumulative number of the predicted distribution.

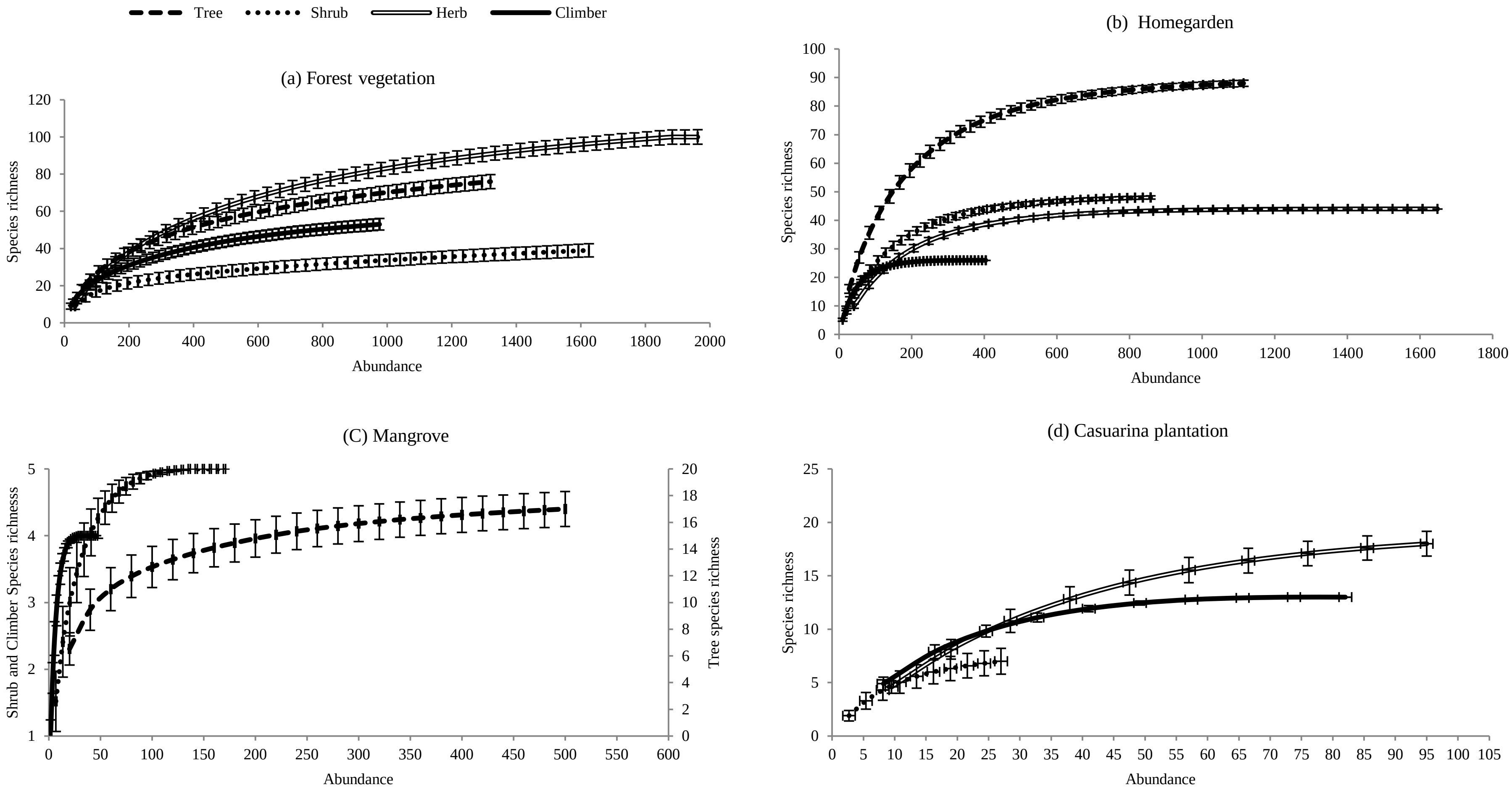


Fig. 3.15: Sample based species accumulation or rarefaction curves (Sobs) for the different components of the overall plant species assemblage's verses abundance in (a) the forest land-use, (b) homegardens, (c) mangrove and (d) the casuarina plantation vegetation.

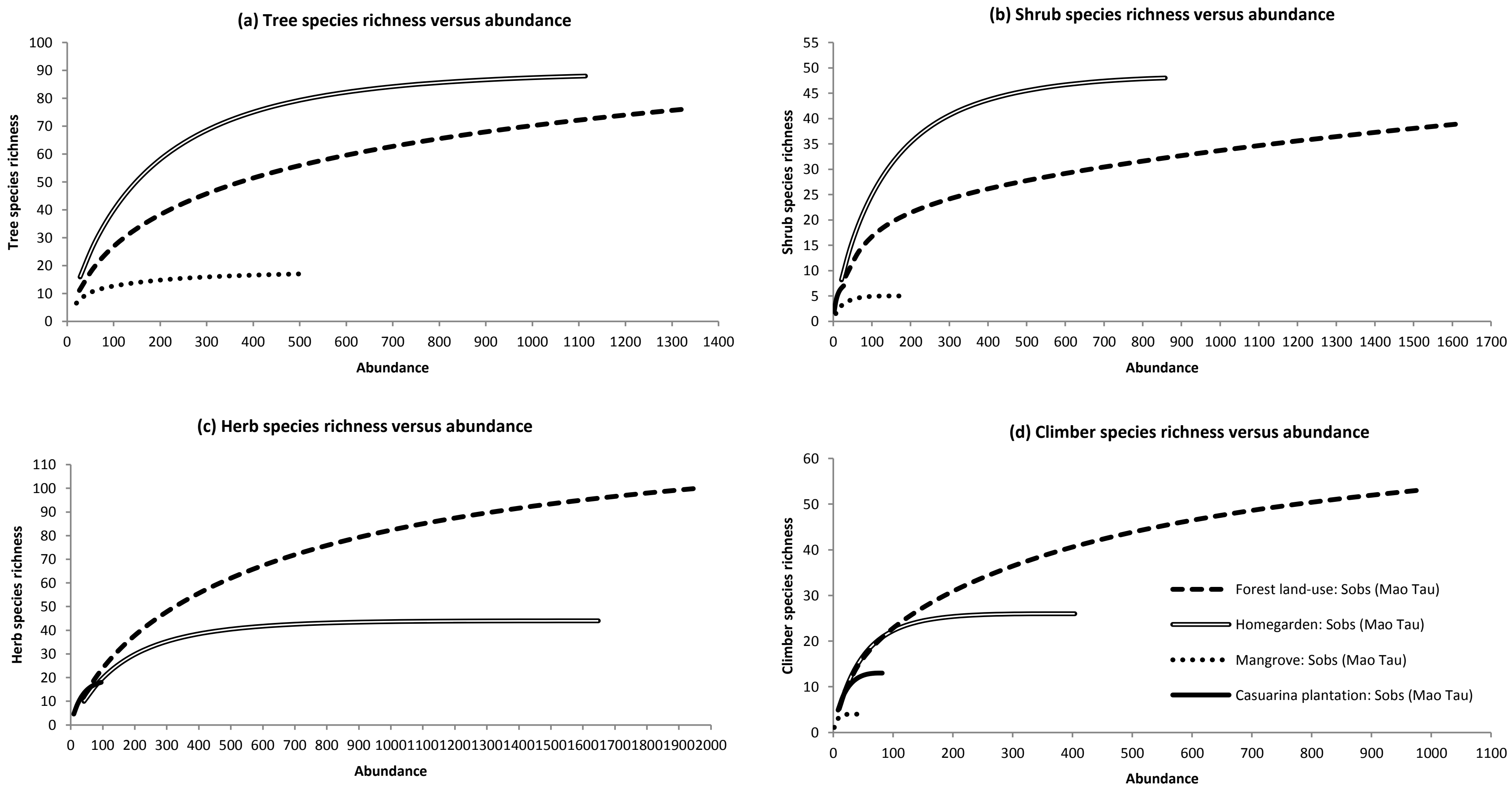


Fig. 3.16: Showing species richness versus abundance in different land-use type for (a) tree, (b) shrub, (c) herb and (d) climber vegetation

3.6.9 Vegetation component and floristic richness

An attempt has been made to compare vegetation component wise species richness at different land-use types (Fig. 3.16). The tree species richness was highest (88 spp.) in homegarden followed by forest land-use (76 spp.). The lowest number of tree species was recorded at mangrove vegetation. The species accumulation curve (see Fig. 3.16_a) for homegarden reached an asymptote with increase in sample number. The tree species accumulation curve for forest land-use lies below the homegarden curve with increase in number of additional species. It denotes chances of discovering new species, which might be increase tree species richness. Similarly, in mangrove vegetation the curve for tree species richness showed early flattening and no anymore possibility of discovering additional species. The similar trend of species richness was observed in case of shrub component at different land-use (Fig. 3.16_b).

Fig. 3.16_c and 3.16_d represents species accumulation curves for herb and climber components at different land-use types, respectively. For both components, the species richness was highest in forest land-use type followed by homegarden. The curves for both components at forest land-use indicate possibility of discovering new species with increase in sample number. However, on other hand the species number of herb and climber component increase gradually at homegarden land-use and reached asymptotically. Herb and climber species richness was lowest in the casuarina plantation and mangrove vegetation.

3.7 Floristic diversity analysis

The results reveal high Shannon Weaver index diversity and species evenness at forest and homegarden sites. However, theses diversity indices values were low for the casuarina monocultures and mangrove vegetation. The data on diversity parameters are summarized in Table 3.5, Fig. 3.18 to 3.18.

3.7.1 Shannon weaver index and species evenness

The data on diversity indices indicate high variation in Shannon Weaver index of diversity. Overall, the highest value of Shannon Weaver index of diversity (Fig. 3.17) was documented in homegarden land-use (4.76) followed by forest land-use type (4.56) and casuarina plantation (2.82) site. However, it was lowest (2.72) for the mangrove. Fig. 3.17 illustrates little overall variation in species evenness values at different land-use types in the study area. The highest species evenness (0.89) was recorded for forest land-use type followed by homegardens (0.82) and mangrove forest (0.82), and the lowest value of evenness was recorded for the casuarina plantation. As the species evenness is the measure of variance in abundances our result demonstrate that the variance in abundance was higher in the casuarina plantation, while in the forest land-use and homegarden sites the species were equally abundant.

An attempt has been made to calculate the Shannon Weaver diversity indices for different vegetation components in each land-use type (Table 3.5). Overall, the diversity values (H') ranges between 0.98 and 3.82. In the casuarina monocultures, the highest Shannon Weaver index was recorded for herbaceous component and lowest for shrub. The study revealed herbaceous vegetation has highest (3.67) Shannon Weaver index value in the forest land-use types followed by tree vegetation (3.36). However, the shrub component exhibit lowest (2.72) H' value.

In the homegardens, the highest diversity index was recorded for tree component (3.82) followed by herbaceous component (3.48) and the lowest for climber vegetation (3.00). As per as mangrove vegetation is concerned the high species diversity was noted for tree component (2.36) followed by climber component (1.31) and it was very low (0.96) for shrub component.

Table 3.5: Showing diversity indices of different land-use types

Land-use type	Component	Shannon Weaver index (H')	Simpsons index (λ)	Simpsons index of diversity (1-λ)	Species evenness (E)
Casuarina Plantation	Tree	-	-	-	-
	Shrub	1.71	0.21	0.79	0.88
	Herb	2.43	0.13	0.87	0.83
	Climber	2.26	0.15	0.85	0.88
	Overall	2.82	0.14	0.86	0.76
Forest land	Tree	3.36	0.06	0.94	0.78
	Shrub	2.72	0.09	0.90	0.74
	Herb	3.67	0.05	0.95	0.80
	Climber	2.97	0.08	0.92	0.75
	Overall	4.56	0.13	0.99	0.89
Homegardens	Tree	3.82	0.04	0.96	0.85
	Shrub	3.32	0.05	0.95	0.85
	Herb	3.48	0.04	0.96	0.92
	Climber	3.00	0.06	0.94	0.92
	Overall	4.76	0.02	0.98	0.82
Mangrove	Tree	2.36	0.11	0.89	0.89
	Shrub	0.96	0.54	0.46	0.59
	Herb	-	-	-	-
	Climber	1.31	0.29	0.71	0.94
	Overall	2.73	0.09	0.91	0.83

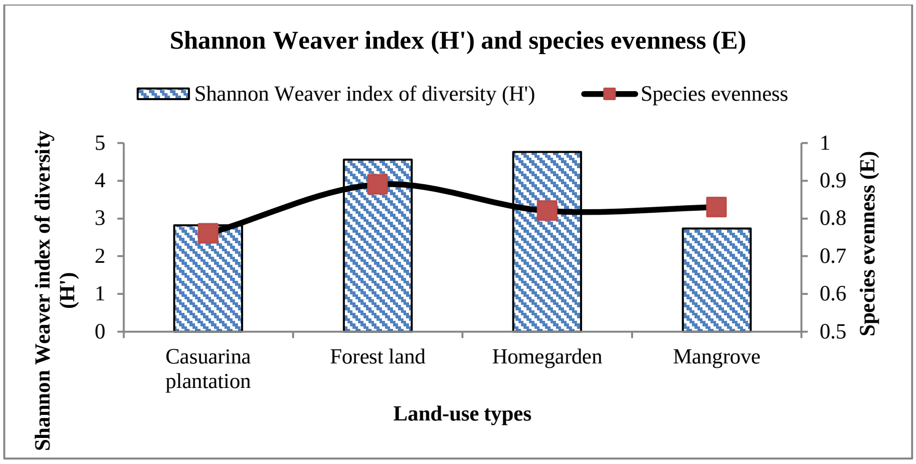


Fig. 3.17: Histogram showing Shannon weaver index and species evenness of four land-use types during the study period.

3.7.2 Simpson's index of dominance and diversity

The histogram (Fig. 3.18) reflects the Simpson's index of dominance and diversity at forest land-use, homegarden, mangrove and the casuarina plantations sites. The highest Simpson's index of dominance was found for the casuarina plantation (0.14) followed by forest land-use type (0.13) and mangrove (0.09), and it was lowest in homegardens (0.02). The Simpson's index of diversity was highest in forest land-use type (0.99) followed by homegarden (0.98). However, it was 0.86 in the Casuarina plantations. It is evident that the dominance values tend to zero it means there is high species diversity at all land-use type. The homegarden exhibits lowest dominance index, which suggests that the homegarden have high species diversity. Whereas the highest Simpson's index of diversity for forest land-use and homegardens reveal high species diversity, however there was no significant difference.

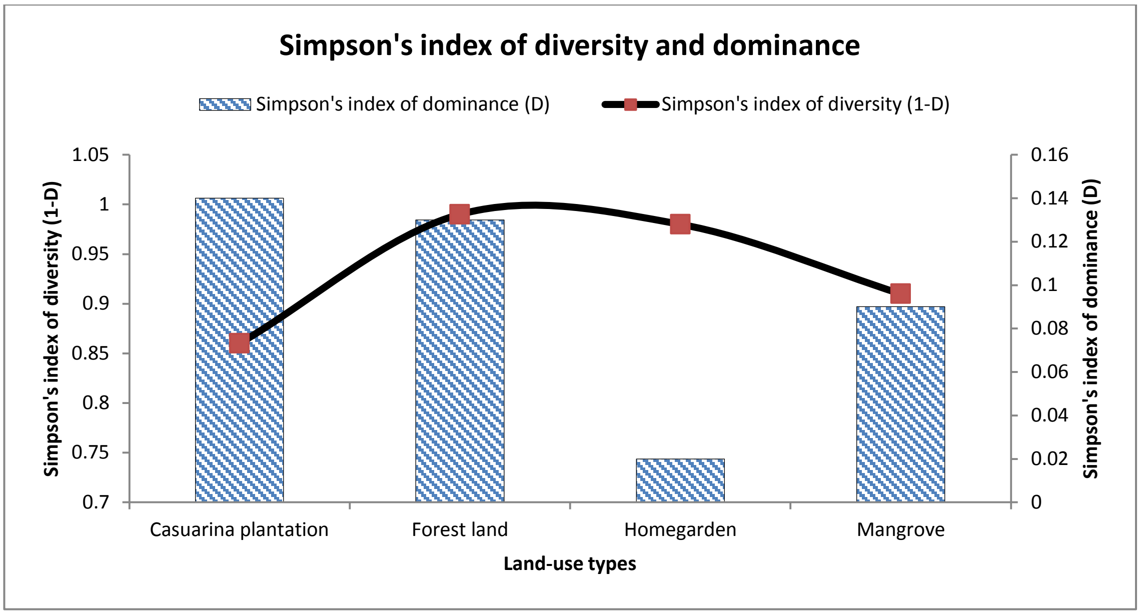


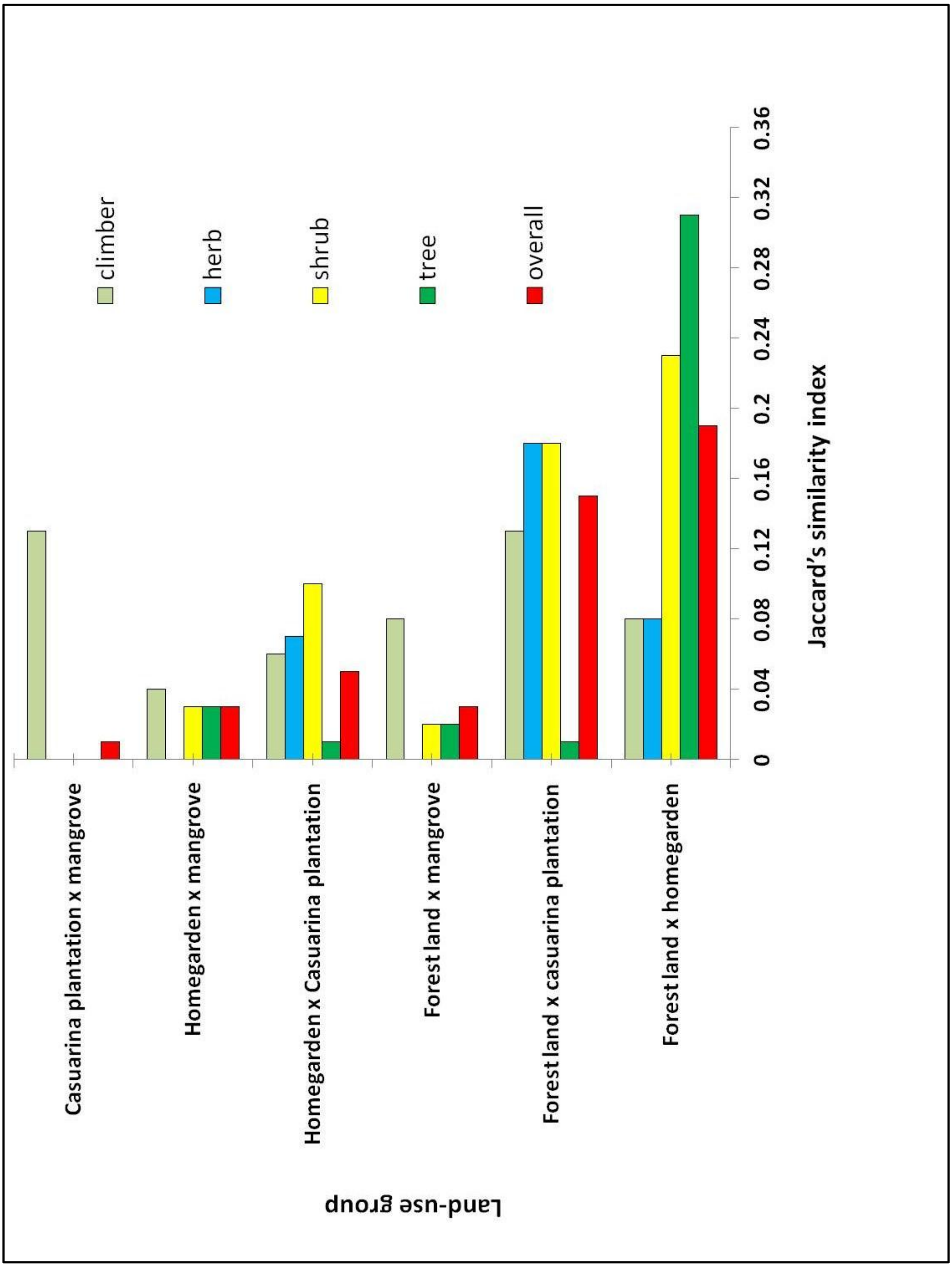
Fig. 3.18: Graph showing Simpson's index of dominance and diversity of different land-use types in the study area.

As per as component wise distribution concerned the Simpsons indices of dominance and diversity values ranges between 0.04 to 0.54 and 0.46 to 0.96, respectively (Table 3.5). In the Casuarina plantations, the highest species diversity recorded for herbaceous component (0.15 dominance index and 0.87 diversity index). The data in Table 3.5 indicate the significantly low values of Simpson's dominance indices (ranges between 0.05 and 0.09) for four vegetation components in the forest land-use types. The result indicates high species diversity among tree, shrub, herb and climber component. The highest species diversity was recorded for herbaceous (0.05) element followed by tree element (0.09). Similarly, as the Simpson's diversity tends to one indicates high species diversity among these vegetation components (Sagar and Sharma, 2012). The value of diversity indices ranges between 0.92 and 0.95. The highest value of diversity index (0.95) for herbaceous component indicate high species diversity. In the homegardens, the values of Simpson's dominance indices are comparatively low (ranges between 0.04 and 0.06) suggest high species diversity. However, there was no significant difference in species diversity between four components. Overall Simpson's diversity values in homegardens are high (ranges from 0.94 to 0.96), which conclude high species diversity in tree shrub, herb and herb component. On other hand, the Simpson's dominance indices for different vegetation components in mangrove forest are comparative high and Simpson's diversity indices are comparatively low, which denotes low species diversity. The high species diversity exhibited by tree component (D = 0.11 and 1-D = 0.89), however, it was lowest for herbaceous component (D = 0.55 and 1-D = 0.46).

3.7.3 Sorenson's quantitative index and Jaccard's index of similarity

The data in Table 3.6 show a comparison of Sorenson's quantitative index of similarity values between two communities in the study area. Overall, the highest value (39% with 77 spp. in common of 397 spp.) of Sorenson's index of similarity was recorded between the forest land-use and homegardens plant communities followed by between the forest land-use and the casuarina monocultures (30% with 40 spp. common of 268 spp.). However, it was lowest between the homegarden and mangrove vegetation (only 5% with 6 common spp. of 200 spp.). For the component wise similarity the values of the Sorenson's quantitative index of similarity ranges from 0 to 62 percent. The highest value (62% with 39 spp. in common of 125 tree spp.) was observed for tree component between forest land-use and homegardens followed by climber component (49% with 13 spp. common of 53 climber spp.) between forest land-use and the casuarina plantations, and shrub component (45% 16 spp. common of 71 shrub spp.) between forest land-use and homegarden vegetation. The lowest value of Sorenson's index of similarity was observed between the homegarden and mangrove vegetation. However, there was no similarity in tree component between the casuarina plantation and mangrove, and shrub component between the casuarina plantation and mangrove. As we did not found any herbaceous species in mangrove vegetation, therefore this land-use shows zero per cent similarity with other land-use types.

Fig. 3.19: Histogram showing Jaccard's similarity index values between different land-use groups



The similar trend was observed in Jaccard’s index of similarity (Fig. 3.19). Overall, highest value of Jaccard’s similarity index was recorded between the forest land-use and homegardens vegetation followed by the casuarina plantations and forest land-use type, while it was lowest between the casuarina plantation and mangrove forest. The Jaccard’s values of similarity indices for tree, shrub, herb and climber components were ranged from zero to 0.31. The highest value (0.31) of Jaccard’s similarity was recorded for tree component between forest and homegarden land-use types. As per as shrub and herbaceous components concerned, the highest Jaccard’s similarity index values (0.18 each) were recorded between the casuarina plantations and the forest land-use type. However, in case of climber vegetation the highest value of Jaccard’s similarity index of noted between the casuarina plantation and forest land-use, and mangrove and the casuarina plantation site (0.18 each).

Table 3.6: Showing values of Sorenson’s quantitative index of similarity between different land-use groups. The values in bracket are number of common species in both communities and total number of species identified in both communities.

Land-use group	**Sorenson’s quantitative index**				
	Overall	**Tree**	**Shrub**	**Herb**	**Climber**
Forest x Homegarden	39 (77, 397)	62 (39, 125)	45 (16, 71)	17 (11, 133)	16 (6, 73)
Forest x Casuarina plantation	30 (40, 268)	4 (2, 91)	36 (7, 39)	36 (18, 100)	49 (13, 53)
Forest x Mangrove	6 (8, 268)	6 (3, 102)	5 (1, 43)	0 (0, 100)	15 (4, 53)
Homegarden x Casuarina plantation	10 (12, 234)	3 (1, 76)	20 (5, 50)	14 (4, 58)	31 (4, 26)
Homegarden x Mangrove	5 (6, 200)	2 (1, 88)	4 (1, 52)	0 (0, 44)	23 (4, 35)
Casuarina plantation x Mangrove	6 (2, 64)	0 (0, 18)	0 (0, 13)	0 (0, 13)	27 (2, 15)

3.8 Discussion

3.8.1 Sampling scheme and methodology

An attempt was made to determine species richness and diversity in different land-use types in the study area. The species richness observed within particular habitats is strongly dependent of sample size (Chazdon *et al*., 1998; Colwell *et al*., 2004). We used a stratified random sampling method for florist analysis of different land-use types, which was based on presence and absence data. Different size quadrates were selected for tree, shrub, herb and climber components during our floristic survey. It has been suggested that the estimation of species richness and diversity depends on sampling design and choice of species richness estimator or statistical model used to analyse the data (Gimaret-Carpentier *et al*., 1998; Dorazio *et al*., 2006). The species accumulation curves and several diversity indices have been used for assessing species richness and diversity (Fisher *et al*. 1943; Shannon, 1948; Simpson, 1949; Sanders, 1968; Gimaret-Carpentier *et al*., 1998).

3.8.2 Overall floristic structure, composition and density

The analysis of the vegetation structure and composition was based on abundance data. The data indicate variation in vegetation structure in the different land-use types. The overall vegetation structure revealed that the study area was home for 407 plant species and the dominant vegetation is composed of tree flora (138 spp.) followed by herbaceous flora (133 spp.). However, the shrub flora is richer than the climber flora. In contrast, the working plan of Ratnagiri forest sub-division, Chiplun demonstrates only 61 species (30 tree, 12 shrub, 8 herb and 11 climber spp.) in the whole division (Takalkar, 2002). Thus, the floral richness in our study indicates 85% more species, which is a small part of the Ratnagiri forest subdivision Chiplun. The family Fabaceae has the largest number of plant species in the study area followed by Convolvulaceae, Asteraceae, Euphorbiaceae and Acanthaceae. These observations are similar to those of several researchers, who concluded that Fabaceae, Asteraceae, Euphorbiaceae, and Acanthaceae were the dominant families along the Western Ghats (Arora, 1964; Nayar, 1980 and 1996; Karthikeyan, 1983 and 1996; Parthasarathy, 1983; Ahmedullah and Nayar, 1986; Nair and Daniel, 1986; Sreekumar and Nair, 1991; Vajravelu and Vivekananthan, 1996; Venu, 1998; Ramesh *et al.*, 2010). In terms of the overall dominance within the quadrates, the high importance values indices differ from one land-use type to another. The forest land-use and homegardens vegetation is characterized by presence of a high number of understory species (shrubs, herbs and climbers). The number of individuals per quadrate of these understories species ranged from one to ten and under such circumstances, we considered that the forest vegetation is mixed in nature. This conclusion is based on the observations of Richards (2002).

In the present study, the casuarina plantations are composed of shrub, herb and climber flora, which are also common to the forest. However, the mangrove vegetation is composed of species specific to this vegetation type. The vegetation composition of these land-use types indicates assemblage of tall to medium size trees, shrubs, herbs and climbers. The variations in the distribution pattern of these vegetation components might be due to the site heterogeneity (Parthasarathy and Karthikeyan, 1997). The presence of high number of species and individuals in few quadrates indicate uneven distribution of the species and individuals at different land-use types. The overall estimated plant density was highest in the forest followed by the Casuarina plantations and homegardens. The higher density was due to occurrence of numerous herbaceous individuals in understory. The tree density was highest in the forest land-use (264 stems ha^{-1}) followed by the mangrove vegetation (200 stems ha^{-1}). In the forest, the tree density value in the study area was comparatively low compared to the value reported for the tropical forest of southern Eastern Ghats of India (Pragasan and Parthasarathy, 2010).

3.8.3 Rarefaction and species richness

The comparison of species richness of the different land-use types revealed significant variation. It has been stated that species richness provides a fundamental measure of community status in quantitative assessment of biological diversity (Dorazio *et al*., 2006). Cornell (1999) suggested that estimation of species richness is not only important for basic comparison among sites, but also for addressing the saturation of local communities colonized from a regional source pool. The rate of addition of new species decreased with increase in number of quadrates. Several researchers have argued that structural complexity or heterogeneity determine species richness in plant communities (Brown, 1981; Upadhaya, 2003). Using species accumulation curves our results indicate high species richness in the forest and homegarden land-use types. Similarly, this supports the conclusion of Parsons and Cameron (1974) that high species richness is the one of characteristic feature of the humid tropical forest ecosystems. It is difficult to point out the exact reason for high species richness in the present study area but it seems that favourable climatic conditions of the area have played a major role in making these land-uses highly complex and species rich. It has been concluded that the high number of rare species in the community contribute to high species richness (Fisher, 1943; Magurran and Henderson, 2003; Loehle, 2005). Goltlli and Colwell (2001) stated that the species richness is a fundamental measurement of community and regional diversity. In our study, it was observed that in the forest the species richness curve for different vegetation components rarely or does not reaches an asymptote. However, in homegardens, the casuarina plantations and mangrove habitat the species accumulation curves reaches an asymptote.

The species accumulation curve for homegarden reached an asymptote as the chance of discovering new species decreased. The curve flattened at about 206 plant species. The species accumulation curve for the forests was initially less steep than the homegarden.

However, the curve for the forests did not show an asymptote, increasing with the further addition of new species. This might be due to less abundant and high number of rare species. The species accumulation curve for the Casuarina plantation indicate a gradual increase in the species number, while with increase in sampling effort the rate of observing new species decreased. In case of the mangroves, the species accumulation curve was lowest indicating low species richness (26 species). After the gradual increasing in species, number the curve remains flattened with no further addition of new species. Pascal (1988) reported that the species pool in the Western Ghats is not relatively high, so that increasing the sample size within vegetation does not change the floristic composition but allows a better representation of the rare species (Gimaret-Carpentier *et al*., 1998).

Overall, in all vegetation types the most numerous species belongs to lowest frequency class A (0-20%). Similarly, Gleason (1929) found the greatest number of species are those of low frequency, falling in frequency class A (0-20%) and concluded that “Raunkiaer’s low of frequency” is merely an expression of the fact that in any association there are more species with few individuals than with many. The plotted frequency distribution diagrams does not resemble with Raunkiaer’s normal frequency diagram (J shaped distribution curve), which suggests the vegetation types in the study area are not structurally uniform. The “law of frequency” was generalized as A>B>C>=<D<E and discussed in literature (Raunkiaer, 1918 and 1934; Kenoyer, 1927; Gleason, 1929; Fuller, 1935; Oosting, 1956; Odum, 1959; McIntosh, 1962).

3.8.4 Species diversity and similarity

Species diversity characterizes the floristic structure and abundance distribution in a particular vegetation type, which can be obtained from relatively small sample size than the whole study area. The vegetation studies of the Western Ghats by Gimaret-Carpentier *et al.*, (1998) suggested that diversity indices are more affected by the addition of rare species with increasing sample size. The lower values of the dominance and higher values of diversity indices indicate that forest and homegardens have a high dominance of few species and numerous rare species. However, on other hand the comparatively higher values of dominance and low diversity index values in the casuarina plantation and mangrove indicate that each habitat exhibit relatively uniform flora with low dominance of few species and a lesser number of rare species. Our study showed high diversity index values with compared to studies of Chandrashekara and Sankar (1998) in sacred groves in Kerala. Whittaker (1967 and 1970) defined vegetation diversity as being dependent upon species richness and abundance in the community. McIntosh (1967) described that index of evenness remain maximum when individuals in the population are evenly distributed among the species population. The species represented by one or two individuals per quadrate have been considered as rare species (Connel and Lowman, 1989; Ramesh *et al*., 2010). Based on this criterion, 78%, 77%, 46% and 35% of the species are termed as rare in the homegardens, forest land-use, mangrove and the casuarina plantation. The highest number of rare species occurred in homegardens and forest vegetation.

The species similarity index for tree, shrub, herb and climber component between two land-use types was determined using presence and absence of data. The data on Sorensen's quantitative index showed that a high similarity in tree and shrub species was observed between homegardens and forest vegetation. However, higher the herb and climber species similarity was recorded between forest vegetation and the casuarina monocultures. In terms of the overall dominance, the studied four land-use types represent different combination of species with different dominants. The Sorensen's quantitative index measures the proportions of the species that overlap between two communities (Plotkin and Muller-Landa, 2002) suggested that the similarity between two samples depends the species composition of the underlying land-use from which the samples were drawn, distribution of species abundances and sample size.

The Jaccard's and Sorensen's indices of compositional similarity are based on presence and absences data. These indices are notoriously sensitive to sample size, particularly for assemblage with numerous rare species (Colwell and Coddington, 1994; Chao *et al*., 2005). These two indices are considered as the oldest and most widely used similarity indices for assessing compositional similarity of assemblages (Magurran, 2004).

3.8.5 Forest land-use floristic diversity

The result showed that the forest vegetation is home for 268 plant species (76 tree, 39 shrub, 100 herb and 53 climber spp.). The significant variation in species richness, density and diversity in vegetation indicates structural heterogeneity. The favourable climatic conditions over a long period may responsible for high species richness and complex vegetation (Putman, 1994). The vegetation analysis revealed that *Terminalia paniculata, Bridelia retusa, Memecylon umbellatum, Terminalia elliptica, Morinda citrifolia, Abelmoschus lampus, Holarrhena pubescens, Leea macrophylla, Leea macrophylla, Carissa congesta, Cassia tora, Daedalcanthus roseum, Senecio bombayensis, Smilax ovalifolia, Dioscorea bulbifera, Calycopteris floribunda* are the most dominant plant species in the forest vegetation. Similarly, Ramesh *et al*., (2010) reported *Terminalia paniculata* most dominant plant species in central Western Ghats of Karnataka. Joshi and Janarthanam (2004) prepared a list of 113 endemic plants in Goa region of the Western Ghats, while only eight species such as *Garcinia indica, Lagerstromia microcarpa, Ixora brachiata, Neuracanthus sphaerostachyus, Amorphophallus commutatus, Impatiens pulcherrima* and *Begonia crenata* were recorded in our study area.

3.8.6 Homegarden biodiversity

In total 206 plant species were encountered in the homegardens. The species richness, stand density and diversity were comparatively high compared to earlier studies on homegardens (127 spp.) in Kerala (Kumar *et al*., 1994). The importance value indices show that the most dominant components in homegardens were *Cocos nucifera, Dendrocalamus strictus, Mangifera indica, Psidium guajava, Areca catechu, Anacardium occidentale, Artocarpus heterophyllus, Jatropha curcas, Musa paradisiaca, Hibiscus rosa-sinensis, Gliricidia sepium, Colocasia esculenta, Hemidesmus indicus, Trichosanthes cucumerina, Piper longum, Piper nigrum* and *Garcinia indica.* Other important species of homegardens included *Murraya koenigii, Tectona grandis, Moringa oleifera* and *Manilkara zapota.* Among theses 206 plants species 39 per cent species (81) are totally cultivated species, 26 per cent (53) are regenerate themselves naturally and remaining 35 per cent (72) species can be either cultivated or showed natural mode of regeneration (Fig. 3.20).

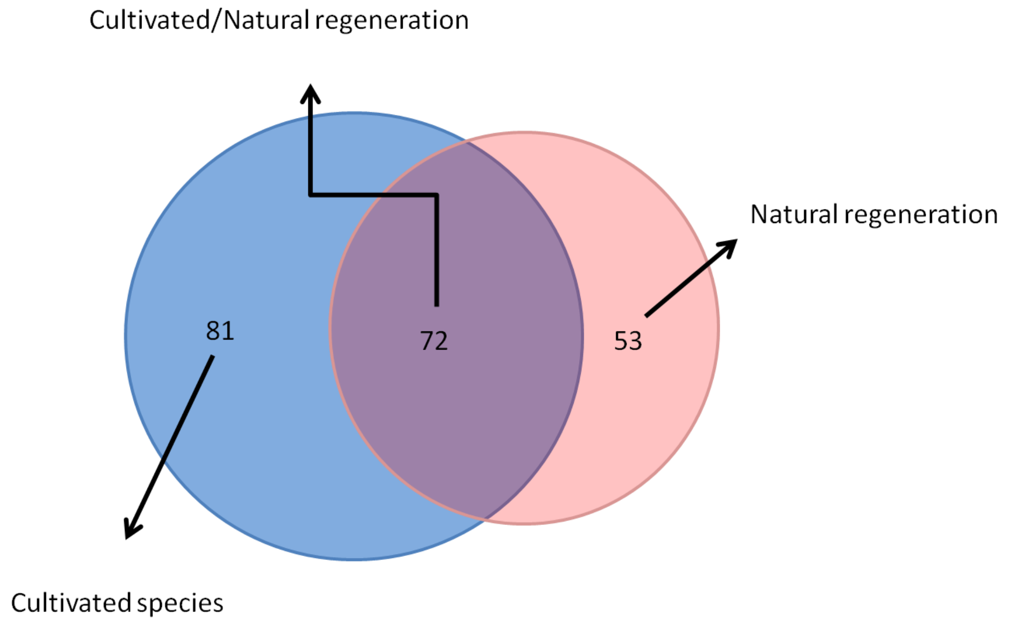


Fig. 3.20: Mode of regeneration of the Homegarden plant species.

The similar trend in dominance was observed in several homegardens studies of Western Ghats and Srilanka biodiversity hotspots (Perera and Rajapakse, 1991; Das and Das, 2005). Our study revealed that on an average 39 species (tree, shrub, herb and climbers) per quadrate were recorded in homegardens, with more dominance of fruit trees and multipurpose species. The overall plant density in the homegardens was 2286 stems ha^{-1}. It is suggested that homegardens or village agroforestry system are structurally similar to tropical forest ecosystem. This could be the reason for high diversity in homegardens. The tree vegetation is composed of numerous fruit crops, timber species as well as multipurpose tree species, while the understory vegetation maintained with staple crops, vegetable, fruit crops, medicinal plants and ornamental plants. Beside the climatic conditions and geographical proximity, other factors such as soil fertility, socio-cultural and socio-economic aspect may play a key role in controlling structure, composition and diversity in the homegardens. Beside aesthetic value, they play important role in increasing soil fertility, soil erosion control, improving socio-cultural and socio-economic situation in the region.

3.8.7 Mangrove vegetation diversity

Recently the MMF, India (2010) has reported 34 true mangrove species in India. It has been also documented that 31, 27 and 24 true mangrove species in Orissa, Sundarbans and Andaman Nicobar Islands, respectively. The exclusive mangrove flora of the study area comprised of 12 true mangrove and 14 mangrove associate species. The number of true mangrove species is comparatively lower compared to the above reports of the MMF, India (2010). The result revealed that *Sonneratia caseolaris, Avicennia officinalis, Excoecaria agallocha (L.), Aegiceras corniculatum, Rhizophora mucronata* and *Acanthus ilicifolius* are the most dominant mangrove species. The highest number of species belongs to the Rhizophoraceae family. Earlier studies also have reported similar species along the

Maharashtra and Goa coasts (Jagtap, 1994; Jagtap *et al*., 2001). However, it has been observed that the other mangrove species like *Bruguiera gymnorrhiza*, *Avicennia marina*, *Rhizophora mangle, Rhizophora apiculata, Ceriops tagal* and *Kandelia candel* are distributed discontinuously over the area of the mangrove vegetation. The number of plant species in study area is in the range of those from other mangroves with 20-30 species in India (Kathiresan, 2000; Suma, 2005) and in Indonesia (Hinrichs, 2009). The mangrove habitat is composed of few dominant understory *Acanthus ilicifolius* shrub, and *Caesalpinia crista* (L.) and *Derris scandens* liana species. However, it is stated that naturally mangroves are characterised by no understory shrub, herb and climber plants except their seedlings (Tomlinson, 1986; Ellison and Farnsworth, 2000; Hinrichs, 2009). It was argued that the presence of *Acanthus ilicifolius* shrub and *Caesalpinia crista* (L.) and *Derris scandens* liana species is associated with natural and human disturbance, which resulted in species invasion in to the mangrove vegetation (Snedaker and Lahmann, 1988; Hogarth, 1999). The overall mangrove stand density in our study area was 444 stems ha^{-1}, which is lower than stand density (720 stems ha^{-1}) in Kerala west coast (Ansari *et al*., 2003). Our findings demonstrate presence of few mangrove associate species such as *Thespesia populnea, Hibiscus tiliaceus, Calophyllum inophyllum* and *Salvadora persica.* This indicates disappearance of the existing mangrove flora and formation of a new assemblage. Several researchers argued that these changes might be due to sea level rise, rapid changes in salinity and extreme weather conditions such as cyclones, storms, tsunamis, excess of precipitation and droughts (Bruun, 1962; Schwartz, 1967). The mangrove diversity in the study area seems to be low and shrimp farming and coconut plantations may affect this. This interpretation supports the argument made by several researchers that shrimp farming has long-term impacts on mangrove ecosystems (Upadhyay *et al*., 2002; Ramasubramanian *et al*., 2006; Gopal and Chauhan, 2006;

Hinrichs, 2009). It is stated that shrimp farming alone caused a loss of 65,000 hectare of mangroves in Thailand (Mukerjee, 1994; Naylor *et al*., 2002; Upadhyay *et al*., 2002; Environmental Justice Foundation, 2006).

3.8.8 The Casuarina monocultures floral diversity

The casuarina monoculture understory is characterized by 40 plant species (7 shrubs, 18 herbs and 13 climbers). *Calotropis procera, Sonchus oleraceus, Sonchus asper, Achyranthes aspera, Ipomoea pes-caprae, Hemidesmus indicus, Tylophora dalzellii and Cucumis setosus* was most dominated the flora. The study revealed that monocultures showed low species richness compared to the forest and homegarden vegetation. However, all species are also common to forest vegetation. The reason behind that may be due to dense crown of *Casuarina equisetifolia,* casting deep shade in the understory and produces maximum litter that decomposes relatively slowly. This may create barrier in regeneration of understory plant species. Parrotta (1995 and 1999) studied disturbed coastal dune casuarina plantations and reported low species richness. He concluded that the overstory vegetation significantly affects the understory composition and inhibits regeneration. In contrast, our study indicates comparatively high species richness in understory casuarina monocultures. This may be due to frequent and often severe disturbances. Recently these monocultures are continually degrading due to anthropogenic activities and some of the patches are almost degraded. The gap formed in the monocultures might be responsible for invasion of the understory vegetation. The coastal dunes of the West coast of Konkan are protected by the casuarina monocultures. In the recent decade, degradation of the monocultures is resulting from anthropogenic activities. This study suggests need of monoculture protection and restoring the plantations through afforestation program.

3.9 Conclusion

The study area is home for 407 species composed of 33% tree, 18% shrub, 32% herbaceous and 17% climber species. The vegetation analysis demonstrates rich floral diversity in South Konkan Coast of Maharashtra. Therefore, the priority should be given to the region for conservation and sustainable management of floral biodiversity, which is facing pressure from increasing population, land-use changes, deforestation and developmental activities. The variation in species richness, dominance and diversity for different vegetation components at each land-use types indicate dynamic nature of the region. The higher number of rare species in the study area is important for conservation point of view. The outcomes of our study will provide baseline data for monitoring and conserving the vegetation diversity of tropical moist deciduous forests, homegardens, the casuarina plantation and mangrove vegetation in the Konkan Coast of Maharashtra state.

4 QUANTIFYING SOIL C STORAGE UNDER DIFFERENT LAND-USE TYPES IN SOUTH KONKAN COAST OF MAHARASHTRA (INDIA)

4.1 Introduction

It has been argued that the climate change is one of the most dangerous environmental problems facing the world (Parry *et al*., 1996; ECCM, 2002; Rathzel and Uzzel, 2009; Council on Foreign Relations, 2011). It is widely accepted that greenhouse gases, and in particular carbon dioxide are the main drivers of the recent global warming (Goto *et al*., 1994; Lal and Singh, 2000; Sedjo, 2001; Guan *et al*., 2006; Pinay *et al*., 2007; Kale *et al*., 2009; Schiermeier, 2011). Carbon storage in biomass and soils is one of the strategies accepted by the United Nations in order to mitigate the high level of atmospheric carbon dioxide (Feng *et al*., 2004; Saha *et al*., 2009). Forest vegetation and soils contain about 1240 Pg carbon stock but varies widely among latitudes (Dixon *et al.,* 1994; Lal, 2005). Magrini *et al*., (2002) argued that soil organic matter and their degradation dynamics in forest soils are difficult to study because of the time consuming sample collection, preparation, and difficulty in analysis and identification of the major components. Prior to this century, CO_2 emissions from changes in forest lands were mainly caused by agricultural expansion. From the turn of the century until about the 1930's, global CO_2 emissions from changes in land-use were similar in magnitude to those from fossil fuel combustion. The past and present patterns of land-use are not only responsible for changes in net fluxes of carbon and other bio-geo chemical cycles but also affects biodiversity. Land-use conversions are the primary source of soil degradation (Tolba and El-Kholy, 1992) and alter ecosystem services; which affects the ability of biological ecosystems to support human needs (Vitousek *et al*., 1997; Lambin *et al*., 2001).

The terrestrial biosphere is an important global carbon sink (Bolin *et al*., 1979; Howard *et al*., 1995; Batjes, 1996; IPCC, 2001; Chhabara *et al*., 2003; Falloon *et al*., 2007), which stores about three times the amount of carbon found in the atmosphere (Watson *et al*., 1990; Jobbagy and Jackson, 2000; Chen and Li, 2003; Lal, 2004). Falloon *et al*., 2007 stated that climate change has the potential to alter terrestrial C storage by changing in temperature, precipitation and carbon dioxide (CO_2) concentrations. This could affect net primary production, C inputs to soil, and soil C decomposition rates. Falloon *et al*., (2007) studied climate change and its impacts on soil and vegetation carbon storage in Kenya, Jordan, India and Brazil and concluded that soil and vegetation carbon storage responds differently to temperature, precipitation and vegetation input. The reason is that Brazil and Jordon experiencing reduction in annual precipitation totals resulting in drier conditions and lower soil carbon stocks, while in Kenya and India wetter conditions were resulting in higher soil carbon stocks due to increased rainfall. This case study concluded that precipitation rather than temperature would appear to control sign of predicted changes in soil carbon, largely through the influence of rainfall on litter inputs to the soil. In general, increase in the temperature and large regional gaps in rainfall are predicted due to climate change in all above region. A comparatively, smaller reduction in carbon storage and high rainfall was predicted in India than Brazil and Kenya. These authors also predicted that the global mean atmospheric CO_2 concentration of 980 ppm by 2100 would result in a temperature increase in excess of 5^0C in these four countries. Lal (2005) reviewed the carbon stock in various biomes of the world and showed that the tropical biomes contain a high carbon stocks (212 Pg) in vegetation biomass. However, the highest soil carbon stock was reported in the Boreal biome (471 Pg) followed by the tropical biome (216 Pg). It has been concluded that tropical forests contain large stocks of carbon (Lal and Singh, 2000) and further additional climate change would have substantial impacts on tropical forests, which would reinforce the contributions of changes in the tropical forests to global climate change (Fearnside, 2004).

Soils of the Konkan coast are already discussed in chapter 2: Description of the study site. The lateritic soils of the hilltop and slopes are prone to erosion and low in organic matter. The seasonal variation in salinity is the key feature of the Coastal soils in the region. Anthropogenic interruptions and natural calamities are source of soil degradation. The Konkan coast is blessed with diverse natural ecosystems such as forest, homegardens, mangroves and grasslands. The main agricultural crop in this region is rice and the local farmers are not aware about the soil fertility status and soil development. The forests are under huge pressure for mango cultivation and industrialization. Increased use of inorganic fertilizers in agriculture and mango plantations by farmers led to change status of the soil fertility and soil properties. The knowledge of effects of land-use type on soil properties and soil organic carbon dynamics in the south Konkan coast of Maharashtra is limited. I expected that current land-use change will have strong influence of soil physical and chemical properties. Therefore, the aim of our study was to determine the effect of land-use on soil bulk density, pH, electrical conductivity, per cent moisture content, salinity, organic matter, carbon storage under different soil depths.

4.2 Review of literature

4.2.1 Soil properties and land-use change

It has been stated that land-use conversion may alter some important changes in soil physical and chemical properties and ultimately it can affect soil fertility, cause soil compaction or increase soil erosion (Geissen *et al*., 2009). Several researchers stated that land-use changes can influence supply and distribution of the soil nutrient by altering soil properties and by influencing biological transformation in the root zone (Murty *et al*., 2002; Majaliwa *et al*., 2010). Majaliwa *et al*., (2010) reviewed that land-use change is associated with reduction in soil organic matter and hence decline soil productivity (Ross, 1993; Singh and Singh, 1991; Sanchez et al., 1997; Palma et al., 2001). Krishnaswamy and Richter, (2002) stated that the ability of soils to retain carbon and other nutrient may alter due to changes in soil pH. Emadi et al., (2008) argued that land-use conversion led to increase in soil bulk density and decrease in soil porosity. Many researchers reported that land-use change due to land conversion, deforestation, overgrazing and use of inorganic fertilizers caused significant variation in soil properties and terrestrial cycles and affect vegetation composition (Fraterrigo et al., 2005; Hacisalihoglu, 2007; Saraswathy et al., 2007; Gol, 2009). Worldwide, soil salinity is one of the major problems and India is not exception for this. The Konkan coast is experiencing high salinity and the area becomes inadaptable to many mangrove species to grow. In some extent, the coastal soils suitable for rice cultivation are prone high salinity and now the areas are not suitable for rice cultivation.

4.2.2 Soil organic carbon dynamics

Soil organic carbon (*SOC*) contains the largest component (approximately 1500 Gt) of the global carbon pool (Johnson, 1992; Jobbagy and Jackson, 2000; FAO, 2001; Bernoux *et al*., 2001; Murty *et al*., 2002; Chhabra *et al*., 2003; Amichev and Galbraith, 2004; Johnston *et al*., 2004; Lopez-Ulloa, 2005; Kaul *et al*., 2010; Brahim *et al*., 2010; Xu *et al*., 2011_a and 2011_b). It acts as a regulator of the atmospheric carbon dioxide levels (Amundson, 2001). It has been demonstrated that the amount and quality of natural soil organic carbon is highly influenced by vegetation type and land-use (Andrade *et al*., 2004). In recent decades, the possibility of a reduction in global soil carbon stock has been predicted as a result of global warming (Jenkinson *et al*., 1991; Kirschbaum, 1995; Schimel *et al*., 1994; Mc Guire *et al*., 1995; Chhabara *et al*., 2003; Jones *et al*., 2005), even in areas where carbon inputs to soil from vegetation or biomass had increased (Jones *et al*., 2003, 2005).

4.2.3 Carbon sequestration and climate change

The storage of C in terrestrial ecosystem sinks (vegetation and soil) can mitigate the risk of further increase in atmospheric CO_2 concentrations through carbon sequestration (Tan and Lal, 2005; Miegroet *et al*., 2005; Williams *et al*., 2008). The studies on effects of climate on organic carbon in Indian soils are well documented in literature (Jenney and Raychaudhari, 1960; Ravindranath *et al*., 1997; Dadhwal *et al*., 1998). Saha et al., (2010) have suggested that the land-use systems with higher tree density and less soil disturbance have a greater contribution to soil carbon storage. The total organic carbon in Indian soils to a depth of 30 cm was estimated by Bhattacharyya *et al*., (2005) to be 9.55 Pg.

Bhadwal and Singh (2002) reported that India has developed three land-use scenarios (LUCS I, LUCS II and LUCS III) to enhance C sequestration estimates in forestry sector. Current LUCS III is a potential scenario where maximum land is put under plantation category by 2015. The amount of carbon sequestered in this scenario is predicted to be 6.937 billion tones. It has been argued that according to this scenario the carbon sequestered in aboveground vegetation will be more than double by the year 2050.

Kale *et al*., (2009) studied patterns of carbon sequestration in Western Ghats and showed that satellite remote sensing is a tool for mapping land-use patterns and estimating vegetation biomass. They studied carbon sequestration in natural mixed deciduous forest and plantations and observed that plantations had a higher sequestration rate than natural forest. Prasad *et al*., (2002) quantified effects of land-use changes on carbon fluxes in Eastern Ghats of India and reported that loss of 47.97 Mt of carbon from forested land as result of land-use conversion. Sharma and Rai (2007) estimated land-use cover and associated carbon fluxes and showed that conversion of forests into another land-uses resulted in a remarkable decline in carbon densities. Recently, Seen et al., (2010) have documented loss of soil organic carbon stocks (6.6 Mg C ha^{-1}) due to conversion of moist deciduous forest into plantations in Western Ghats. A significant reduction in *SOC* after conversion of humid tropical forests to maize cultivation in the south-eastern Ethiopia was reported by Solomon *et al*., (2002). Martin *et al*., (2010) studied soil organic carbon storage changes in Indian Himalayan Mountain and concluded that carbon accumulation and its movement in the soil profile are influenced by combine impact of climate, altitude and intensive agriculture.

4.3 Materials and methods

The study was carried out in the South Konkan Coast of Maharashtra state. The detail information about the study site is given in Chapter 2 'Description of the study site'.

4.3.1 Soils and land-use types

Soils of the study area belong to three classes' viz., lateritic, coastal alluviums and salt lands. Lateritic soils, which are predominant in the study area, vary in colour from bright red to brownish red owing to the preponderance of hydrated iron oxides and are suitable for rice cultivation. The soil occurs under forests, homegardens, mango plantations and grasslands. The coastal strips in study area are covered with coastal alluvium soils of recent deposits and the casuarina plantations grow vigorously on this soil. Due to the inundation of the sea, a part of the coastal soils have become salty and habitat for mangrove vegetation.

4.3.2 Field sampling

Soil sampling was conducted during January-June 2009. A systematic 1km x 1km square grids of 460 points, was randomly superimposed over the entire study area and different land-use types or habitats, such as forest land, mangrove forest, homestead gardens, grasslands, and the casuarina plantations were identified at each grid intercept point location. The sampling points were randomly selected from a land-use in the grid. In total 60 sample points (10 sample points each in agricultural land, forest land, homegardens, grasslands and mango plantations and 5 sample points at mangroves and the casuarina plantation land-use types) were placed randomly (Fig. 4.1 and 4.2). From each sampling point, composite bulk soil samples were collected from three soil depths: 0-10, 20-30 and 40-50 cm. Thus in total 180 samples were collected using a stainless steel soil core sampler (53 mm in diameter by 50 mm depth). All soils samples were immediately placed in plastic bags labelled and brought to the laboratory to further analysis.

4.4 Analysis of soil

4.4.1 Soil bulk density

The bulk density was determined by dividing the net mass of oven dried soil by the volume of core sampler cylinder (100 cm^3). Soil sample were collected from undisturbed soil using a stainless steel core sampler and dried at 105^0C to a constant weight and the oven dry mass of the soil recorded. The volume of the core was measured and recorded accordingly. The soil bulk density was calculated using following formula.

$$\textbf{Soil bulk density } (\mathbf{g}/\boldsymbol{cm^3}) = \frac{\text{Mass of oven dried soil sample (g)}}{\text{Volume of core sampler } (cm^3)}$$

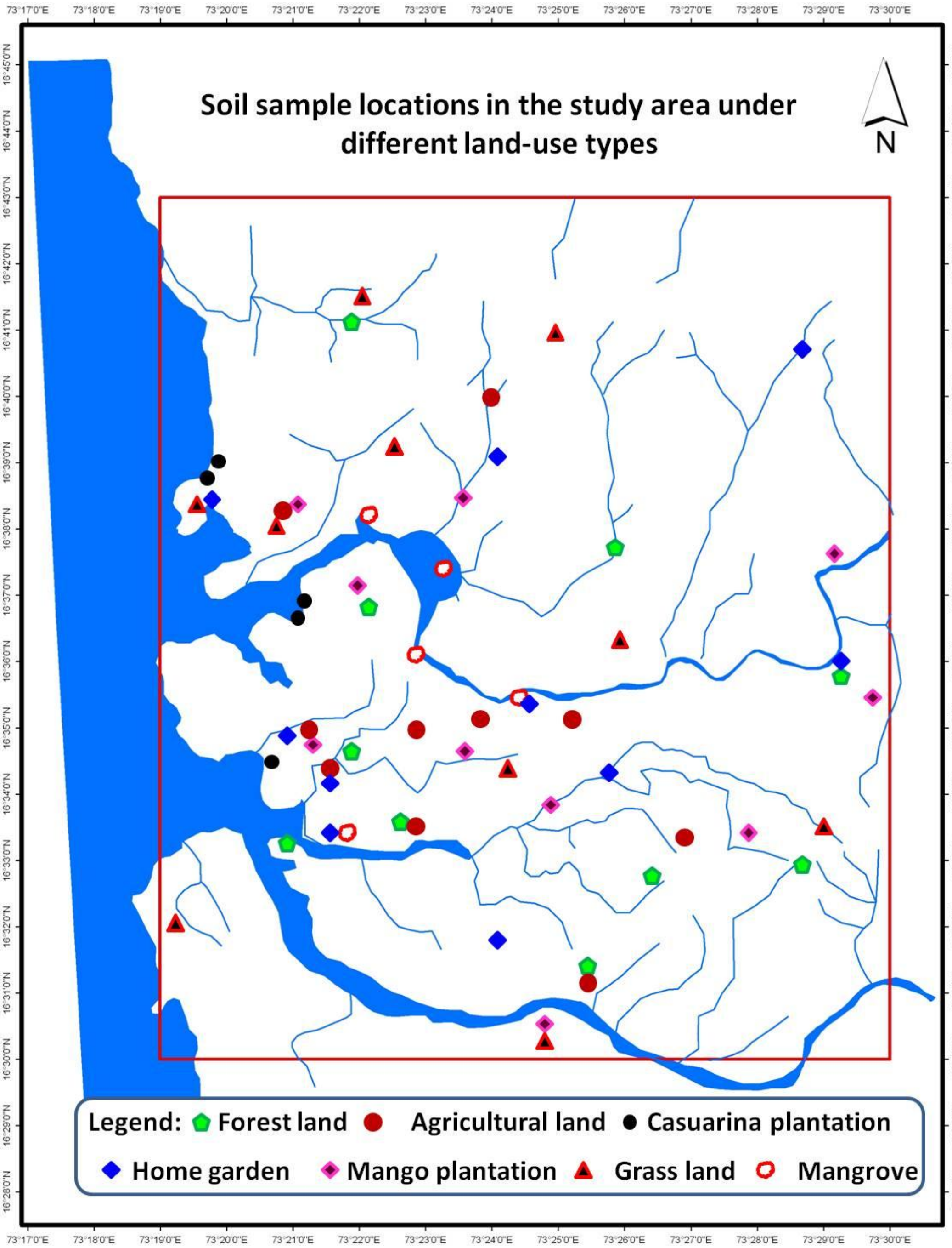


Fig. 4.1: Soil sample locations in the study area under different land-use types

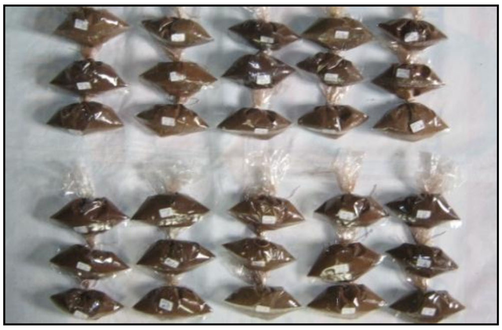
Fig. 4.2: Soils of the seven land-use types showing soil colour variation in the study area.

Agricultural land soil

Casuarina plantations soil

Forest land soil

Grass land soil



Homegarden soils

Mango plantation soils

Mangrove soil

4.4.2 Soil pH and Soil electrical conductivity

Soil pH and electrical conductivity (EC) were determined in 1:2.5 ratio of soil: water suspension using an EC and pH meter (Jenway 4010 EC meter and Orian 410A pH meter).

4.4.3 Soil moisture content and soil salinity

Field moist soil (5 gram) was dried in an oven at 105^0C to constant weight and moisture content was determined gravimetrically.

$$\textbf{Soil moisture content}\ \% = \frac{\mathrm{W2} - \mathrm{W3}}{\mathrm{W3} - \mathrm{W1}} \times 100$$

Where, W1 = Mass of crucible (g), W2 = Mass of the crucible with field - moist soil (g) and W3 = Mass of crucible plus oven dried soil at 105^0C (g).

The soil salinity was calculated by using following equation (Joshi and Ghose, 2003).

$$\textbf{Soil salinity}\ (\textbf{ppm}) = 0.064 \times \mathrm{EC} \times \frac{\%\ \text{soil moisture content}}{100} \times 10$$

4.4.4 Soil Organic Matter (*SOM*) and Soil Organic Carbon (*SOC*)

Soil Organic Matter (*SOM*) and Soil Organic Carbon (*SOC*) were determined by the weight loss-on-ignition method (LOI) following Ball (1964), Dean (1974), Bengtsson and Enell (1986), Wilke (2005) and Abella and Zimmer (2007), Wright, *et al*., 2008; Rawlins *et al*., (2008). The sieved (< 2 mm) air dried soil samples were heated in porcelain crucible at 105^0C. The preheated samples (5 g) were combusted in muffle furnace at 450^0C (Rawlins *et al.*, 2008) overnight until mass consistency was achieved. The per cent soil organic matter content was calculated from the mass difference before and after heating as follows.

$$\% \ \textbf{Soil Organic Matter} \ (\textbf{SOM}) = \frac{\Delta \text{m}}{\text{ms}} \ \text{x} \ 100 = \frac{\text{W3} - \text{W4}}{\text{W3} - \text{W1}} \ \text{x} \ 100$$

Δm = loss of mass of the soil after ignition at 450^0C (g).

ms = mass of the soil dried at 105^0C (g).

W1 = Mass of porcelain crucible (g),

W3 = Mass of porcelain crucible and oven dried soil at 105^0C (g).

W4 = Mass of the porcelain crucible and oven dried soil in muffle furnace at 450^0C (g).

Soil organic carbon (*SOC*) was calculated using a correction factor 1.9 from empirical studies, based on the assumption that on average, the organic matter contains 50% carbon (Broadbent, 1953; Schlesinger, 1977; Ajtay *et al*., 1979; Pribyl, 2010).

$$\% \ \textbf{Soil Organic Carbon} \ (\%\textbf{SOC}) = \frac{\text{Per cent soil organic matter } (SOM)}{1.9}$$

The carbon content per unit area was determined in tonnes C ha^{-1} for a given soil depth (e.g. for 0-10 cm, 20-30 cm and 40-50 cm). The soil organic carbon stock ha^{-1} was calculated formulas shown below.

$$\textbf{Organic Carbon stock} \ (\mathbf{g \ C \ m^{-2}}) = \frac{\text{Concentration of } SOC \ (\text{g kg}^{-1})}{\text{Soil bulk density (kg l}^{-1})} \times 100$$

Organic Carbon stock (kg C $m^{-2)}$ = Organic Carbon stock (g C m^{-2}) ÷ 1000

Organic Carbon stock (t C $ha^{-1)}$ = (Organic Carbon stock in kg C m^{-2} × 10000) ÷ 1000

Based on this available data the total organic carbon storage values for the 10-20 cm and 30-40 cm were determined using polynomial regression equations as nonlinear relationship between the dependent and independent variables were observed. The values of the dependent variables (*SOC* storage) and independent variable (soil depth) were modelled and using these equations, the values of dependent variable were calculated for the corresponding independent variable. Then total organic carbon stock was obtained by summing the *SOC* content of the constituent soil layers or soil depths.

4.5 Statistical analysis

The difference in variables were tested with ten replicates from the agricultural land, forest land, grassland, homegardens and mango plantation and five replicates from casuarina plantation and mangroves values using one way ANOVA following SPSS version 14.0 to assess overall effects of different treatments (land-use types, soil depth etc.). Further Tukey HSD post hoc procedures were followed to compare means and explore exactly which combination differs significantly. Pearson's correlation was used to determine the relationship between soil bulk density, pH, per cent moisture content, EC, salinity, organic matter, organic carbon concentration and organic carbon storage ha^{-1} (correlation was tested at 0.01 level).

4.6 Results

4.6.1 Soil bulk density

The data shown in Fig. 4.4 indicate that the bulk densities ranged from an average of 1.15 g cm^{-3} to an average 1.48 g cm^{-3} up to 50 cm soil depth in the different land-use type. The result showed the soil bulk densities differed significantly between agricultural land and the casuarina plantation, agricultural land, grass land soils, and homegarden soils, between agricultural land, mango plantation, agricultural land, mangrove soils, between forest land, grassland soils, and between grassland and mango plantation soils (the mean difference is significant at 0.05 levels). The highest bulk density (1.48 g cm^{-3}) was observed in grass land soils followed by mangrove (1.37 g cm^{-3}), the casuarina plantation (1.35 g cm^{-3}), and homegarden (1.34 g cm^{-3}) soils; however there was not statistically significant variation between them. The result indicates that the grassland soil bulk density differed significantly between agricultural land, forest land and mango plantations. The lowest soil bulk density was recorded for agricultural land (1.15 g cm^{-3}) followed by the forest soils (1.24 g cm^{-3}). However, there was no significant difference in soil bulk densities between agricultural and forest soils. The soil bulk density in mango plantation differed significantly to agricultural and soils and grassland soils. There was no significant variation in bulk densities between the casuarina plantations and forest land soils, the casuarina plantation and grassland soils, the casuarina and homegarden soils, the casuarina and mangrove soils, forest land and homegarden soils, and forest land and mangrove soils.

The data shown Fig. indicates mean bulk density values between different land-use types, which differed significantly under different soil depth (the mean difference is significant at 0.05 level). The values ranged between 1.04 g cm^{-3} and 1.64 g cm^{-3}. The bulk densities increased vertically with increasing soil depth in all seven land-use types. In the study area, on an average highest soil bulk density was reported in the 40-50 cm layer (1.47 g cm^{-3}) followed by 20-30 cm layer (1.29 g cm^{-3}) and it was lowest (1.19 g cm^{-3}) in the top soil layer (0-10 cm). At the 40-50 cm depth the highest soil bulk density was recorded in grassland soil (1.64 g cm^{-3}) followed by the homegarden (1.55 g cm^{-3}) and mangrove soils (1.50 g cm^{-3}); however it was lowest in agricultural land soils (1.28 g cm^{-3}) followed by the casuarina plantation soils (1.40 g cm^{-3}) and forest land soils (1.43 g cm^{-3}). Similarly, in the top layer (0-10 cm depth) the highest soil bulk density was recorded in the grassland soil (1.37 g cm^{-3}) followed by the casuarina plantation soils (1.32 g cm^{-3}); however it was lowest in the agricultural land soils (1.04 g cm^{-3}) followed by the forest land soils (1.09 g cm^{-3}).

Table 4.1: showing soil pH and soil electrical conductivity under different soil depths in seven land-use types. For soil pH, the values in brackets indicate standard error and for soil EC the values is brackets indicate natural logarithmic transformed mean values.

Soil properties	Soil depth	Land-use type: Agricultural land	Casuarina plantations	Forest land	Grass land	Homegardens	Mango plantations	Mangroves
Soil pH	0-10 cm	6.1 (±0.12)	6.9 (±0.17)	6.5 (±0.12)	5.6 (±0.12)	6.1 (±0.12)	6.1 (±0.12)	5.3 (±0.17)
	20-30 cm	6.4 (±0.12)	7.1 (±0.17)	6.7 (±0.12)	5.8 (±0.12)	6.1 (±0.12)	6.3 (±0.12)	5.7 (±0.17)
	40-50 cm	6.4 (±0.13)	7.1 (±0.17)	6.6 (±0.12)	5.9 (±0.13)	6.0 (±0.12)	6.3 (±0.12)	5.5 (±0.17)
Soil electrical conductivity (EC) (m/cm)	0-10 cm	15.56 (2.62)	1.44 (1.80)	0.10 (1.63)	0.15 (1.64)	2.32 (1.81)	0.01 (1.61)	794.84 (4.92)
	20-30 cm	1.95 (1.88)	0.52 (1.70)	0.04 (1.62)	0.05 (1.62)	0.57 (1.71)	0.02 (1.61)	345.56 (4.29)
	40-50 cm	3.75 (1.96)	0.83 (1.74)	0.03 (1.62)	0.07 (1.62)	7.04 (2.00)	0.01 (1.61)	133.79 (4.14)

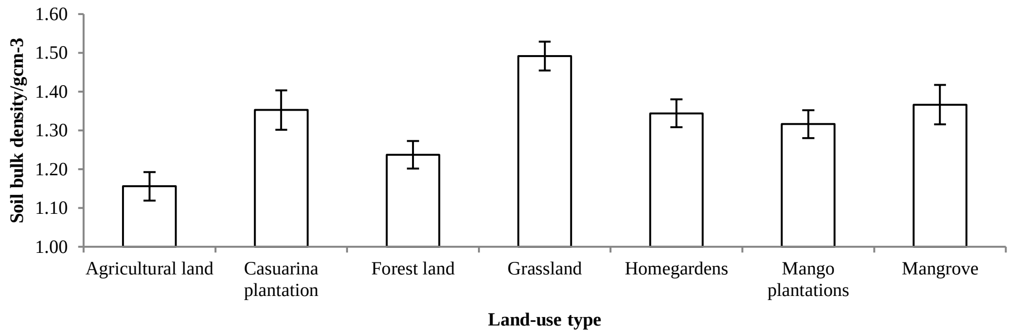


Fig. 4.3: Mean soil bulk density (g cm^{-3}) to a depth of 50 cm in seven land-use types. Error bars shows SE (±).

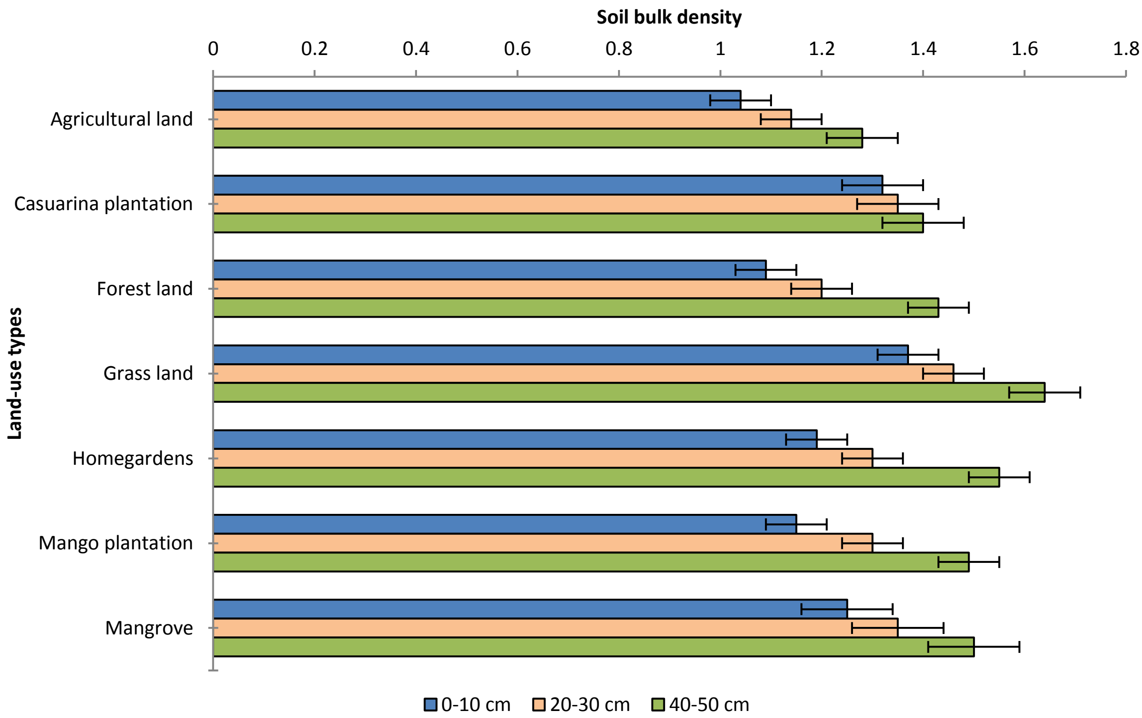


Fig. 4.4: Showing soil bulk density in different land-use type at different soil depth. Error bars shows SE (±).

4.6.2 Soil pH, soil salinity, soil EC and per cent moisture content

The data on soil pH for the different land-use type is represented in Fig. 4.5 and Table 4.1 Fig. 4.5 shows the mean pH for all soil depths measures. Table 4.1 shows the influence of soil depth on pH. Soil pH observations were ranged from 3.89 to 7.49 in the study area under different land-use types. The Duncan test of significance revealed that the soil pH differed significantly between different land-use types (the mean difference is significant at 0.05 level).

For the mean values for the profile, the highest soil pH was recorded in the casuarina plantation sites (7.04) followed by forest land-use (6.61), agricultural land (6.28) and mango plantations (6.19) and homegarden sites (6.06), and the lowest values were recorded in mangrove soils (5.50) and grassland soils (5.77). However, was observed that there was no significant difference in pH values between homegardens, mango plantations and agricultural land soils. Overall soil pH values decreased vertically in the study area. However, in forest land-use, homegardens and mangrove sites the values decreased from 20-30 cm depth to 40-50 cm depth. It is observed that the highest soil pH (6.27) was recorded in top 0-10 cm depth followed by 40-50 cm depth (6.24) and lowest in 20-30 cm depth (6.08). However, no significant difference observed between 20-30 cm and 40-50 cm soil depth. The data in Table 4.1 indicate that in 0-10, 20-30 and 40-50 cm soil depths the highest mean soil pH values were recorded in the casuarina plantations soils (6.9, 7.1 and 7.1, respectively) and lowest in mangrove soils (5.3, 5.7 and 5.5, respectively).

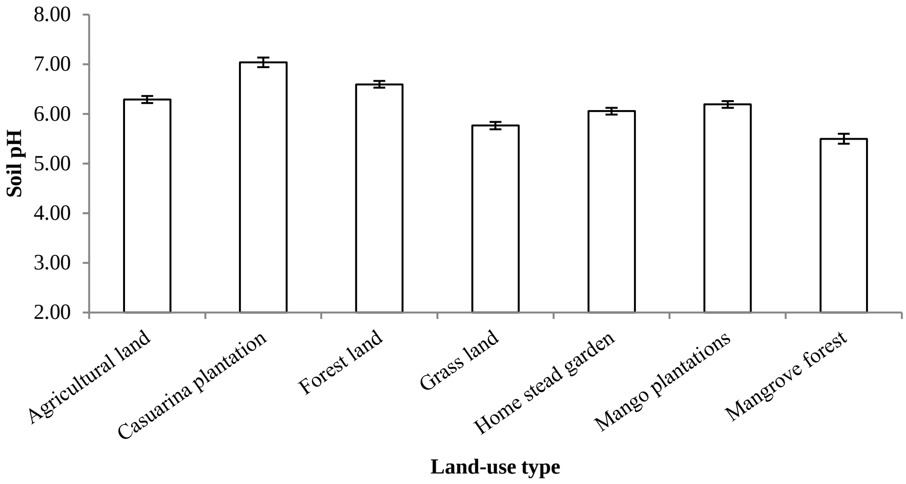


Fig. 4.5: Mean soil pH to a soil depth of up to 50 cm in seven land-use types in the study area. Error bar shows SE (±).

The data of soil electrical conductivity and per cent soil moisture content is shown in Fig. 4.6. The values of soil electrical conductivity ranged from 0.002 ms/cm and 3350 ms/cm. It was observed that the highest mean soil electrical conductivity (424.7 ms/cm) was in mangrove soil, which differed significantly than other six land-use types. The values of EC of soil from agricultural land, homegardens, the casuarina plantations, grasslands, forest land and mango plantation soils were 7.08 ms/cm, 3.31ms ms/cm, 0.93ms/cm, 0.09 ms/cm, 0.06 ms/cm and 0.01 ms/cm, respectively. The EC values differed significantly between agricultural land and forest land soils, and agricultural land and mango plantation soils. However, there was no significant difference between the casuarina plantations, grasslands, and homegardens soils electrical conductivity (the mean difference is significant at 0.05 level). The result indicates that soil electrical conductivity decrease with an increase in soil depth, however, no significant difference observed between soil depths (Table 4.1). On an average in 0-10 cm, 20-30 cm and 40-50 cm soil depths the highest EC values were recorded for mangrove soils (794.84 ms/cm, 345.56

ms/cm and 133.79 ms/cm, respectively) and lowest in mango plantation soils (0.01 ms/cm, 0.02 ms/cm and 0.01 ms.cm, respectively).

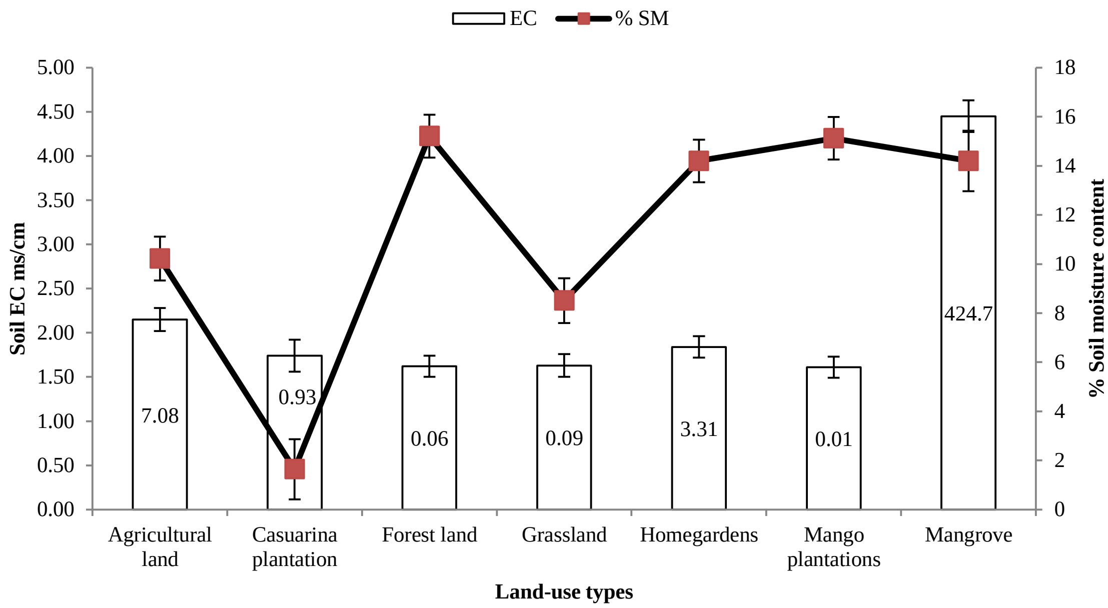


Fig. 4.6: Comparison of soil electrical conductivity (EC) and per cent soil moisture content in seven land-use types. (Values for EC are log transformed- LN(X+5) and the data labels indicate original average EC values per land-use type). Error bars shows SE (±).

Fig. 4.6 illustrates mean per cent soil moisture content in different land-use types. The highest mean per cent moisture content was observed in forest land and mango plantations soils (15% each) followed by homegarden soils (14%) and mangrove soils (12%), while no significant difference was observed between these soils. The lowest mean per cent soil moisture content (1.6%) was recorded in the casuarina plantations soil followed by grassland soils (8.5%) and agricultural soils (10%). The lowest mean per cent moisture content was observed in the casuarina plantation soils and it significantly differed with other six land-use soils. The result showed statistically significant variation in per cent soil moisture content between forest, agricultural and grass land soils. Per cent soil moisture content increase vertically with an increase in soil depths except the casuarina plantation soils. The per cent moisture content was highest at 40-50 cm depth (13.78%) followed by 20-30 cm depth (12.36%); however there was no significant variation among these two soil depths. The lowest per cent moisture content (9.12%) was exhibited in 0-10 cm soil depth. The results indicate that percent moisture content differed significantly in 0-10 cm than 20-30 cm and 40-50 cm soil depth (the mean difference is significant at 0.05 level). The percent moisture content values ranged between 0.5% and 29%. The mean per cent moisture values by soil depth ranged from 1.6% to 19% in the study area. The highest average per cent moisture content (19%) was recorded in 40-50 cm soil depth for mango plantation soils followed by 16 % each in forest land soils (at 40-50 cm and 20-30 cm depth) and homegarden soils (at 20-30 cm depth). The lowest moisture content was observed at 0-10 cm, 20-30 cm and 40-50 cm depth in the casuarina plantations (1.8%, 1.6% and 1.6%, respectively) followed by grassland soils (6%, 8% and 12%, respectively).

The data on soil salinity under seven land-use types is shown is Fig. 4.7. The highest soil salinity (6.5 ppm) was found in mangrove forest soils followed by mango plantation (2.5 ppm) and homegarden soils (2.1 ppm). However, mangrove soil salinity differed significantly to the other land-use types. In addition, mango plantation soil salinity showed significant variation with forest land soils, grass land and agricultural soils. The lowest soil salinity (0.1 ppm) was recorded in casuarina plantation soils followed by agricultural land soils (0.3 ppm), grassland soil (0.9 ppm) and forest land soil (1.1 ppm), while the mean salinity values for these soils did not showed statistically significant variations. Overall, the result indicates that the soil salinity increases with the soil depth. The soil salinity differed significantly with soil depths. The significantly highest soil salinity was found at 40-50 cm depth and lowest at 0-10 cm soil depth. However, no significant variations were recorded between 0-10 cm and 20-30 cm, and 20-30 and 40-50 cm soil depths.

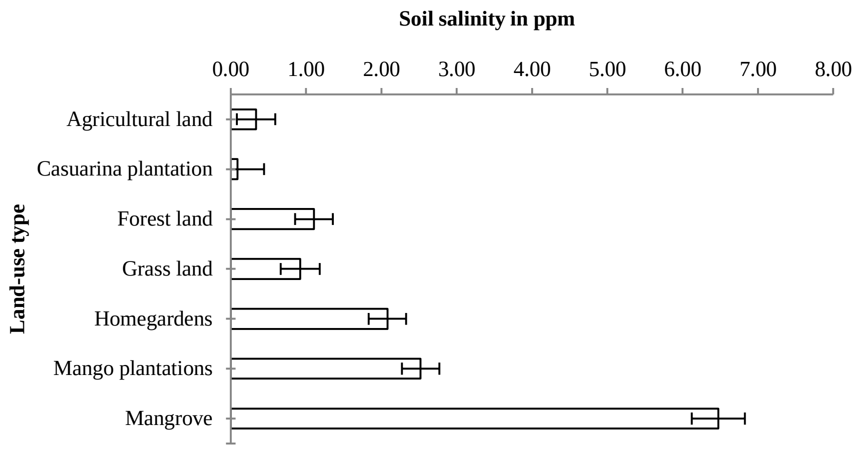


Fig. 4.7: Mean soil salinity values to a soil depth of 50 cm in seven land-use types. error bar shows SE (±).

4.6.3 *SOM* and *SOC* concentration

The data on the mean soil organic matter (*SOM*) for all soil depths measures and the influence of soil depth on *SOM* in different land-use types in shown in Fig. 4.8 and 4.9, respectively. The observed sample wise values of per cent *SOM* were ranged between 1.01 and 22.84. The mean per cent *SOM* values in decreasing order are 14.8, 13.5, 12.7, 11.0, 11.0, 10.5 and 3.2 for forest land, mango plantation, mangrove, grassland, agricultural land, homegarden and the casuarina plantation soils, respectively. The highest mean *SOM* was contained in forest land soils (14.8%) followed by mango plantation soils (13.5%) and mangrove soils (12.7%), while no significant difference was observed among these soils. The lowest *SOM* was reported in the casuarina plantation soils (3.2%) and the values differed significantly with other land-use soils. Pair wise comparison of *SOM* across different land-use types showed highly significant variations among the agricultural land and forest land soils, agricultural land and mango plantation soils, forest land and grassland soils, forest land and homegarden soils, grassland and mango plantation soils, and homegarden and mango plantation soils (the mean difference is significant at 0.05 levels).

However, there was no significant difference in *SOM* among homegarden, agricultural land, and grassland and mangrove soils.

The result indicates that *SOM* content decreased gradually with increase in soil depth. ANOVA revealed that the variations in *SOM* along the three-soil depth were highly significant for all land-use types. The highest *SOM* content (13%) was reported in top soil layer (0-10 cm depth) and significantly differed than *SOM* content at 20-30 cm and 40-50 cm depth. The lowest *SOM* content was observed in 40-50 cm soil depth (10%) followed by 20-30 cm depth (11%); however, there was no significant variation among these two soil depths. It is observed that at 0-10 cm soil depth the significantly high *SOC* content was recorded in forest land soils (17.6%) followed by mangrove (15.3%) and mango plantation soils (15.0%) than 20-30 cm and 40-50 cm soil depths (the mean difference is significant at 0.05 level). The results revealed that the soils across all three depths under the casuarina plantation had significantly low organic matter content (3.8%, 2.4% and 3.5%, respectively) than soils of other land-use types.

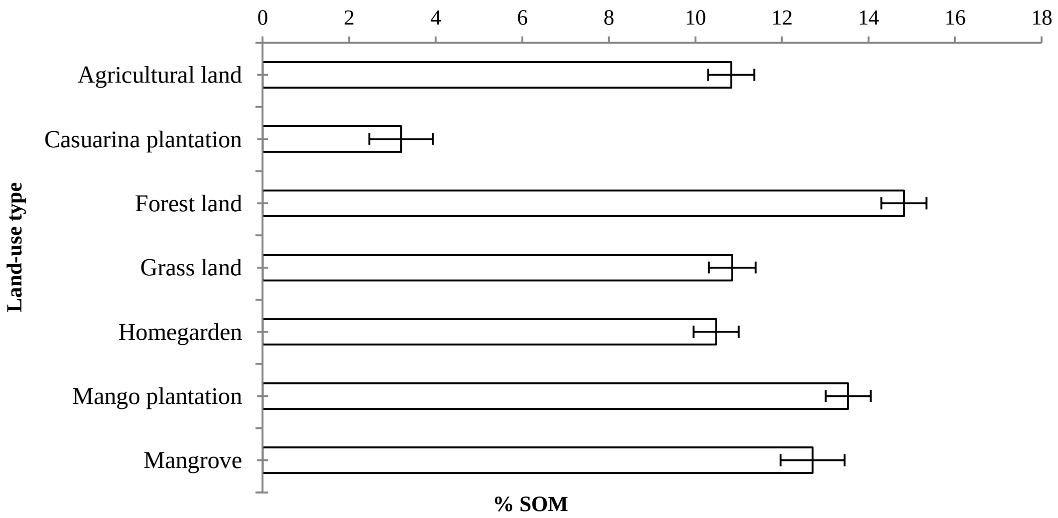


Fig. 4.8: Mean per cent *SOM* content to a soil depth of 50 cm in seven land-use types.

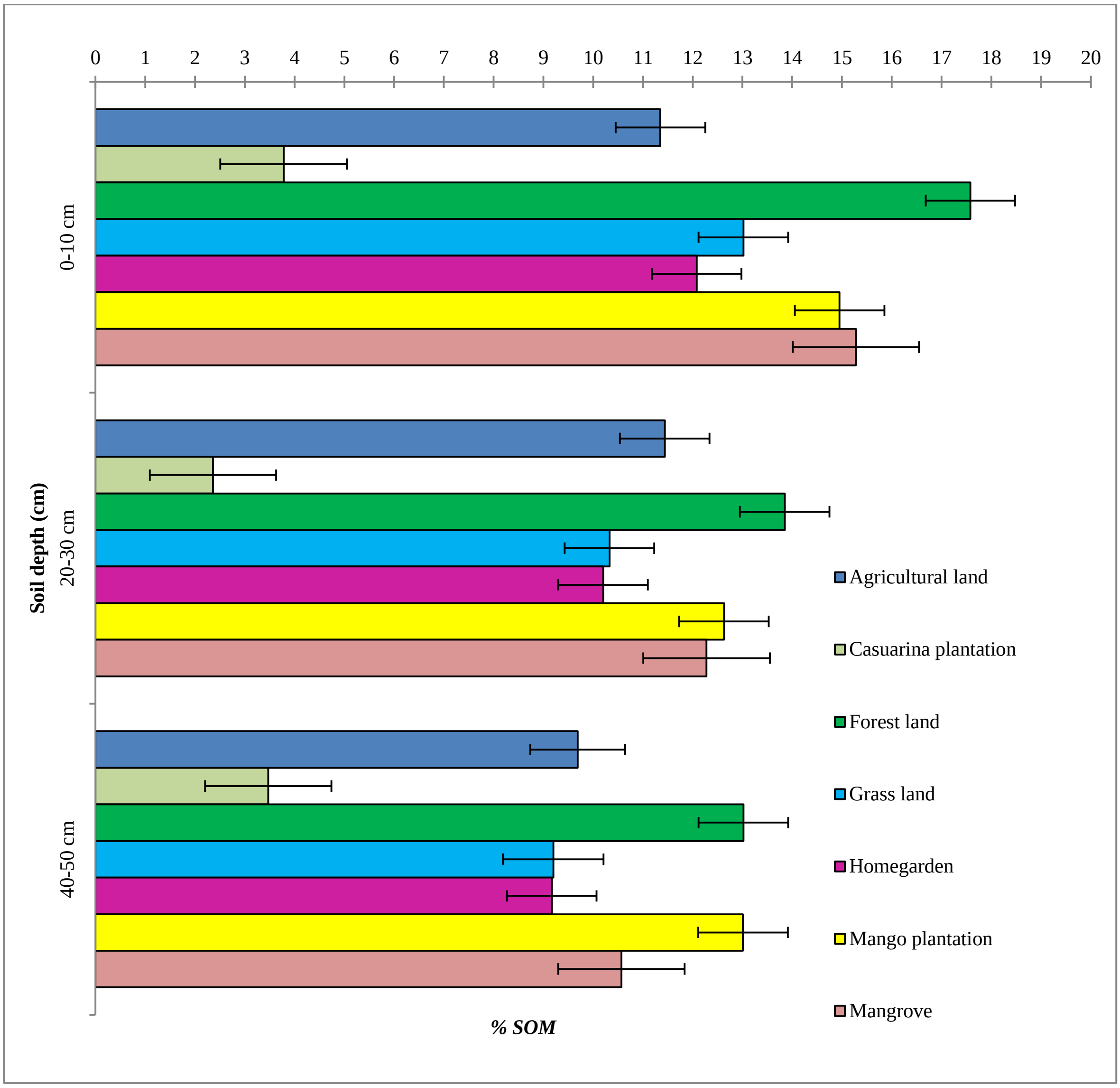


Fig. 4.9: Showing soil organic matter under different land-use types estimated by los on ignition. Bar indicates SE (±).

4.6.4 Distribution of *SOC* density and total *SOC* storage

The data on mean *SOC* density (kg C m^{-2}) for the three depth intervals at different land-use type is represented in Fig. 4.9. The mean *SOC* density up to 50 cm soil depth varied 1.3 kg C m^{-2} (the casuarina plantation soil) to 6.7 kg C m^{-2} (forest soil). The highest mean *SOC* density was found in the forest land soil followed by mango plantation (5.6 kg C m^{-2}), mangrove (5.2 kg C m^{-2}), agricultural land (5.1 kg C m^{-2}) and homegarden soils (4.4 kg C m^{-2}). However there was no significant difference between forest and mango plantation, and between mango plantation, mangrove, agricultural land and homegarden soil organic carbon densities. The results showed that average *SOC* density differed significantly between the forest, mangrove, grass land and the casuarina plantation soils. The lowest mean organic carbon density was found in the casuarina plantation soils followed by grass land soils (4.03 kg C m^{-2}). The results indicated that the mean casuarina plantation *SOC* density differed significantly with other six land-use soils.

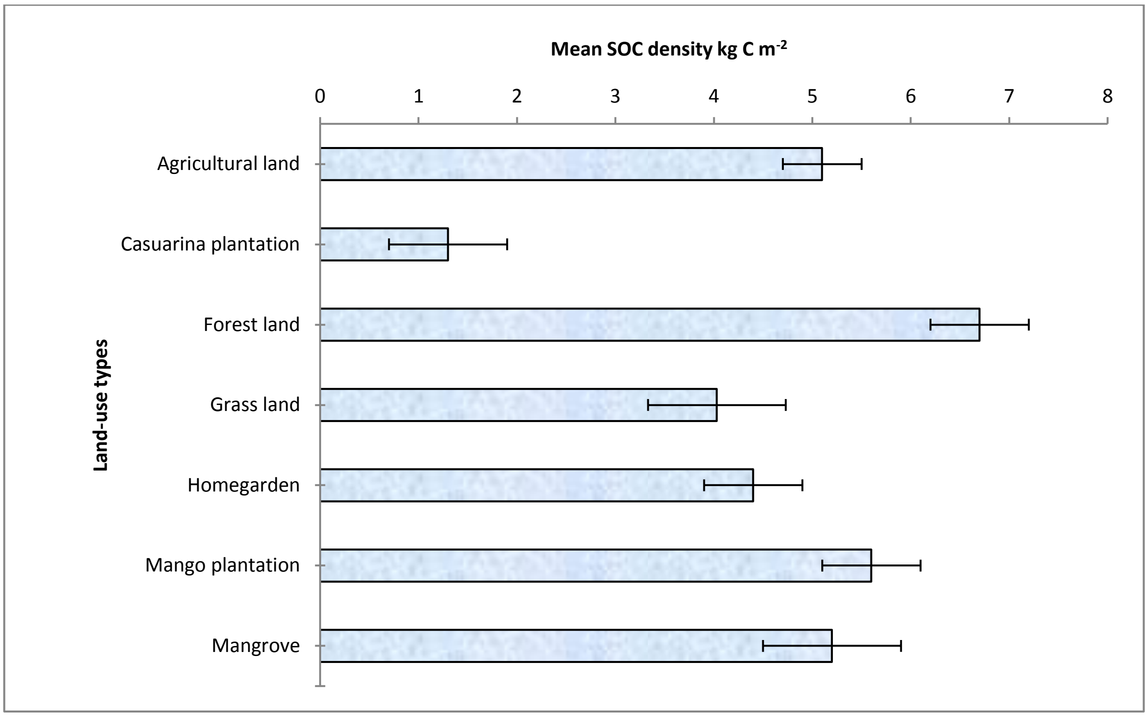


Fig. 4.10: Mean *SOC* density in kg C m^{-2} across seven land-use types. Error bar = SE (±).

Statistically significant variation was observed in mean *SOC* density between three soil depths. The result showed that the mean *SOC* density decreased vertically with an increase in soil depth. The highest (6.1 kg C m^{-2}) mean *SOC* density was observed at 40-50 cm depth followed by 20-30 cm depth (4.6 kg C m^{-2}), and the lowest at the top 0-10 cm layer (3.7 kg C m^{-2}).

The results in Table 4.2 showed that the highest total C storage (328 t C ha^{-1}) up to 50 cm depth was found in forest soils followed by mango plantation (274 t C ha^{-1}), mangrove (258 t C ha^{-1}) and agricultural land soils (257 t C ha^{-1}). The study revealed that the lowest total organic carbon storage in the casuarina plantation soil (59 t C ha^{-1}) followed by grass land (196 t C ha^{-1}), and homegarden soils (219 t C ha^{-1}). Overall, it was observed that the *SOC* stocks decreased with an increase in soil depth. The study revealed that on an average about 61- 69 % of the carbon stocks was observed in top 30 cm layer.

Table 4.2: Estimated mean organic C storage (t C ha^{-1}) to 50 cm soil depth

	***SOC* stocks by land-use types (t C ha^{-1})**				
Land-use type	**0-10 cm**	**0-20 cm**	**0-30 cm**	**0-40 cm**	**0-50 cm**
Agricultural land	58	114	168	216	257
Casuarina plantation	15	26	36	46	59
Forest land	89	162	225	279	328
Grass land	52	95	133	165	196
Homegarden	57	106	150	187	219
Mango plantation	69	128	180	228	274
Mangrove	69	128	177	220	258

4.6.5 Correlation between soil properties

The relationship between soil organic carbon concentration (*SOC*), soil organic matter (*SOM*), soil bulk density, soil electrical conductivity, soil salinity, soil pH, soil moisture content and soil organic carbon storage was established using Pearson's correlation coefficient. The study revealed that the *SOM* and *SOC* concentration had positive correlation with per cent soil moisture, soil salinity and soil organic carbon storage and negative correlation with soil pH and soil bulk density. Soil pH showed significantly negative correlation with EC, soil salinity, soil organic carbon storage (correlation is significant at the 0.01 level). The soil EC showed positive correlation with soil salinity. However, pair wise comparison between *SOM* and soil EC, *SOC* and soil EC, soil pH and soil moisture content, soil pH and soil bulk density, soil EC and soil moisture content, EC and soil bulk density, EC and soil organic carbon storage t C ha^{-1}, bulk density and soil salinity. However, soil moisture content and soil bulk density did not show any correlation. The result showed significant negative correlation between soil organic carbon storage t C ha^{-1} and soil bulk density (correlation is significant at the 0.01 level). It has been observed that soil moisture content has significant positive relationship with soil organic carbon storage t C ha^{-1} and soil salinity. Similarly, significant positive correlation was found between soil salinity, organic carbon storage t C ha^{-1} and soil bulk density.

4.7 Discussion

This study was conducted to characterize variability in soil bulk density, pH, per cent moisture content, EC, salinity, organic matter, organic carbon concentration and organic carbon storage ha^{-1} under different land-use types in the Konkan coast of Maharashtra. The weight loss-on-ignition (LOI) method was used to determine soil organic matter and soil organic carbon storage. This method is rapid, reliable and widely acceptable for most laboratories due to its simplicity in protocols, result accuracy, cost and labour effectiveness and availability of facilities (Ball, 1964; Schulte and Hopkins, 1996; Abella and Zimmer, 2007; Konen *et. al*., 2002; Wright, *et al*., 2008; Rawlins *et al*., 2008; Konare, *et al.,* 2010); Hobley and Willgoose, 2010). The per cent organic carbon concentration in soil was determined using a conversion factor 1.9 from empirical studies and based on the assumption that on average, the organic matter contains 50% carbon (Broadbent, 1953; Schlesinger, 1977; Pribyl, 2010). These researchers argued that this factor is more accurate than that the conventional correction factor 1.724 (Read and Ridgell, 1922; Lunt, 1931; Broadbent, 1953; Howard, 1965; Christensen and Malmros, 1982; Nelson and Somers, 1996; Perie and Ouimet, 2008; Bianchi *et al*., 2008; Rawlins *et al*., 2008; Hollis *et al*., 2012). This was based on the assumption that on an average the organic matter contains 58% carbon. The soil bulk density and per cent soil organic carbon concentrations are the two prerequisites to estimate soil organic carbon stocks (Xu *et al*., 2011_a and 2011_b).

4.7.1 *SOM* and *SOC* under different land-use

The *SOM* concentration varies considerably according to land-use, type of soil, soil texture, vegetation type, depths of measurement, rainfall and different management practices (Jobbagy and Jackson, 2000; Post and Kwon, 2000; Magdoff and Weil, 2004; Collard and Zammit, 2006; Hobley and Willgoose, 2010). The *SOM* and *SOC* concentration determined by weight loss on ignition method varied from 1.01 to 22.8% and 0.6 to 13%, respectively. We estimated the highest organic matter in the forest land soils followed by mango plantation soils and mangrove soils compare to the agricultural land, homegarden and grassland soils, while lowest was in the casuarina monoculture soils. It was observed that the soil organic matter gradually declined with increase in soil depth. Overall, organic carbon stocks significantly declined over depth up to 50 cm for all land-use type soils; however the rate of decline in *SOC* stocks along vertical intervals was mostly same in all land-use soils. It has been stated that the vertical distribution of the absolute amount of *SOC* stored is controlled by various factors such as, vegetation, climate and clay content (Jobaggy and Jackson, 2000). However, the climate is the dominant controlling *SOC* content factor in upper surface layer, which is negatively correlated with temperature and positively correlated with rainfall (Hobley and Willgoose, 2010)

Saha *et al*., (2010) examined soil C storage in natural forest, homegardens, paddy field and coconut stands in Thrissur, Kerala (India) and concluded that the highest total C stock (176 Mg C ha^{-1}) was found in forest soils. Similarly, in our investigation the highest C storage (328 t C ha^{-1}) was found in forest soil, however the estimate was higher compared to Saha *et al*., (2010).

The experimental evidence showed *SOM* and *SOC* had significant positive correlation with soil pH, soil moisture content, total soil organic carbon storage and negative correlation with soil bulk density. The soil bulk density increased with increase in soil depth and in contrast *SOM* and *SOC* declined with increase in soil depth and soil bulk density. De Vos et al., (2005), Steffens et al., (2008), Martinsen et al., (2011) reported the similar trend. It has been stated that organic matter is determinant of soil bulk density and the topsoil is characterised by high organic matter and low bulk density (Hollis, 2012). Oguike and Mbagwu (2009) stated that the soil properties deteriorate with change in land use especially from forest to agricultural land. Our experimental results exhibit significant variation in soil bulk densities, these variations across soil depths between different land-uses could be attributed to varying *SOC* content. The significantly smaller soil bulk densities of top soil layer seem to result from the porous nature of organic matter. The *SOM* and *SOC* concentration does not have any correlation with soil electrical conductivity.

4.7.2 *SOC* in agricultural land

In the study area, the main agricultural crop is rice. Sahrawat (2005) studied organic matter accumulation in submerged rice soils and reported that the decomposition of organic matter is comparatively slow, inefficient and incomplete under flooded or anaerobic soil conditions. However, in study area the submerged conditions remain until it is time to the harvest crop, and the agricultural field is left fallow for the next season crop. Therefore, high temperature in summer and tillage practices allows time to decompose the litter and crop residues under aerobic conditions. Further, the farmers mostly follow a slash and burn agricultural system. The ash containing charcoal formed from the combustion during slash and burn agriculture practice and the litter from adjacent forest, crop residue such as rice straw, cow dung and root residues from crop can make a significant contribution to the total organic carbon in the agricultural soils.

Our result indicates that agricultural land stores 257 t C ha^{-1} in up to 50 cm depth. Agricultural soil organic carbon stocks showed statistically significant variation to the casuarina plantation and forest soils. However, no significant variation was recorded with grass land, homegarden, mango plantation and mangrove soils. Comparatively higher organic matter and C storage in agricultural soils than the grassland and homegarden soils might be due to fertilizer application and slash and burn practices. The agricultural fields in the study area are adjacent to the forests and homegardens, and litter along with the C leached from the forest and homegardens deposit in to the agricultural soil. Again, this might be responsible for high C content in agricultural soils. Several researchers shown that soil organic matter levels in agricultural lands can manipulated by changes crop management such as crop rotation, tillage regimes, fertilizer application and crop residue application (Grace *et al*., 1994; Haynes, 2000; Gregorich *et al*., 2001; Farquharson *et al*., 2003; Magdoff and Weil, 2004). Saha *et al*., (2010) examined soil C storage in various land-use types in Thrissur, Kerala (India) and showed that the lowest total C stock (55 Mg C ha^{-1}) was found in agricultural (paddy) soils. In contrast, our investigation showed significantly high C storage (257 t C ha^{-1}) compared to Saha *et al*., (2010).

4.7.3 *SOC* storage under the casuarina monocultures

The study showed lowest organic carbon content (59 t C ha^{-1}) up to 50 cm soil depth in the casuarina plantations soils compared to other land-use soils. In general, the casuarina plays protective and aesthetic role in the ecosystem. The casuarina plantations occurred primarily on coastal sand dunes. These soils are characterized by high bulk density and low organic carbon content. Very little is known about C storage in the study area. The surface of the soil remains covered with the litter. It is well known that the leaves, catkins, cones and debris of the casuarina plant decompose slowly or with moderate rate (Maily and Margolis, 1992; Gourbiere and Debouzie, 1995; Parrotta, 1999; Duttaa and Agrawal, 2001). The source of C in this soil is litter, understory shrub and herbaceous vegetation and root activities of the plantation (Parrotta, 1999). This might be a reason to have a low C content in casuarina plantations. Parrotta (1999) reported that C*asuarina equisetifolia* plantation in Puerto Rico stores 65 Mg C ha^{-1} total soil carbon in up to 40 cm depth. In contrast, our result showed that casuarina plantation stores low soil carbon (46 t C ha^{-1}) in top 40 cm depth compared to estimate of Parrotta (1999).

4.7.4 Organic Carbon in tropical moist deciduous forest soils

The highest *SOC* was found in forest land soil in the study area. In general, the forests are characterized by high amounts of litter and root activities. In forest ecosystem, the input of the organic matter is largely from the aboveground litter, soil microbial biomass, and root activities (Powlson *et al*., 1987; Trujilo *et al*., 1997; Shrestha *et al*., 2004; Sharma *et al*., 2004), therefore the in forest soils the *SOM* tends to concentrate in topsoil. The concentration of soil organic matter depends on the quality of litter inputs to the soils. The soil organic matter content are intimately associated with ecosystem productivity, and fertility and nutrient content of a forest soil has a large influence in C sequestration (Khanna *et al*., 2001. The highest C content in forest soils may be due to tree species. Khanna *et* al., (2001) suggested that C sequestration in forest soil is influenced by the tree species.

Some researchers argued that roughly half of the soil organic carbon of the top 1 meter soil is found in upper 30 cm layer (Jobbagy and Jackson, 2000; Bradley *et al*., 2005). In the forest soils, the organic carbon concentrations decreased with increase in soil depth as expected and varied significantly between the depths. Compared to the other tropical studies our result showed higher *SOC* storage than the estimates of global tropical means (Post *et al*., 1982; Brown *et al*., 1993; Batjes, 1996; Amthor and Huston, 1998; Jobbagy and Jackson, 2000; Grimm *et al.*, 2008). Our results indicate that about 69% soil organic carbon storage in forest soil was observed in top 30 cm layer. The total *SOC* storage up to 30 cm depth (225 t C ha^{-1}) in forest is comparable to the figures estimated in past studies (40 t C ha^{-1}, 42 t C ha^{-1}, 67 t C ha^{-1}, 79 t C ha^{-1} and 57 t C ha^{-1}) in tropical moist deciduous forests by Das, 1975; Rajamannar and Krishnamoorthy, 1978, Banerjee *et al*., (1986), Jha *et al*., (1979) and Ravindranath *et al.*, (1997), respectively. Lal (2005) calculated soil organic carbon densities for major biomes of the world, and showed that on an average tropical biome contains 125 Mg C ha^{-1}. In comparison to these estimates, our estimates are higher for forest soils (328 t C ha^{-1}). Chaturvedi *et al*., (2001) reported 22 t C ha^{-1} *SOC* storage in tropical dry forest of India up to 30 cm soil depth. This estimate was comparatively lower than our estimate (168 t C ha^{-1}). Xu *et al*., (2011) estimated forest *SOC* stocks in Republic of Ireland and our estimates of 328 t C ha^{-1} were higher compared to his estimates of 236 t C ha^{-1} for up to 50 cm soil depth.

Several researchers studied soil C storage in tropical moist deciduous forests in Madya Pradesh, Kerala, Uttar Pradesh, West Bengal, Mizoram, Tamil Nadu, Uttarakhand, Andaman and Nicobar Islands and Maharashtra (India). The estimated *SOC* stocks under this forests are in the range of 8.9–177 t C ha^{-1} and 14.5-328 t C ha^{-1} in top 50 cm and 100 cm soil depth, respectively (Yadav and Sharma, 1968; Jose and Koshy, 1972; Rajamannar and Krishnamoorthy, 1978; Banerjee *et al*., 1981; Singh *et al*., 1982; Singhal *et al*., 1982; Das and Roy, 1982; Singh and Datta, 1983; Prasad *et al*., 1985; Samra *et al*., 1985; Prasad *et al*., 1986; Totey *et al*., 1986a; Totey *et al*., 1986b; Narain *et al*., 1990; Banerjee *et al*., 1990; Banerjee and Sharma, 1990; Srivastava *et al*., 1991; Mongia and Bandyopadhyay, 1992; Raina *et al*., 1999; Chhabra *et al*., 2003). In our study, the C storage up to 50 cm depth is very high (328 t C ha^{-1}) compared to the above estimates recorded in other tropical moist deciduous forests of the country. Further no any evidences storage in Western Ghats and Konkan coast available on C storage. The higher estimates in current study might be due to high humidity, high rainfall, and the mixed species type vegetation.

4.7.5 *SOC* in grasslands

In general, high *SOC* concentrations resulted in high carbon stocks. The grassland soil constitutes an exception in that as they have low *SOC* concentration and high *SOC* storage. This is due to their comparatively high bulk density. In grassland soil, the *SOC* storage decreased vertically with increase in soil depth. It has been stated that the grass species generally have a shallow root system compared to tree species, and which allocates the majority of root biomass to the top soil layer (Haile *et* al., 2009). In subsoil layer of the grass land the carbon is presumably not from grass origin (carbon transported down the soil profile with water). However, most of the *SOC* in deeper soil layer originated from the tree components (Haile *et* al., 2009). Similarly, in our study in the deep soil layer the carbon content might be due to presence of few trees and shrub species on grassland site. *SOC* content in the grass land soils differed significantly with the casuarina plantation, mango plantation and forest soils. While no significant variation was observed between grass land, agricultural land, homegardens and mangrove soils. Xu *et al*., (2011) estimated grassland *SOC* stocks in Republic of Ireland and our estimates of 196 t C ha^{-1} were low compared to his estimates of 207 t C ha^{-1} for up to 50 cm soil depth.

4.7.6 Organic C in homegarden soils

Homegardens of the study area are characterized by variety of tree, shrub, herb and climber vegetation. Many of these plant species are managed to provide some extent of biomass for use as mulches and green manure. This might result in release of nutrient from biomass, accelerate microbial activities and manipulate rate of conversion of these inputs to the soil organic matter. Saha *et al*., (2010) investigated soil C storage of homegardens in Thrissur, Kerala (India) and reported that 108 Mg C ha^{-1} and 119 Mg C ha^{-1} of total *SOC* stocks was found in small and large homegardens, respectively. However, our study showed significantly high *SOC* storage (219 t C ha^{-1}) compared to Saha *et al*., (2010). The *SOC* content decreased with an increase in soil depth. Saha *et al*., (2009) reported that higher *SOC* stocks in upper layer were due to higher quantities of litter, other organic minerals, and their rapid decomposition. The majority of shrub and herb root systems are restricted within the upper 50 cm layer in homegardens (Waisel *et al*., 1991). Saha *et al*., (2009) indicated that tree species richness and density influence the *SOC* content in homegardens within 50 cm depth. However, in our study, no conclusion can be drawn that tree density or species richness influences the *SOC* content; this could be a subject of future research. Homegarden soils contain 33% less *SOC* than forest soils, 37% higher than the casuarina plantation soils, 13% higher than grassland soils and 15 % less than agricultural land soils. Obviously, forest soils are characterized by low soils disturbance, high species diversity and high rate of litter.

4.7.7 *SOC* stocks in mango plantations

In recent past, most of the forests are cleared for mango plantations in the Konkan Coast of Maharashtra. Mango is the only cash crop of the area and favourable climatic conditions are the two main reasons for expansion of the mango plantations in the entire Konkan Coast. The result showed that mango plantation soil stores 278 t C ha^{-1}. Overall, significant variation was observed between mango plantation, agricultural land and the casuarina plantation soils. The forest, mango plantation, mangrove and grassland soils exhibit little differences in C storage, while did not differed significantly. Next to the forest soils, the mango plantation showed highest C content. This might e due to litter, branches, other debris and fertilizer application. As already stated the plantations are established on forest land or adjacent to the forest patches. The C leached from the adjacent forest may drain to the mango plantation soils. However, we could not strongly predict the high C stored in the land-use.

4.7.8 *SOC* in mangrove soil

Our study showed that the total *SOC* storage up to 30 cm depth (177 t C ha^{-1}) in mangrove vegetation soil is also highly comparable to the figures estimated in past studies (34.9 t C ha^{-1} and 30.2 t C ha^{-1}) in littoral and swamp forest by Sahoo *et* al., (1989) and Ravindranath *et al*., (1997), respectively. Very little is known about C storage in mangroves of Konkan coast of Maharashtra. Our study indicates that the mangrove soils contain comparatively higher *SOC* than the casuarina plantation, grassland and homegarden soils. In the wetland soils, the higher C content may be related to low soil pH, high salinity, higher clay and silt content (Noordwijk, *et al*., 1997). Chhabra *et al*., (2003) reported 92.1 t C ha^{-1} *SOC* stocks in littoral and swamp forests of India. In this current study, the mangrove soils are characterized by high electrical conductivity and salinity. The C content of Sunderban mangrove forest ranges between 38-64 t C ha^{-1} (Bandyopadhya, 1986). The study in Konkan coast mangrove soils showed 93.3 – 154 t C ha^{-1} C storage (Powar and Mehta, 1999). In our study, the mangrove soils contain 258 t C ha^{-1} C stocks in up to 50 cm depth, which is much higher compared to the above estimates by Chhabra *et al*., (2003), Bandyopadhya, (1986) and Powar and Mehta, (1999). Mangroves produces large amount of litter in the form of leaves, branches, roots and other debris, and its decomposition and organic detritus contribute to the production of dissolved organic matter in the soil (Kathiresan and Bingham, 2001). It has been reported that mangrove litter decompose quickly with high leaching rate in the first few weeks of exposure in the field (Valk and Attiwill, 1984; Mfilinge *et al*., 2005). In India, the litter decomposition rate of the mangrove species like *Avicennnia officinalis* is very fast (Wafer *et al*., 1997), and this might be responsible for high C storage in mangrove soils in the study area.

4.8 Conclusion

In this study, *SOM* and SOC were calculated for seven land-use types from the soil surface down to a depth of 50 cm. The forest land soils are rich in per cent of *SOM* and total *SOC* storage followed by mango plantation. The casuarina plantation soils are poor in *SOM* and total *SOC* storage followed by agricultural land and homegarden soils. Overall, the *SOC* storage gradually decline vertically with an increase in soil depth for all land-use soils. Overall, mean *SOC* storage under different land-use types across the soil depth showed statistically significant variation. The total *SOC* storage was highest in forest soils followed by forest land and mangrove soils, and the casuarina plantations contained lowest *SOC* stock. The study revealed significant positive correlation between the *SOM*, *SOC* concentration and *SOC* storage. These parameters showed positive correlation with soil moisture content and negative correlation with soil pH and bulk density. The strong negative correlation was found between soil pH, soil moisture content and soil EC. Evidence form this study demonstrate unique relationship between *SOC*, *SOM*, soil bulk density, soil pH, soil electrical conductivity and soil moisture content in the south Konkan coast of Maharashtra.

5 QUANTIFYING SEASONAL COMPOSITION, ABUNDANCE, DIVERSITY AND SPECIES RICHNESS OF AVIFAUNA AT DIFFERENT LAND-USE TYPES IN THE KONKAN COAST REGION

5.1 Introduction:

India comprises of 1219 bird species that contribute 12% of the world's total bird species and of these 7% of bird species are threatened (Kumar *et al*., 2000). ENVIS centre on avian ecology published that in India there are 79 endemic birds or restricted range species of which, 18 (23%) species are globally threatened, 19 % are near threatened, 34% are least concern and status of 20 % species is not confirmed (Jathar and Rahmani, 2006). On other hand Threatened Bird Forum (2007) argued that India has 75 globally threatened bird species and among these 12 bird species are critically endangered, 10 endangered and 53 vulnerable. Threatened Bird Forum (2007) has stated that most threatened bird species are specialized in their habitat requirements, and are totally dependent on a particular type for their survival such as forest, grassland or wetland. Many bird species visits India during winter season. Similarly, some bird species shows local migration depending on season and availability of food and water. Robertson and Hackwell (1995) and Harisha and Hosetti (2009) argued that seasonal change in avifaunal diversity occurs due to their foraging behaviour. Gutzwiller and Barrow (2002) reviewed that avian community structure can be influenced by season and land-use type at different spatial scale (Wiens and Rotenberry 1981, Wiens 1989). Avifaunal structure and composition is highly related to vegetation structure (Harisha and Hosetti, 2009). In general, forest vegetation attracts more bird species due to habitat suitability. Many birds are associated with regeneration of many plant species and this mutual relationship plays vital role in their life cycle.

Several researchers stated that the birds have been considered good predictors of habitat quality, because they relate to changes in their associated habitats in numerous ways (Raman *et al*., 1998; Raman, 2001; Chettri *et al*., 2001; Chettri *et al*., 2005). The monitoring of the bird-habitat relationship as well as species distribution pattern is important because they are sensitive to anthropogenic changes. Gregory and Strien (2010) argued that among bio-indicators, birds are probably better known and better studied than any other taxa. Estimates of bird abundance are one of the cornerstones of the IUCN Red List classification scheme (IUCN, 2001). Similarly, Lambert (1993) and Buckland *et al*., (2008) stated that bird population and density (abundance) estimates are widely used in bird conservation across the world, which allow us to determine changes in population size and helps us to understand the impacts of the habitat loss, pollution or harvesting.

The rapid deterioration of the tropical forests and large-scale human disturbances affects vegetation structure as well as bird communities (Schulte and Niemi, 1998). Many researchers argued that that conversion of native forest to pastures, croplands and other human dominated habitats is major reason of biodiversity deterioration in the tropics (Myers, 1992; Sala *et al*., 2000; Naidoo, 2004). Recent work has been emphasized the importance of common bird species to ecosystem functioning and suggested that the depletion of their populations might significantly affect ecosystem services (Gregory and Strien, 2010).

Almost nothing is known about the avifaunal diversity and species richness of the Konkan coast of the Western Ghats in relation to different land-use types. The study of comparing seasonal bird distribution and variation at different land-use types or habitats of the study area aims at understanding potential future impacts of the land-use changes on birds. Species richness and diversity studies of bird communities in the study area are urgently needed. The World Conservation Monitoring Centre (1992) reported that avifaunal endemism level in Western Ghats is low compared to floral endemism. However, recently many ornithologists considered Western Ghats as hotspot of bird endemism in tropical region (Bhagwat *et al*., 2005, Gunawardene *et al*., 2007). Although the avifauna in tropical forest of Western Ghats, Malabar and Goa region has been relatively well studied but little is known about bird diversity, species richness and distribution in tropical moist deciduous forest of Konkan coast. The major objectives of the present study are as follows

1. To prepare the inventory of the bird species at different land-use types or habitats such as forest land, agricultural land, homegarden, grassland, mangrove forest, casuarina plantation and mango plantation in Konkan coast.
2. To characterize seasonal composition, abundance, diversity and species richness of different bird species at different land-use types or habitats in Konkan coast.
3. To determine the species conservation status of species in the study area.

5.2 Review literature:

As far as present and past biodiversity concerned our knowledge of today's bird diversity is as near to being complete as any other group of organisms on earth (Bruford, 2002; Chapman, 2009; Global Biodiversity Information Facility, 2010; Renner, 2011). Bruford (2002) explained that we have a reasonable knowledge of how present day bird species are distributed across the globe, where they are absent, how many species have gone extinct in the recent past, where those extinctions took place, how many species under risk of extinction, and what are the reasons for the extinction. In latest assessment of IUCN Red List, out of the total 9895 bird species of the world 1240 (12.5%) species are considered as threatened with extinction (Birdlife International, 2010; IUCN, 2011a). There is now a considerable knowledge of bird numbers and distribution in some countries (Bibby *et al*., 2000).

In Asia the knowledge of birds and bird population is extremely good and different kind of monitoring data exist, however it is suspected that there may be gaps in countries, species, site and habitat coverage (Gregory and Strien, 2010). The challenge for humankind is to examine and compare relevant long-term bird monitoring data and to access the extent to which it might contribute to global wild bird indicators. In European bird monitoring studies it is reported that wild bird indicators only measure a component of biodiversity change, and need to be used carefully to assist policy makers and land managers, but they proved that birds are the powerful tool in generating awareness of rapidly growing threats to nature.

Waltert *et al*., (2005) in a review showed that most information on bird species richness in tropical land-use systems is available from America (Estrada *et al*., 1997; Greenberg *et al*., 1997a and 1997b; Calvo and Blake, 1998; Daily *et al*., 2001; Hughes *et al*., 2002; Mas and Dietsch, 2004). Only few studies exist from Africa (Blankespoor, 1991; Kofron and Chapman, 1995; Plumptre, 1997; Lawton *et al*., 1998), South or Southeast Asia (Beehler *et al*., 1987; Thiollay, 1995), or Australia (Poulsen and Lambert, 2000).

5.2.1 Seasonal variation in bird, abundance, density, diversity and species richness

The structure and composition of bird assemblages and how they are altered by habitat features have been one of the most permeative themes of investigation in community ecology (Block and Brennan, 1993; Jayapal *et al*., 2009). Herzog *et al*., (2002) reviewed that assessing bird species richness has gained increasing importance in environmental impact assessment (Fjeldsa 1999), conservation planning (Bibby *et al*., 1992; Stotz, 1996), and ecological research (Huston, 1994; Rosenzweig, 1995). A number of bird count and census methods are characterized and standardized in Holartic regions where species richness is low (Holmes *et al*., 1986; Bibby *et al*., 2000). However, in the tropics these methods are not applicable due to highly complex bird habitats and heterogeneous environment (Terbourgh *et al*., 1990; Remsen, 1994). Therefore, the detailed quantitative studies of tropical avifaunal communities are highly labour intensive (Terbourgh *et al*., 1990). Bird species richness and community structure differs from region to region (Karr, 1976; Pearson, 1975; Recher *et al*., 1996), within a region, as many biotic as well as abiotic factors vary from habitat to habitat. Several researchers have identified the factors responsible for variation in bird fauna from habitat to habitat outside India (Anderson, 1970; Beedy, 1981; Manuwal, 1983) and within India (Beehler *et al*., 1987; Johnsingh *et al*., 1987; Joshua and Johnsingh, 1988; Daniels, 1989; Katti, 1989; Rai, 1991; Joshua and Johnsingh, 1994). Tropical forest bird species contribute a great proportion of threatened species, where quantitative data are sparse (Birdlife International, 2004). Lee and Marsden (2008) reviewed that the true estimates of the bird density are often vital for identifying important bird areas (Hill *et al*., 2001), studies in population trends (Cahill *et al*., 2006), species reactions to land-use change (Marsden, 1998), studies of direct exploitation (Lambert, 1993), assessment of extinction risk (Birdlife International, 2004) and to determine the effectiveness of conservation management actions (Chari *et al*., 2003). He also stated that estimates of the density of birds are often crucial. Most of the researchers showed that the bird species composition differs significantly between land-use types. The recent past studies revealed that forested areas contain more bird species than agricultural land (Blankespoor, 1991; Daniels *et al*., 1992; Thiollay, 1995; Daily *el al*., 2001; Naidoo, 2004). The distribution of many bird communities is affected by habitat fragmentation and reflects inter-specific dynamics and population trends associated with the habitat (O'Connell *et al*., 2000).

5.2.2 Birds as indicators of biodiversity and environmental change

Many scientists in Europe explained why birds might be useful indicators of nature more broadly (Gregory and Strien, 2010). Gregory and Strien (2010) showed that birds have proven to be highly effective indicator of impacts of environmental change. Urfi *et al*., (2005) reviewed that there has been extensive research work on the standardization of bird count techniques (Ralph and Scott, 1981; Verner, 1985; Bibby *et al*., 1992); however, as per Indian context it turns out that most writings are general in nature (Gaston, 1973; Verghese, 1995; Javed and Kaul, 2000; Urfi, 2004). Harisha and Hosetti (2009) stated that birds are among the best monitors of environmental changes. There are number of reasons why birds act as indicator of biodiversity. Birds are major component of food chain and are sensitive to anthropogenic and natural environmental alteration. They are considered as most diverse, mobile and widespread living organisms on the earth. In recent past researchers studied wetland bird communities of India and stated that birds are excellent indicators of water quality beside their beauty and recreational and economic importance (Bilgrami, 1995; Harisha and Hosetti, 2009; Gupta *et al*., 2011).

5.2.3 Birds and ecosystem services

Birds have a resonance and connection with humans and their lives from the public to policy makers alike. Gregory and Strien (2010) stated that birds could act as excellent tool to create awareness of biodiversity issue in a way that many other taxa cannot. They deliver ecosystem services to humans not only in terms of cultural services but also in terms of provisioning, regulating and supporting services (Whelan *et al*., 2008). The avifauna is an important part of an ecosystem playing roles such as scavengers, pollinators and predators of insect pest (Dhase *et al*., 2009).

5.2.4 Threats to bird biodiversity and their conservation

Birds are the part of biodiversity and their widespread declines point out a fundamental malaise in the way that humans treat the planet Earth. Birdlife International (2010) informed that the most important threat to the worlds bird are spread of agriculture, human use of biological resources (direct over exploitation of bird population and indirect impacts of forest logging on bird population), species invasion, environmental pollution and human induced climate change. It is evident from the IUCN Red List Index for the world's bird shows that there has been a steady and continuing deterioration in the threat status since 1988. In the recent past, several researchers have been applied a rapid assessment approach to maximize data collection with limited funds, time and personnel in order understand tropical bird communities. Rapid assessment survey of tropical bird communities are increasingly used to estimate species richness and to determine conservation priorities, but results of different studies often not comparable due to lack of standardization (Herzog *et al*., 2002).

Western Ghats has about 500 bird species of which 22 (4%) are endemic (Gunawardene *et al*., 2007). However, seven of the 22 endemic bird species are globally threatened. The habitat loss and fragmentation is the main threat of bird diversity in Western Ghats, which is likely to impact large and wide – ranging as well as highly restricted geographic ranges bird species (Mudappa and Raman, 2009). The forest below 500 m MSL has almost completely been cleared long ago. The remaining forest face a number of pressures, such as the increasing human population, which has led to increased encroachment into forest lands, intensive spread of agriculture, over grazing, conversion of forest land to miscellaneous plantations and over harvesting of fuel wood and minor forest products. The coastal plains of the Western Ghats are supposed ideal for generating hydroelectric, thermal, wind and nuclear energy power. The Western Ghats is recognized as one of the Endemic Bird Areas of the World (Stattersfield *et al*., 1998).

5.3 Materials and methods

Birds are considered as relatively most easy to find, identify, survey and census. Their taxonomy is relatively well agreed (Bibby, 2002) and their phylogenetic status is well defined. It been suggested that various methods of bird counting or survey design and analysis are well developed but that the data are realistic and expensive unless the survey or census made by skilled, competitive and motivated observer (Gregory and Strien, 2010). However, bird mobility and migratory behaviour compare to other taxa is major problem to study the bird population dynamics (Greenberg and Marra, 2005).

The details of field method used, sampling framework, land-use type selection, the layout of transects, selection of points on the transects, season and duration of counts, equipment used, distance estimates, reasons for selecting method and bird identification methods used in the bird survey are given below

5.3.1 Field methods for the bird survey, the study area and sampling framework

A point transect method based on distance sampling (following Bibby *et al*., 2000, Buckland *et al*., 2001; Sutherland *et al*., 2004; Gibbons and Gregory, 2006) was used to survey the bird community at different land-use types in Konkan coast of Maharashtra state, India. The counts were conducted under two favourable weather conditions in the dry season and monsoon season during December 2008 to May 2009 and June 2009 to November 2009 respectively. The detailed description on study site is given in chapter 2: Description of the study site.

Point transect is defined as "A transect along which the point count method is used; with no recordings are made between stations" (Ralph, 1981_a). In other words bird counting applications based on point counts, distances measured from a point of observation (instead of transect) which is referred as "point transect" (Buckland *et al*., 2001; Royle *et al*., 2004). In other words, in a point transect survey the observer is stationary and records birds in a radius around him (Taylor, 2007). Buckland *et al*., (2006) stated that points transect methods works well for all species, but some species are insufficiently visible or noisy to allow adequate numbers of detections by observers standing at random points. Although point transect methods have been widely used in bird surveys, there have been no attempts made to orient field methods and maximize the accuracy of abundance estimates by minimizing the violation of the following critical assumptions (Taylor, 2006; Lee and Marsdan, 2008a).

1. Birds at 0 m distance are detected with certainty
2. Birds are detected at their initial location and,
3. Distances to object are measured accurately.

5.3.2 Land-use type selection

The detailed description on land-use selection given in chapter 2: Description of the study site.

Table 5.1: The number of line transects used in different land-use types (length 500m each).

Sr. No	**Land-use type**	**Number of transects**
1	Forest land	35
2	Agricultural land	17
3	Grassland	24
4	Mango plantation	8
5	Homegardens	11
6	Mangrove forest	5
7	Casuarina plantation	3
Total number of point transects		**103**

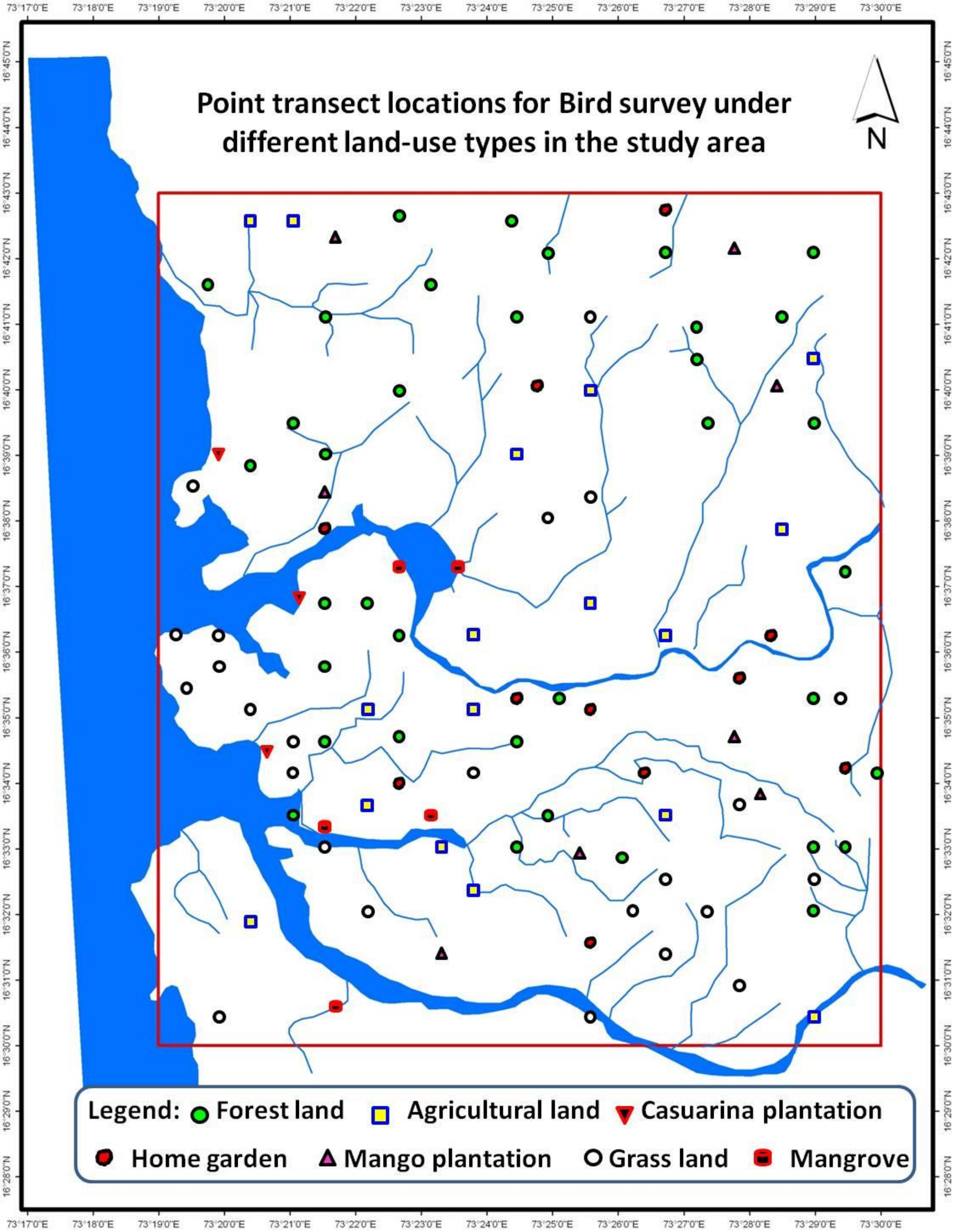


Fig. 5.1: Map showing point transects locations for bird survey under different land-use types in the study area. Geographical coordinates: 16° 30' to 16° 43' N latitudes and 73° 19' to 73° 30' E longitude

5.3.3 Sampling strategy: Layout of transects and selection of points on transects

The work was carried out using a stratified random sampling scheme in which the sample universe is divided into group of sample units (strata). The strata are assumed to have a more homogeneous bird abundance than that of sample universe as whole (Pendleton 1995). Here we used land-use types as strata. All over 103 point transects randomly located within seven strata by using random numbers Table (Panse and Sukhatme, 1985). Transects were formed from a line transect, with circular shape survey plots (Marques, 2009). The 500 m long point transects were located at the 103 randomly selected sampling units of different land-use types or habitats. These transacts were then surveyed. The number of transects walked in each land-use type or habitat are given in Table 5.1. Strata need not have an equal number of samples, but weighted estimates may be needed for some unequal sample allocations (Cochran, 1977). The flagging tapes were used to mark out the start and finish points and five points were marked out along each transect. The first point was established at fifty meter distance from the starting point and all others at 100 m interval apart (Fig. 5.2). Thus in total 5 point counts were taken along each transect. In total, 515 census points covering seven land-use type or habitat along 103 transect were surveyed in the dry and monsoon season (Fig. 5.1).

5.3.4 Season, duration of count and field data collection

In both seasons, visual bird censuses were conducted between 0700 and 0900 hours when birds are the most active, during good weather conditions at different habitats. It was assumed that birds are most vocal at or before sunrise (Robins, 1981; Bart and Herrick, 1984). To avoid bird disturbance caused by observer's arrival the count were started four minute after reaching the point. The all birds detected visually and acoustically during fifteen minutes at each point along transects were identified, counted and recorded within 50 m radial distance (Fig. 5.2). The radial distance of each individual bird or cluster of birds detected was estimated using measuring tape and rangefinder from the point where the observer was standing. The bird seen beyond 50 m range and flying overhead were excluded from the count. The key issue was to estimate the probability of detecting birds given that the birds are hidden by vegetation. Riley (2003) explained that incorporating a longer bird counting period is advantageous in tropical forests where many birds are cryptic and the vegetation structure means that birds may be hard to locate. This helps in recording inconspicuous species as the observer has more time to detect and identify the bird species in the surrounding area. However, a drawback of increasing the count period is the increase in probability of birds moving in to the area or getting chances of double counting due undetected movements (Reynolds *et al.*, 1980; Scott and Ramsey, 1981; Fuller and Langslow, 1984; Verner, 1985).

The special care was taken to avoid double counting of the birds. The counts were not conducted when wind velocities were > 16 km/hour or when it was raining. The detail survey information on land-use, list number, transact number, nearest village, transect GPS location, date of survey, start and finish time, local name of bird species, number of individual birds, radial distance of the bird or cluster of birds from observer and number of species was recorded in data sheet (Appendix VI). The activities of the birds, such sitting on the ground, rocks, roads, electricity wire and poles, ponds, trees or flying but landing with-in 50 meter radius from observer, were recorded in data sheet.

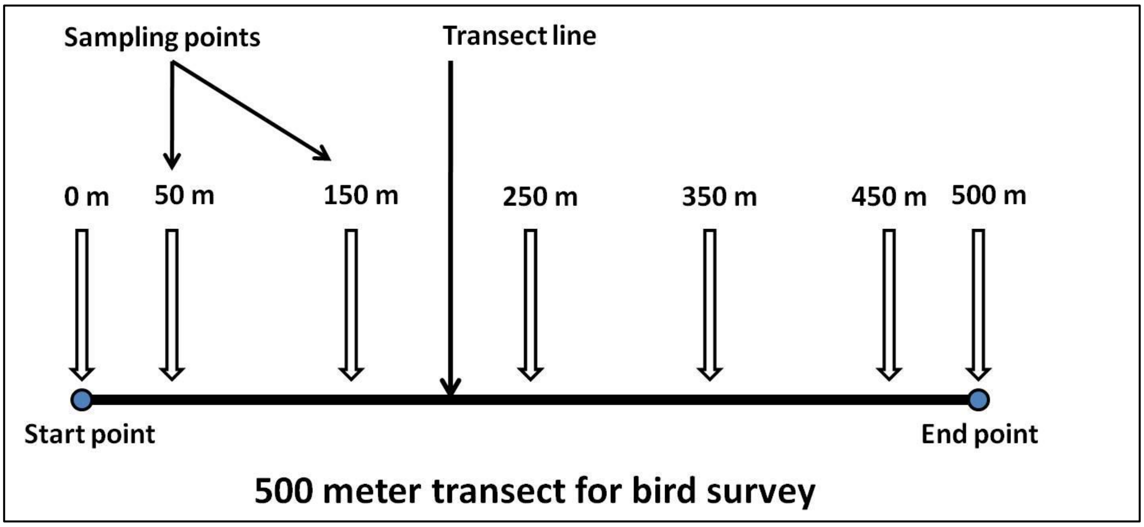


Fig. 5.2: Layout of the points on transect

5.3.5 Distance estimates and Identification of birds

Distance sampling is a way of estimating bird densities from point count transect data and assessing the degree to which our ability to detect birds differ in different habitats and at different times (Buckland *et al*., 2001; Rosenstock, 2002; Buckland *et al*., 2008). Distance sampling is increasingly being used in a wide range of bird population studies (Marsden, 1999; Brotons, 2005; Lee and Marsden, 2008). Alldredge (2007) reviewed that bird abundance estimation is central to studies comparing spatial and temporal patterns of bird diversity and abundance (Kepler and Scott, 1981, Scott *et al*. 1981). Buckland *et al.* 2001) suggested that the distance sampling is one common method used to estimate avian abundance. It is believed that point transect method is perhaps now the most widely used distance sampling technique in density estimation for multispecies survey in tropical forest. As already stated, for each encounter, radial detection distance measure associated with each bird or cluster of bird from observer were taken. The radial detection distance associated with the cluster and or individual bird was recorded. We briefly considered the key assumptions of the basic point transect method stated in various publications (Buckland *et al*., 2001; Thomas *et al*., 2010). The key assumptions were: 1) objects on point are detected with certainty; 2) objects do not move; 3) all measurements are exact; and species are not misidentified.

An exclusive fieldwork was carried out with adequate level of bird identification skills. The binocular (8x40 and 10x42) was used to view the birds. During the field work photograph's of the birds also taken where possible. Birds were identified using physical features with the help of field guides and reference books (Grimett *et al*., 1999; Ali and Ripley, 1983; Pande *et al*., 2003; Besten, 2008; Grimett *et al*., 2005).

5.4 Data analysis

The analysis of variance was carried out to test the null hypotheses that variation in seasonal bird survey at different land-use or habitats will not bring about significant changes to the number of individual birds, number of species detected. Abundance, frequency and density were calculated by using following formulae. The data was analysed by using Microsoft Excel, EstimateS version 8.2.0 (Colwell, 2009) and Eco-sim version 7.72 (Gotelli and Entsminger, 2011) and Distance 6.2 release 2 (Thomas *et al*., 2010).

5.4.1 Quantitative analysis:

Frequency and abundance was calculated by following formulae. Frequency is the number of plots, stations, counts (visits), transects, or intervals in which a species is detected and it is calculated by following formula

$$\text{Frequency (F)} = \frac{\text{Number of sampling in which spp. occured}}{\text{Total number of point transects studied}} \text{ x } 100$$

Bird density is the number of birds per unit area (Ralph, 1981_b). It is a fundamental property of all populations that can vary spatially and temporally in response to habitat change (Holmes and Sherry, 2001; Morris, 2003; Bock and Jones, 2004).

Abundance is the average number of individuals of a species per point transect for the point transect in which it occurs and it is calculated by following equation.

$$\text{Abundance (A)} = \frac{\text{Total number of individual of the spp. in all sampling points}}{\text{Number of sampling units in which the spp. occured}}$$

5.4.2 Application of Distance software 6.0 release 2:

An attempt has been made to analyse the densities of the all species by using Distance 6.0 release 2 (Thomas *et al*., 2010). Detection function, abundance, EDR, encounter rate, Mean cluster size, density estimates and associated variance estimates were obtained using MCDS analysis engine in Distance 6.0 release 2. The use of these method is to increases the reliability of density estimates made on subsets of the whole data (e.g., estimates of different habitats or species), to increase precision of density estimates (Marques *et al*., 2007). We fitted the half normal with cosine model in MCDS engine to the pooled data. Delectability curves were estimated for all species together in each land-use type.

5.4.3 Species richness and species accumulation curve

The detail methodology for estimating species richness and constructing species accumulation curves refer chapter 3: 3.5.2.

5.4.4 Bird species diversity:

There are number of species diversity indices used in the large amount of literature on biodiversity and ecological monitoring (Spellerberg and Fedor, 2003; Harisha and Hosetti, 2009). The different indices such as the Shannon-Weaver index of diversity, evenness, Simpson's index of dominance, Simpson's index of diversity, Sorenson's quantitative index of similarity and Jaccard's similarity indices used are described in chapter 3: 3.5.3.

5.5 Results

The overall avifaunal research findings of the dry and monsoon season point transect surveys at seven land-use types (agricultural land, forest land, casuarina plantations, mango plantations, grasslands, homegardens and mangroves) in Konkan coast of Western Ghats (India) are summarized under the consequent headings.

5.5.1 Overall bird composition and structure in the study area

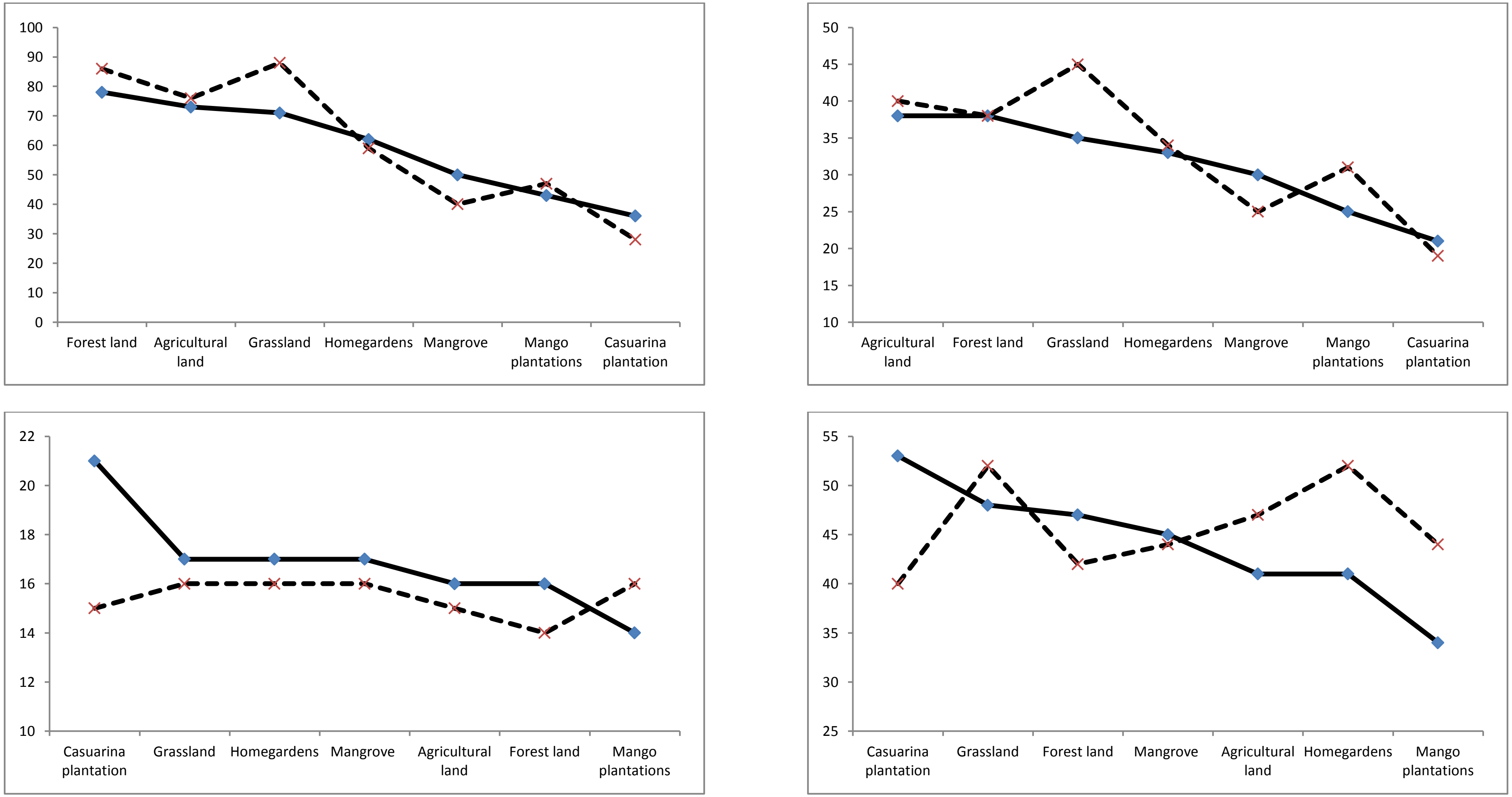
A list of birds recorded in the study area and their common name vernacular name (Marathi), scientific name, family IWPA status, local abundance status and IUCN Red list conservation status is reported in Appendix VIII. A total number of 4796 encounters, comprising 9348 individual birds and 114 species belonging to 51 families were detected from seven habitats in two seasons during the study period. Of theses a total number of 2473 encounters, comprising 4587 individual birds and 83 bird species belonging to 40 families in the dry season and 2323 encounters, comprising 4761 individual birds and 113 species belonging to 51 families in the monsoon season were detected at seven habitats (Table 5.2, Fig. 5.3 and 5.4).

The data indicates that number of encounters decreased in monsoon season but total number of bird detected increased due to larger cluster size. Among 114 species 82 (72 %) bird species were common to both seasons, however only one species (red rumped Vulture belonging to the Accipitridae family) and 31 (27%) bird species belonging to 21 families were exclusive to the dry and monsoon seasons, respectively (Table 5.2, Fig. 5.3 and 5.4). In the dry season, the highest number of bird species belongs to family Accipitridae (10) followed by Columbidae (5) and in monsoon season Accipitridae (10) followed by Muscicapidae (6). The maximum number of families (45) was occurred at the grassland site followed by agricultural land (40) in the monsoon season. The number of families per land-use type increased in monsoon season except the casuarina plantation site and mangrove forest site. However, there was no significant change in number of families within agricultural land, forest land and homegarden sites in two seasons (Fig. 5.5).

In the monsoon, the number of bird species increased due to additional 31 species belonging to 21 families. Among them, the highest number of bird species belongs to family Scolopacidae and Sturnidae (four spp.) followed by Cuculidae (three spp.). Majority of the occurrence of these additional bird species was observed on agricultural land, forest land and the grassland sites. However, none of these species was sighted at the casuarina plantation site. The Asian paradise-flycatcher, bank Myna, golden fronted Leaf-bird, common Sandpiper, Eurasian Curlew, Hoopoe, jungle Starling, pied-crested Cuckoo, river Tern, small Minivet, Whimbrel and yellow-wattled Lapwing were the most common additional species which occurred in the monsoon season (Table 5.4).

It is observed that out of the total 114 bird species only 10 (9%) bird species (Table 5.3) such as *Dicrurus macrocerus* (black Drongo), *Bubulcus ibis* (cattle Egret), *Saxicoloides fulicata* (Indian Robin), *Corvus macrorhynchos* (jungle Crow), *Vanellus indicus* (red-wattled Lapwing), *Pynonotus jocosus* (red-whiskered Bulbul), *Psittacula krameri* (rose-ringed Parakeet), *Merops orientalis* (small Bee-eater), *Streptopelia chinensis* (spotted Dove), and *Halycon smyrnensis* (white-throated Kingfisher) were recorded at all land-use types during the dry and monsoon season bird survey. Out of the observed 83 bird species in the dry season survey 19 (23%) species were common to all land-use types. Asian Koel, black Kite, greater Coucal, grey-hooded Warbler, house Sparrow, Indian Pond-heron, large grey Babbler, Indian pied Hornbill, jungle bush Quail along with the above ten bird species were observed at all land-use types only in the dry season. Among 113 bird species observed in monsoon season only 13 % (14 species such as baya Weaver, brahminy Kite, coppersmith Barbet and Indian house Crow including above 10 bird spp.) were commonly detected at all land-use types (Table 5.4).

Fig. 5.3: Graphs showing number of (a) bird species, (b) families, (3) average number of bird species per point transect and (4) average number of bird per point transect in the dry and monsoon season bird survey. The solid and dashed line represents the dry and monsoon season survey.



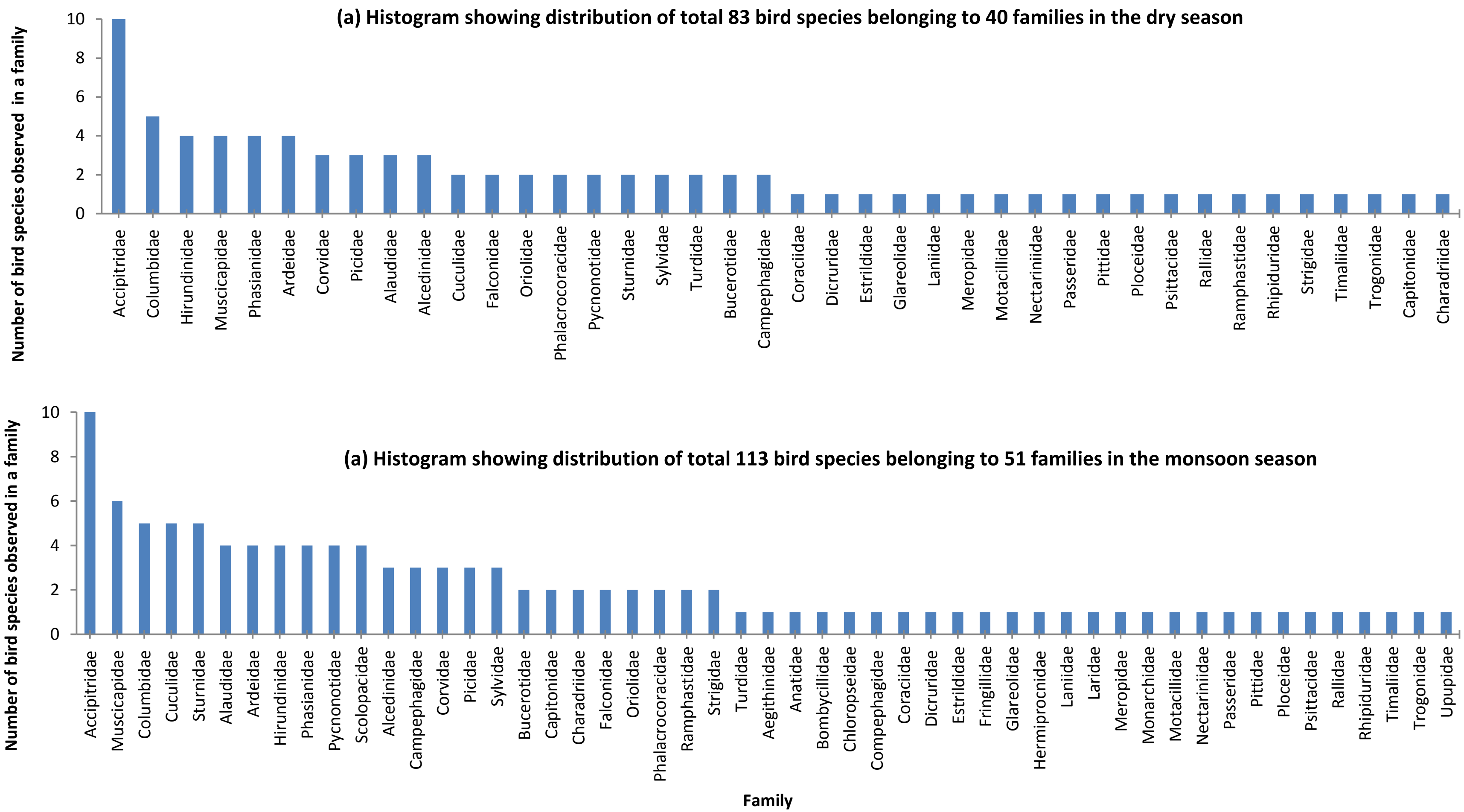


Fig. 5.4: Cumulative family wise distributions of the bird species in the dry (a) and monsoon season (b) during study period.

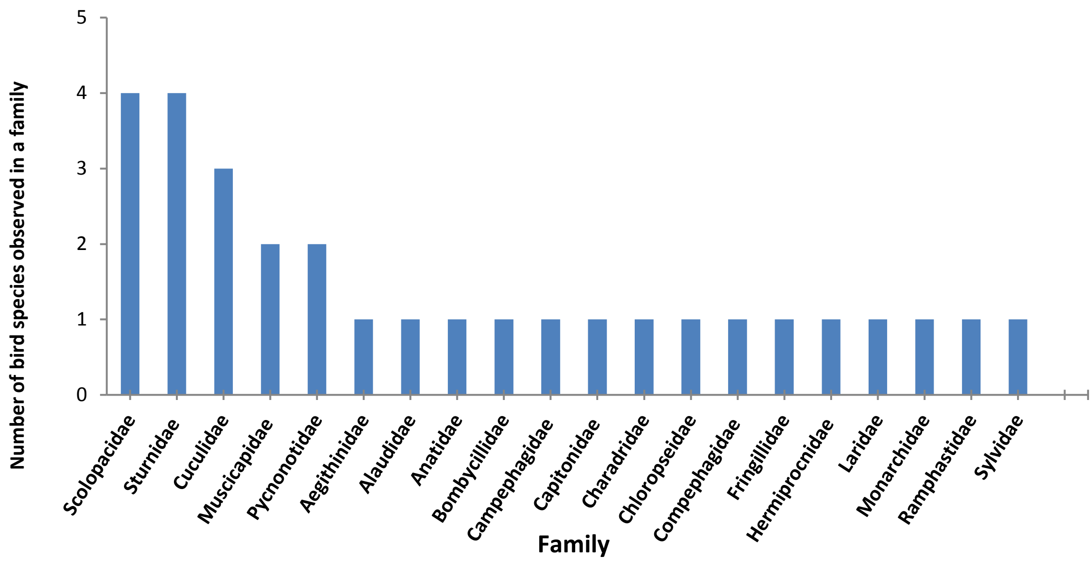


Fig. 5.5: Histogram showing family wise distribution of newly observed birds in the monsoon season.

5.5.2 Seasonal comparison of species richness and abundance:

There was significant variation in total number of bird recorded between different land-use types during the entire survey. The highest number of birds were recorded at forest land (33%) followed by grassland (26%) and agricultural land (16%). The lowest numbers of birds were recorded in the casuarina plantations; however, there was no significant difference between homegardens (11%) mango plantations (7%), Mangrove forest (5%) and casuarina plantations (3%). The land-use wise comparison of seasonal patterns of number encounters, number of species, number of total individual birds, families, average number of species per point transect and average number of bird per transect is summarized in Table 5.2 and 5.3. A complete list of birds observed in the study area during survey along with their local name, scientific name, family, IWPA schedule status, abundance status and IUCN Red List status (IUCN, 2011) is given in Appendix VII. The number of bird species and number of birds per point transect in the study area ranges from 6 to 33 and 9 to 120 respectively. On an average 16 bird species and 45 birds were recorded per point transect in the study area.

Table 5.2: The list of the bird species observed in the study area with the land-use in which they occurred. The species occurred in the dry season (D) and monsoon season (M) at all land-use types (D), and the species occurred in both season (D/M) at all land-use type.

List of the common bird species sighted in the dry and monsoon season and the land-use in which they occurred					
Sr.	**Species**	**Land-use type**	**Sr.**	**Species**	**Land-use type**
1	Asian Koel **(D)**	A, CP, F, G, H, MP, MF	11	Common Kestrel	A, CP, F, G, H
2	Bar-Winged Flycatcher-Shrike	A, F, G, H, MP, MF	12	Common wood Shrike	A, F, G, MF
3	Baya Weaver **(M)**	A, CP, F, G, H, MP, MF	13	Common/ Indian Myna	A, F, G, H, MP, MF
4	Black Drongo **(D/M)**	A, CP, F, G, H, MP, MF	14	Common Blue Kingfisher	A, F, H, MP, MF
5	Black Kite **(D)**	A, CP, F, G, H, MP, MF	15	Coppersmith Barbet **(M)**	A, CP, F, G, H, MP, MF
6	Black shouldered Kite	A, CP, F, G, MP, MF	16	Crested Hawk Eagle	C, G, H
7	Black-Hooded Oriole	A, F, G, H, MP, MF	17	Crested Honey Buzzard	A, CP, F, G
8	Blue-Capped Redstart	A, F, H, MP, MF	18	Crested Serpent-Eagle	C, F, G, H, MF
9	Brahminy Kite **(M)**	A, CP, F, G, H, MP, MF	19	Dusky Crag-martin	A, F, G, H
10	Brown-Headed Barbet	A, F, G, H	20	Emerald Dove	A, F, G, H, MP, MF

Sr.	Species	Land-use type	Sr.	Species	Land-use type
21	Cattle egret **(D/M)**	A, CP, F, G, H, MP, MF	35	Eurasian Black Bird	F, G, H
22	Cliff Swallows	A, CP, F, G, H, MP, MF	36	Eurasian Golden Oriole	A, F, G, H, MP, MF
23	Common Barn Swallow	A, CP, F, G, H, MF	37	Gray Francolin	A, F, G, H, MP, MF
24	Common Chiffchaff	A, F, G	38	Greater Coucal **(D)**	A, CP, F, G, H, MP, MF
25	Green Bee-Eater **(D/M)**	A, CP, F, G, H, MP, MF	39	Lagger Falcon	A, F, G, MP, MF
26	Grey Headed Fish-Eagle	F, G	40	Large Grey Babbler **(D)**	A, CP, F, G, H, MP, MF
27	Grey Hooded Warbler **(D)**	A, CP, F, G, H, MP, MF	41	Laughing Dove	A, CP, F, G, H
28	Heart Spotted Woodpecker	A, CP, F, H, MP, MF	42	Lesser Gold Backed Woodpecker	A, F, G, H, MP, MF
29	House Sparrow **(D)**	A, CP, F, G, H, MP, MF	43	Little Cormorant	A, CP, F, G, H, MF
30	Indian Grey Hornbill	A, F, G, H, MF	44	Little Egret	A, CP, F, G, H, MF
31	Indian House Crow **(M)**	A, CP, F, G, H, MP, MF	45	Long-Tailed Shrike	A, G, H
32	Indian Peafowl	A, F, G, H, MP, MF	46	Indian Pied Hornbill **(D)**	A, CP, F, G, H, MP, MF
33	Indian Pitta	A, F, G, H, MP, MF	47	Malabar / Indian Trogon	A, F, G, H
34	Indian Pond-Heron **(D)**	A, CP, F, G, H, MP, MF	48	Malabar-Crested Lark	A, F, G, H, MP, MF

Sr.	Species	Land-use type	Sr.	Species	Land-use type
49	Indian Robin (D/M)	A, CP, F, G, H, MP, MF	63	Night Heron	A, F, MF
50	Indian Roller	A, F, G	64	Orange-Headed Thrush	A, F, G, H, MP, MF
51	Indian Shag/ Cormorant	A, F, G, H, MP	65	Oriental Magpie-Robin	A, F, G, H, MP, MF
52	Indian Small Sky Lark	A, F, G, H, MP, MF	66	Painted Spurfowl	A, F, G, H, MF
53	Indian/Rufous Treepie	A, F, G, H	67	Pied Harrier	A, F, G, H
54	Jungle Bush-Quail **(D)**	A, CP, F, G, H, MP, MF	68	Purple Sun Bird	A, CP, F, G, H
55	Jungle Crow **(D/M)**	A, CP, F, G, H, M, MF	69	Red Munia	A, F, G, MP
56	Red-Rumped Swallow	A, F, G, H, MF	70	Spotted Dove **(D/M)**	A, CP, F, G, H, MP, MF
57	Red-Vented Bulbul	A, F, G, H, MP, MF	71	Spotted Owlet	A, F, G, H, MP
58	Red-Wattled Lapwing **(D/M)**	A, CP, F, G, H, MP, MF	72	Stork-Billed Kingfisher	A, CP, F, G, H, MF
59	Red-Whiskered Bulbul **(D/M)**	A, CP, F, G, H, MP, MF	73	Tickells Blue-Flycatcher	A, CP, G, H, MP, MF
60	Pigeon	A, CP, F, H	74	White-Bellied Sea-Eagle	F, G
61	Rock Pigeon	A, F, G, H, MP, MF	75	White-Breasted Waterhen	A, CP, F, G, H, MF
62	Rose-Ringed Parakeet **(D/M)**	A, CP, F, G, H, MP, MF	76	White-Browed Wagtail	A, F, G, H, MF

Sr.	Species	Land-use type	Sr.	Species	Land-use type
77	Rosy Starling	F, MP	80	White-Throated Fantail-Flycatcher	A, CP, F, G, H, MP
78	Rufous-Tailed Lark	A, F, G, H	81	White-Throated Kingfisher **(D/M)**	A, CP, F, G, H, MP, MF
79	Small Pratincole	A, F, G, MF	82	Yellow-Fronted Pied-Woodpecker	CP, F, G, MP, MF

List of the bird species sighted only in the dry season and the land-use in which they occurred

Sr.	Species	Land-use type
1	White-Rumped Vulture	G

List of the bird species sighted only in monsoon season and the land-use in which they occurred

Sr.	Species	Land-use type	Sr.	Species	Land-use type
1	Asian Paradise-flycatcher	A, G, H	7	Hoopoe	A, G, H, MP, MF
2	Bank Myna	H, MP, MF	8	Jungle Starling/ Myna	A, F, G, H, MP, MF
3	Black Bulbul	A, F	9	Large Cuckoo Shrike	A, F, G
4	Brahminy Starling	F, G	10	Pied-Crested Cuckoo	A, F, G, H
5	Brain fever Bird	A, F	11	River Tern	A, F, G
6	Brown Fish-Owl	A	12	Ruddy Shelduck	A, G

Sr.	Species	Land-use type	Sr.	Species	Land-use type
13	Common Iora	F, G	13	Singing Bush Lark	A, F, G
14	Common Redshank	A, G	24	Sirkeer Malkoha	A, F,G
15	Common Rosefinch	A, F, G	25	Small Minivet	A, F, G, H, MP, MF
16	Common Sandpiper	A, G	26	Whimbrel	G
17	Common Stone Chat	A, F, G	27	White-Bellied Blue-Flycatcher	G
18	Crested Tree Swift	G	28	White-Cheeked Barbet	A, F
19	Eurasian Curlew	G	29	Yellow-Browed Bulbul	A
20	Golden fronted Leaf bird	A, F, G, H, MP, MF	30	Yellow-Fronted Barbet	F
21	Greenish Leaf Warbler	F	31	Yellow-Wattled Lapwing	A, F, G
22	Grey Hypocolius	F			

Where, A = agricultural land G = Grassland F = Forest land H = Homegarden

CP = Casuarina plantation MP = Mango plantation MF = Mangrove forest

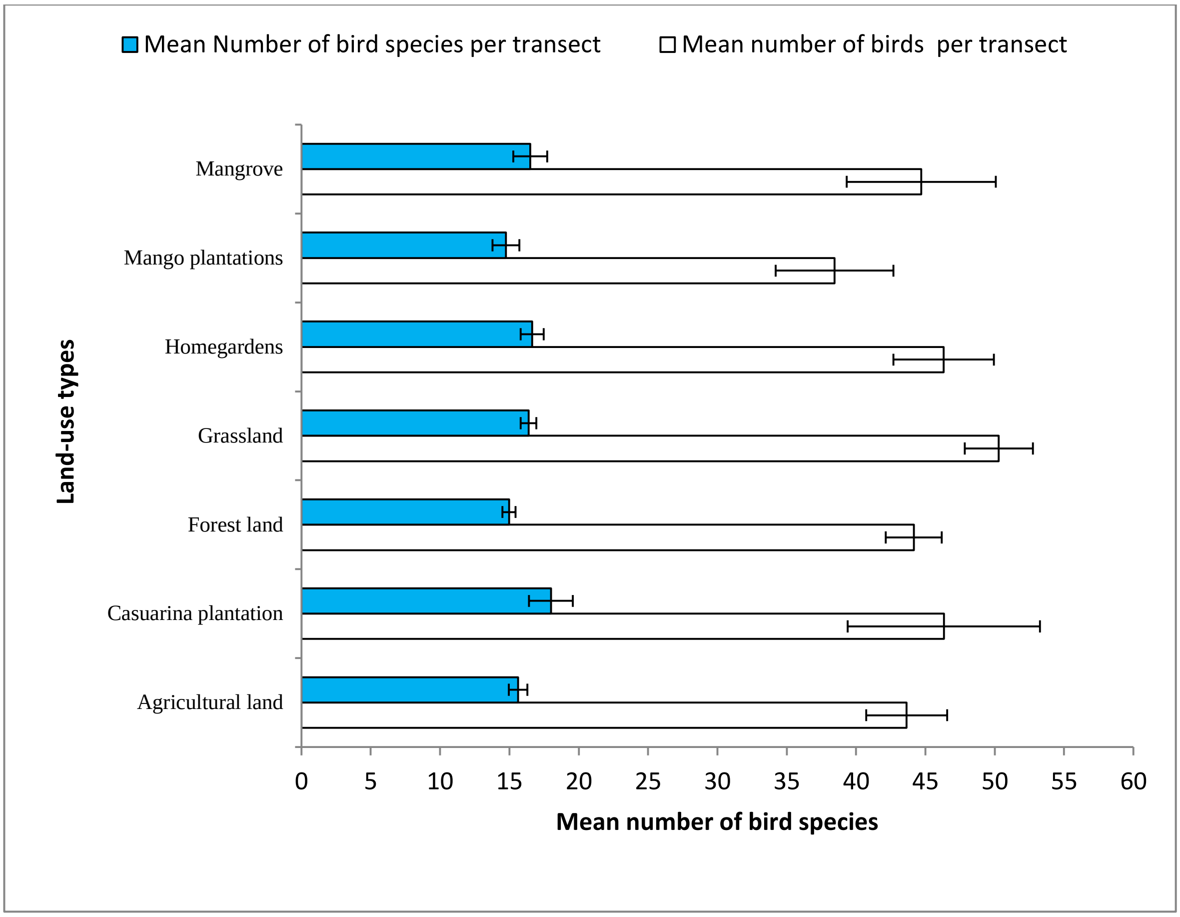


Fig. 5.6: Average number of bird species and mean number of birds per point transect at different land-use in the study area. Error bars shows SE (±).

5.5.3 Seasonal variation in bird composition and structure at different land-use

Seasonal variation in average number of birds per point transect was significant (at significance level = 0.05 and 95% confidence interval). The mean numbers of bird species per point transect were highest in the dry season (17) and lowest in monsoon season (15). The number of bird species per point transects ranges from 6 to 33 in the dry season and 10 to 26 in monsoon season. However, the there was no significant difference (at significance level = 0.05 and 95% confidence interval) in average number of birds per point transect in both seasons. The case was reverse for average number of birds per point transects in the dry season (44) and monsoon season (46). The number of birds per point transects ranges from 9 to 91 and 9 to 120 in the dry season and monsoon season respectively. Fig. 5.6 and

Fig 5.7 (a-d) illustrates the average number of bird species and average number of individual birds per point transect at different land-use types in the dry and monsoon season. These results showed strong significant correlation (Pearson correlation is significant at 0.01 level, 2-tailed) between mean number of bird species and mean number of bird recorded per point transect.

In the dry season maximum mean number of bird species (21) and mean number of birds (53) per point transect were observed at the casuarina plantation and minimum 14 species and 34 birds at mango plantation site. However, in monsoon season mean number of bird species and mean number of birds per transect ranges from 14 (Forest land-use type) to 16 (Homegarden) and 40 (Casuarina plantation) to 52 (Grassland).

It is observed that mean number of species per transect were decreased in monsoon season except mango plantation. On other hand exact opposite result indicate that the mean number of birds per transect were increased in agricultural land, grassland, homegarden and mango plantation sites. However, the mean number of birds per point transect at the casuarina plantation, forest land and mangrove forest decreased.

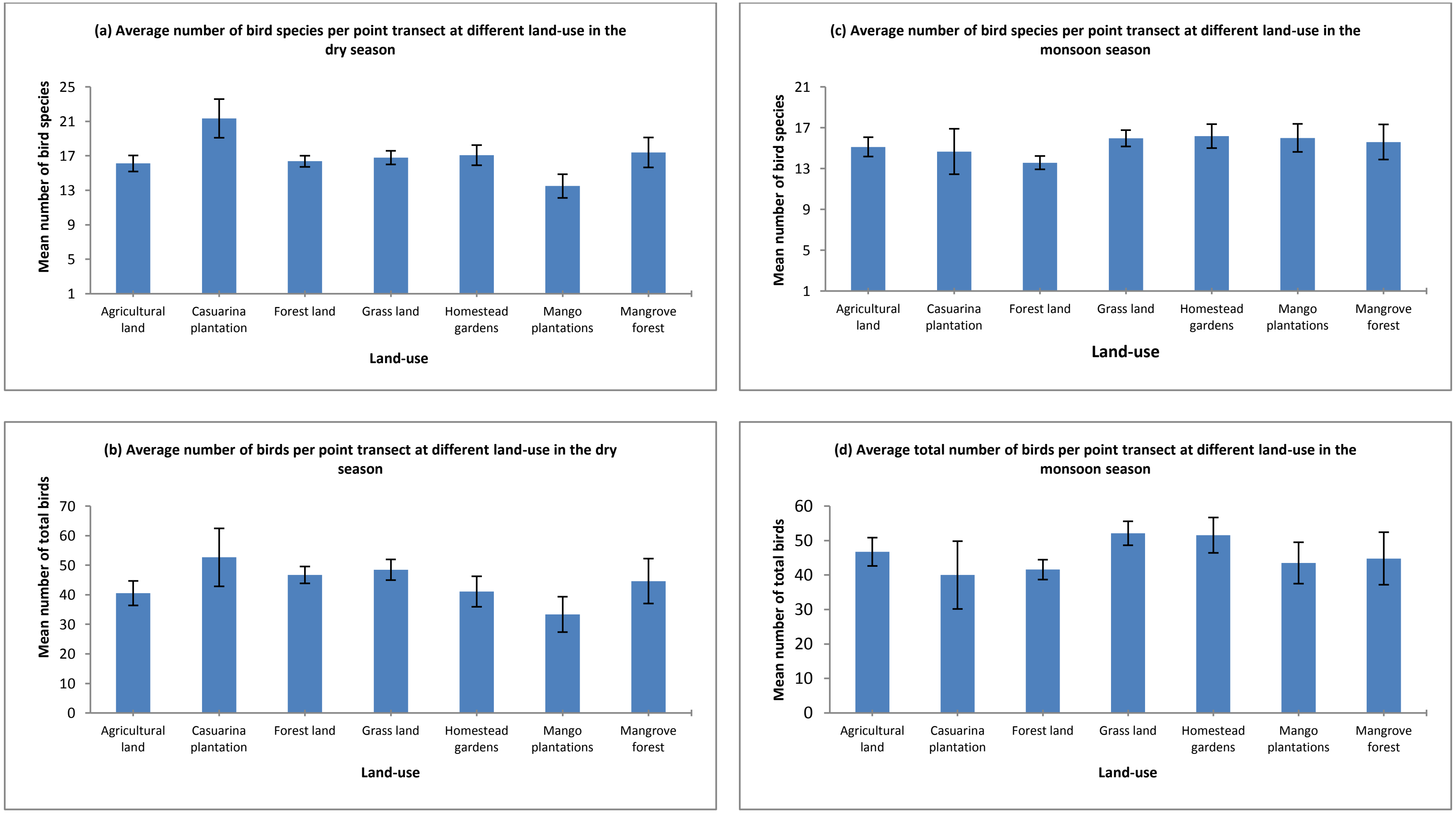


Fig.: 5.7: Showing average number of bird species and average number of individual birds recorded per point transect at different land-use types in the dry and monsoon season bird survey. Error bar shows SE (±).

5.5.4 Bird species distribution pattern

The bird species (e.g. jungle crow (*Corvus macrorhynchos*), baya weaver (*Ploceus philippinus*), brahminy kite (*Haliastur Indus*), red wattled lapwing (*Vanellus indicus*), spotted dove (*Streptopelia chinensis*), Indian myna (*Acridotheres tristis*), rose ringed-parakeet (*Psittacula krameri*), red whiskered bulbul (*Pycnonotus jocosus*), red vented bulbul (*Pycnonotus cafer*), Indian pied hornbill (*Anthracocerous coronatus*), large gray babbler (*Turdoides malcolmi*), black drongo (*Dicrurus macrocerus*), small bee-eater (*Merops orientalis*), jungle bush quail (*Perdicula asiatica*), black shouldered kite (*Elanus caeruleus*), India house crow (*Corvus splendens*), cattle egret (*Bubulcus ibis*) that numerically dominated the bird assemblage detected in agricultural land, the casuarina plantation, forest land, grassland, homegarden, mango plantation sites and mangrove forest land-use. This indicates that all land-use types are suited for colonization of these bird species. The species such as *Acridotheres ginginianus, Galerida malabarica, Hemipus picatus*, *Cyornis tickelliae, Gyps bengalensis, Aegithina tiphia, Athene brama, Carpodacus erythrinus, Centropus sinensis, Chalcophaps indica, Columba livia, Cyornis tickelliae, Dendrocitta vagabunda, Dendrocopos mahrattensis, Eudynamys scolopaceus*, *Falco tinnunculus, Galloperdix lunulata, Harpactes fasciatus, Hemicircus canente, Hirundo concolor, Hirundo rustica, Lanius schach, Megalaima flavifrons, Megalaima zeylanica, Nectarinia asiatica, Nisaetus cirrhatus, Ocyceros birostris, Phoenicurus coeruleocephalas, Phylloscopus trochiloides, Psittacula krameri, Rhipidura albicollis, Saxicola torquatus, Seicercus xanthoschistos, Turdus merula, Upupa epops* are the rare species recorded in the study area.

5.5.5 Bird conservation status

The findings clearly indicate that most of the abundant bird species were distributed throughout study area. However, most of the bird occurrence was restricted to coastal side where all land-use types seem to be interlinked. An attempt has been made to compare abundance status based on the species occurrence in the study area (Fig. 5.8). Our study indicated that among 114 bird species sighted 53% (61) species were common and 16% (18) were uncommon. Twelve per cent (14) bird species were abundant and 8% (9) were occasional. It is observed that 8% (9) rare bird species were recorded in the study period. Gray-hooded Warbler and Malabar Trogon are near threatened species. One vulnerable bird species (common Kestrel) was recorded in the study area (see Appendix- VII)

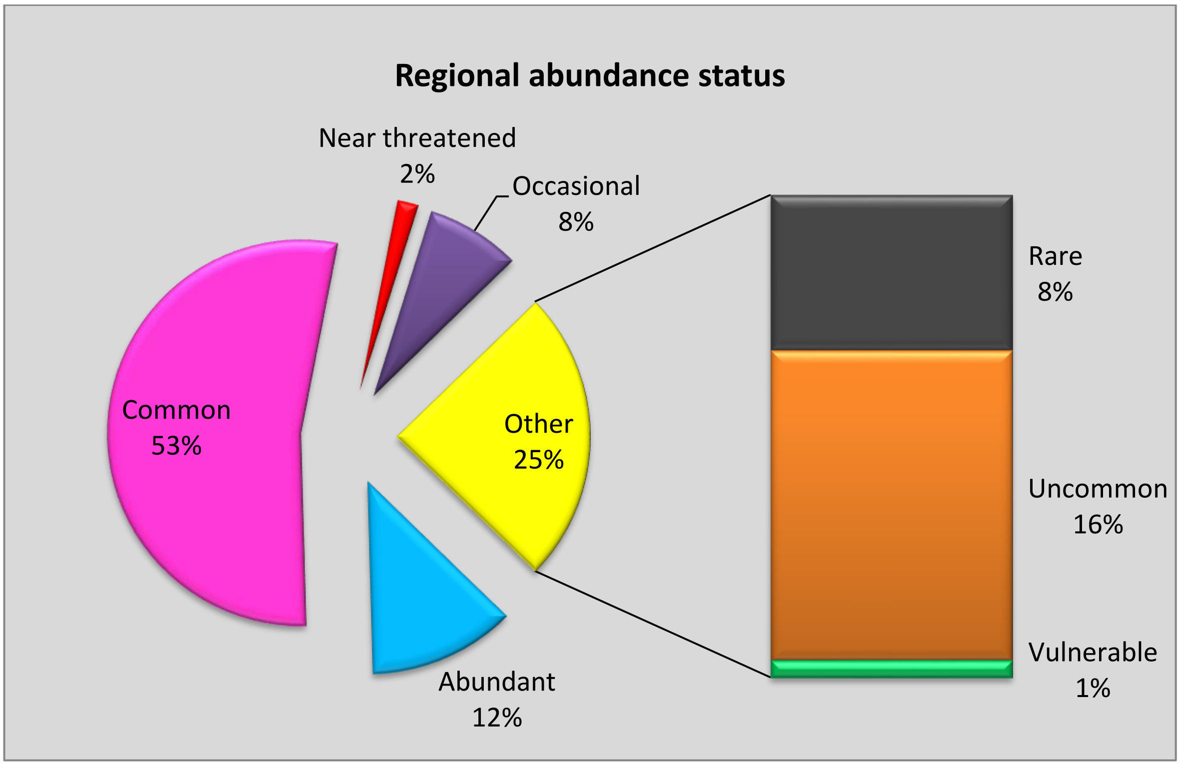


Fig. 5.8: Abundance status of the bird status recorded in this study period

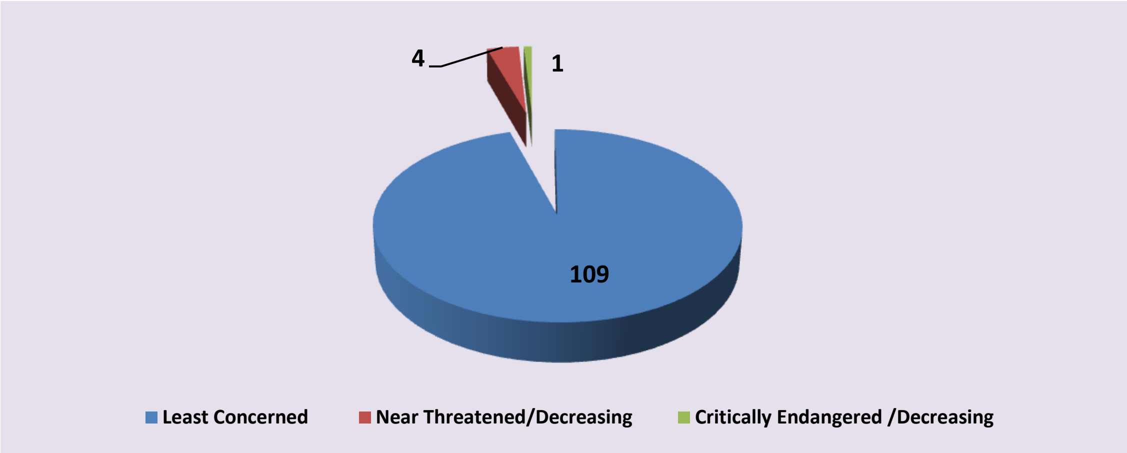


Fig. 5.9: Pie chart showing IUCN status of the bird species

As per IUCN red list status (IUCN, 2011) among 114 bird species recorded in the study area 109 bird species has least concerned status. Four species (Eurasian Curlew, Gray-Headed Fish-Eagle, Lagger Falcon and Malabar-Pied Hornbill) are near threatened and globally their population is decreasing. One critically endangered bird species (White-Rumped Vulture) was sighted in at grassland site in the dry season (Fig. 5.9 and Appendix VII). Fig. 5.11 Appendix VII, represent IWPA status (Fig. 5.10) of 114 bird species. It is observed that 93% (106) species belongs to schedule-IVth of The Indian Wildlife (Protection) Act, 1972 and 6% (7) species to schedule-Ist. However, only one species (Indian House Crow/ Common Crow) belongs to schedule-Vth (Anon, 1997).

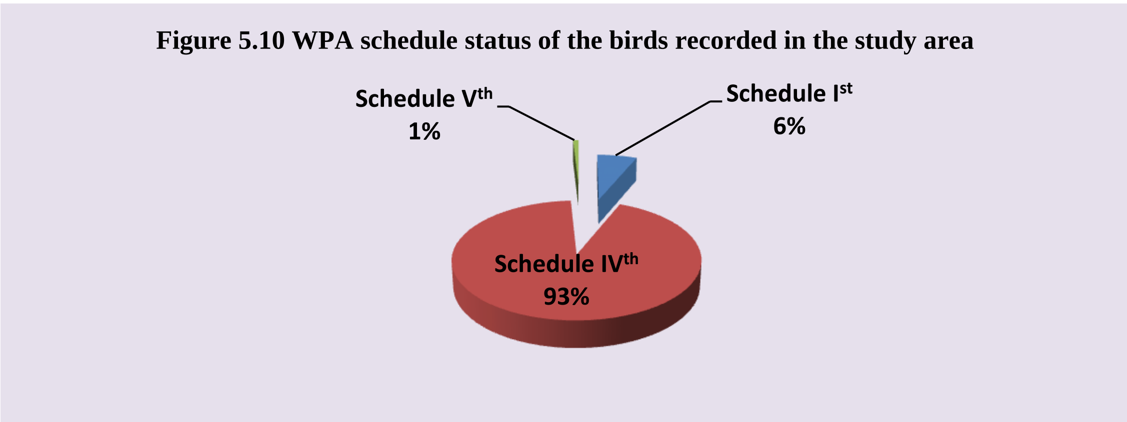


Fig. 5.10: WPA schedule status of the birds recorded in the study area

5.5.6 Seasonal variation species richness at different land-use

Bird species richness was estimated for each land-use type or habitat in the dry and monsoon season by using species accumulation curves or rarefaction curves. The number of species observed (Sobs) was calculated using EstimateS program, which is equivalent to the species accumulation curve. The rarefaction curves depicted in Fig. 5.11 and 5.12 reflects the bird species richness and abundance of different land-use types in the dry and monsoon season. The values represents the mean expected richness for the dry and monsoon season separately at a given land-use type or habitat. The curve predicts the rate of accumulation of species with increasing number of individual or abundance. The avian species richness of the different land-use types can be compared in terms of the number expected species.

One noticeable result of an investigation of the rarefaction curves is that grassland has highest species richness followed by forest land and agricultural land-use types in both season bird surveys. This means that bird species richness is highest in these land-use types. The land-use types with low species richness are the casuarina plantations, mangrove forest, mango plantations and homegardens. Fig. 5.11 shows that the rarefaction curves for all land-use types are asymptotic which indicates that that sampling was adequate to meet the objectives of the study. Species accumulation curves for the seven heterogeneous land-use types in both season indicated a rapid increase in initial number of species discovered. However, an earlier plateauing of the dry season species richness accumulation curves compared with monsoon season suggest that species richness in monsoon season exceed that of the dry season (Fig. 5.12).

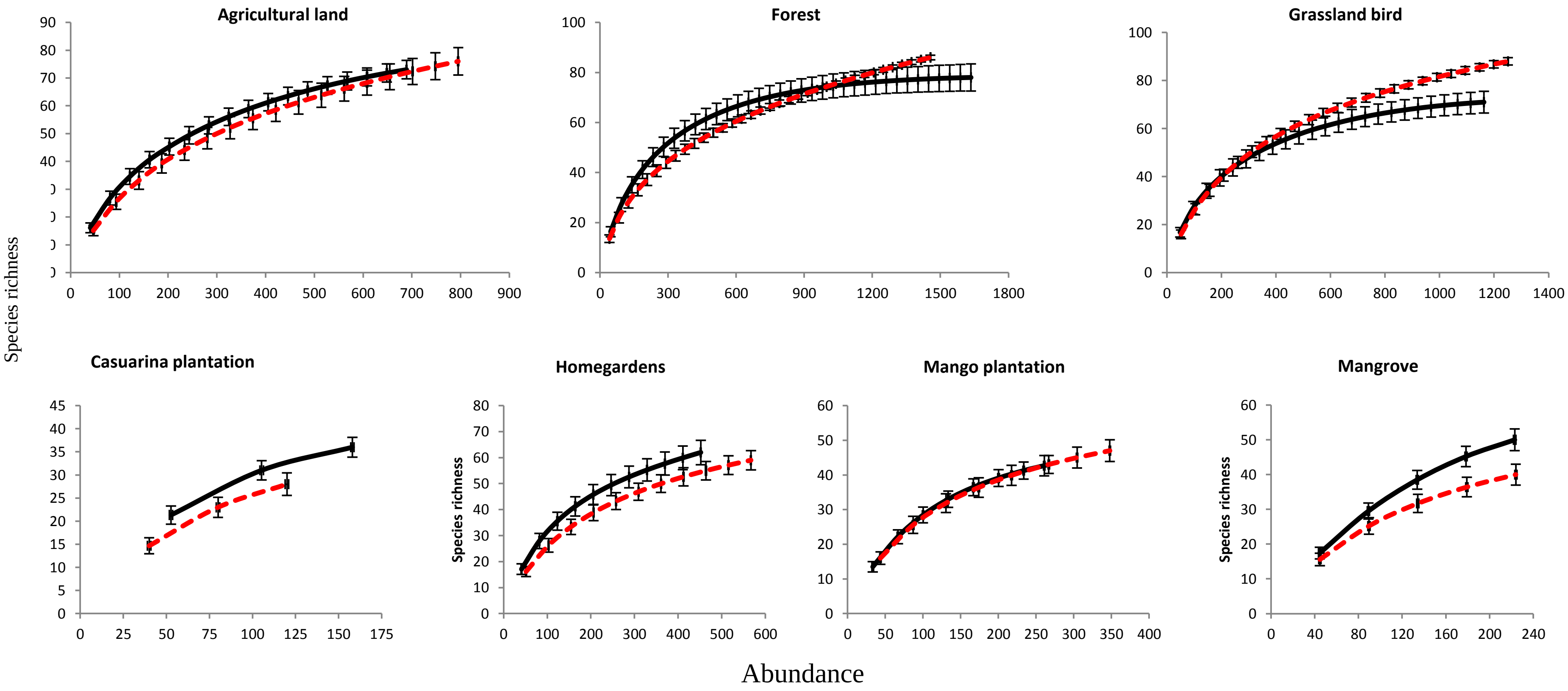


Fig. 5.11: Predicted sample based Rarefaction curves (EstimateS 8.2.0 version) showing bird species richness verses abundance for (a) Agricultural land, (b) Casuarina plantations, (c) Forest land, (d) Grassland, (e) Homegardens, (f) Mango plantations and (g) Mangrove forest in the dry season. Solid lines represent species richness in the dry season and dotted lines represents species richness values in the monsoon season.

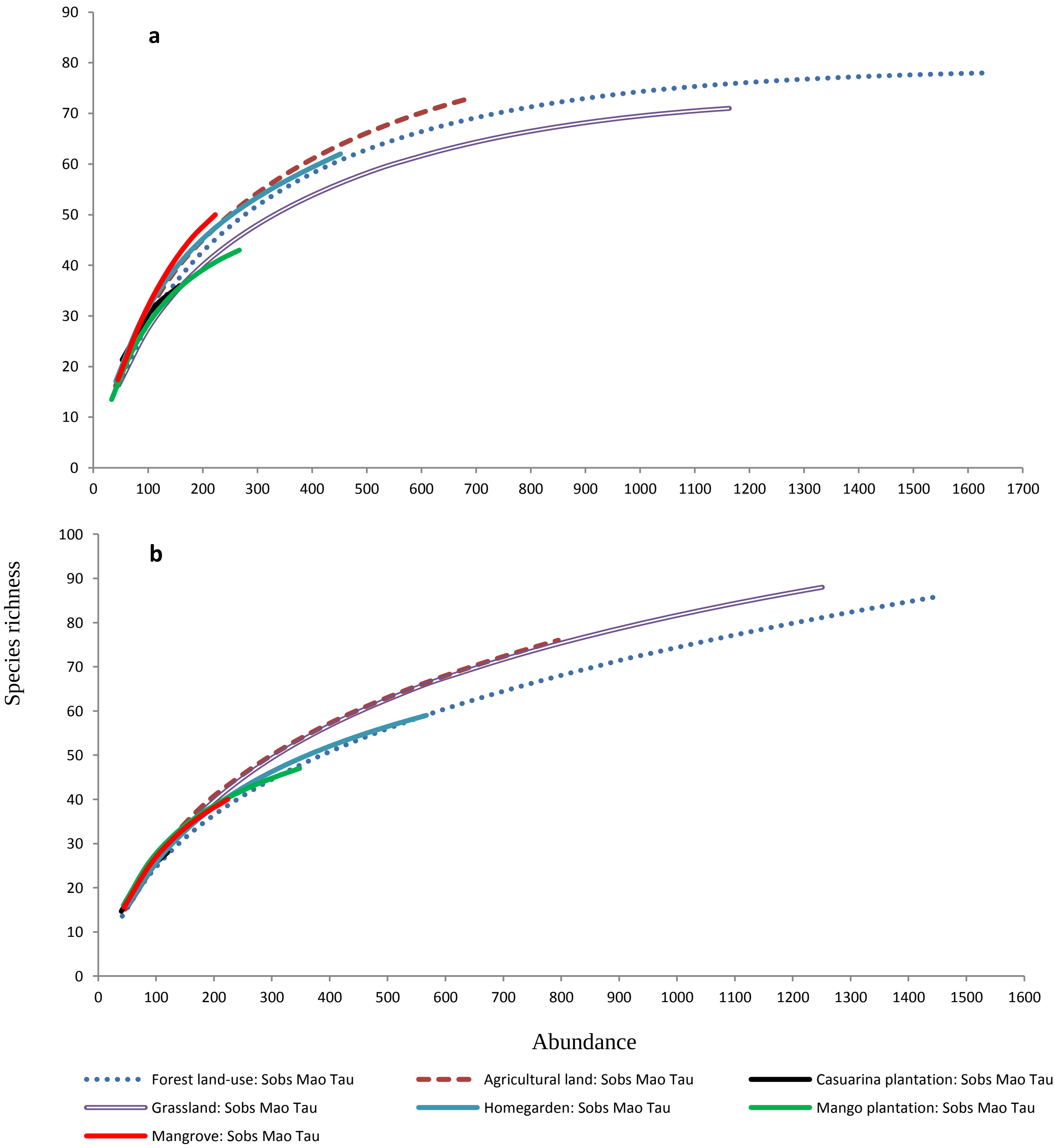


Fig. 5.12: Sample based species accumulation or rarefaction curves (S_{obs}) for the bird assemblage's verses abundance at different land-use types in (a) the dry season and (b) monsoon season bird survey. Each point transect along with the curve corresponds to an estimate of mean cumulative number of the predicted distribution.

In the dry season, the avian species richness is highest at forest land-use (78 spp.) followed by the agricultural land (73 spp.) and grassland (71 spp.). Initially the curve for forest land species richness was the highest but chance of discovering new species decreased and the curve begins to flatten. However, the curve for grassland bird species richness reaches indicates that more sampling efforts is required to reach the expected species richness and there are chances to discover newer species. The curve for agricultural land lies below the grassland and forest land shows that the rate of observing new species is slow. The most interesting observation we noticed that rarefaction curve for the mangrove forest rises suddenly indicating that less sampling effort need to observe expected species and species richness is comparatively high (Fig. 5.11 and 5.12).

On other hand in the monsoon season, rarefaction curve for grassland is the highest indicating the greatest (88 spp.) species richness followed by forest land (86 spp.), agricultural land (76 spp.), and the chance of observing an additional new species is high. In case of forest land and agricultural land species richness result was exact opposite than the dry season, where the curve does not seem to flatten. There are chances of discovering additional species. The rarefaction curves for the casuarina plantations (28 spp.), mangrove forest (40 spp.) and a mango plantation (47 spp.) show the lowest species richness. It was observed that the species richness increased for grassland, forest land agricultural land and mango plantation habitats in monsoon season. However, it decreased for homegarden, mangrove forest and casuarina plantation habitats (Fig. 5.11 and 5.12).

The bootstrap analysis carried out in EcoSim 7.72 software indicated that species richness grew asymptotically as the number of point transects surveyed at each habitat see Fig. 5.13 and 4.14. The rate of observing a new species decreased with increase in number of point transects. It is observed that the variance decreased as increase in sample number. We compared seasonal variance in bird species richness using the sample based rarefaction curves at each land-use type. The research findings showed that species richness was greater in the monsoon season bird survey at agricultural land, forest land, grassland, homegarden and mango plantation than the dry season bird survey. However, richness was higher in the dry season bird survey at the casuarina plantations and mangrove forest than monsoon season survey (Fig. 5.13 and 5.14).

5.5.7 Detection function, detection probability, effective detection radius:

For each encounter, distance of the bird or cluster from the observer was recorded. Distance sampling is based on the detection function, which in denoted by g(r) for point transects. We estimated this function from distance data and are used to compute probability of detection (p). It was observed that the delectability decreased with distance within of 50m of an observer. We used a “half normal” detection function to model the relationship between distance and probability of detection.

Fig. 5.15 indicates that there is significant seasonal variation in detection probability. Overall estimated probabilities of detection during the study period ranged from 0.22 to 0.67 in the dry season and 0.16 to 0.49 in the monsoon season bird survey. In the dry season, detection probability was highest in the casuarina plantation (0.67) followed by agricultural land (0.45), mango plantation (0.41), mangrove forest (0.39) grassland (0.38) and homegarden (0.31), However the probability of detecting a bird was least (0.22) in forest land-use type. It is evident that probability of detecting bird was decreased in monsoon season except mangrove forest site. Highest probability of detecting a bird species was recorded in the casuarina plantation (0.44) and lowest (0.16) in forest land. Overall, average effective detection radius was 30m in at different land-use types in two seasons. However, it was 31m and 29m in the dry and monsoon season respectively.

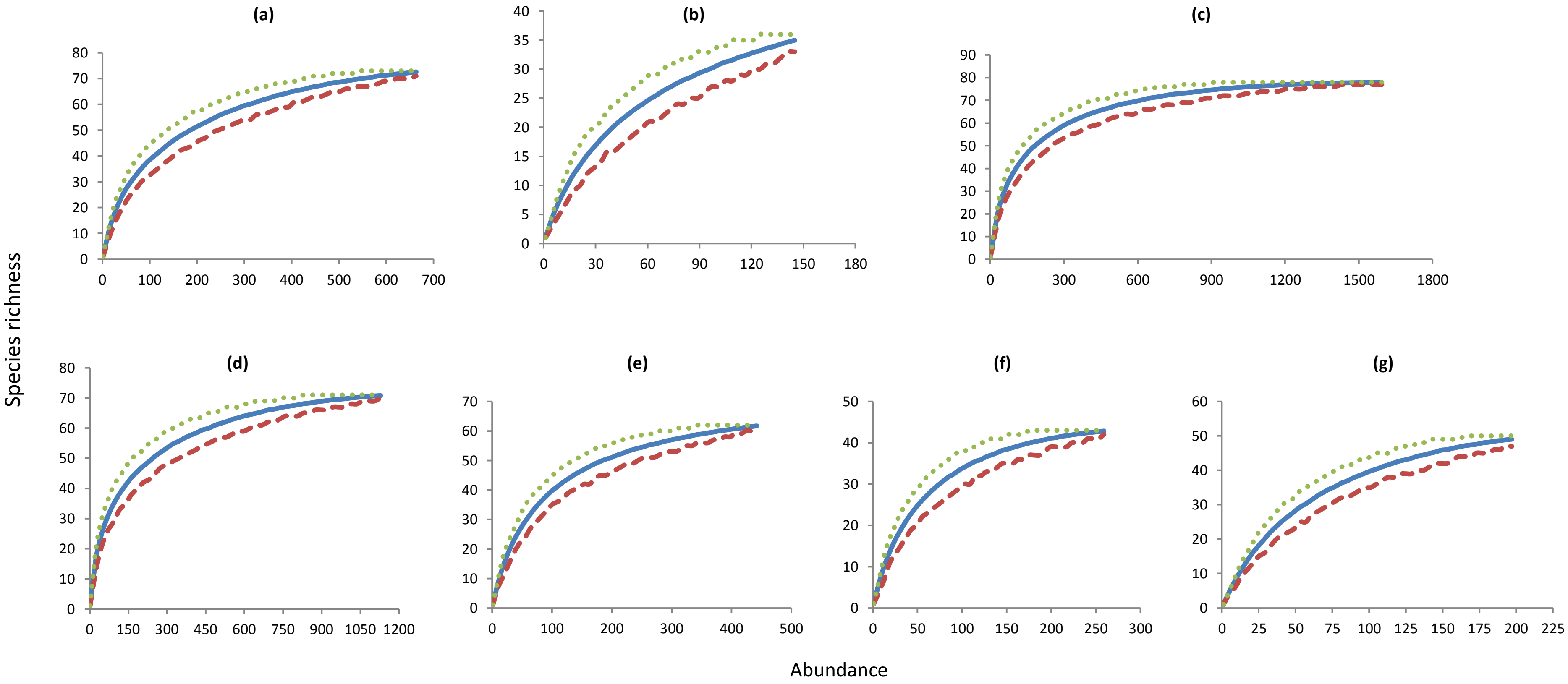


Fig. 5.13: Predicted sample based rarefaction curves (EcoSim Version 7.72) for the bird species showing richness verses abundance at (a) Agricultural land, (b) Casuarina plantations, (c) Forest land, (d) Grassland, (e) Homegardens, (f) Mango plantations and (g) Mangrove forest in the dry season. 1) Expected species richness values (solid lines) 2) 95% confidence interval lower bound values (square dots) 3) 95% confidence interval upper bound (round dots) and bar indicates variance.

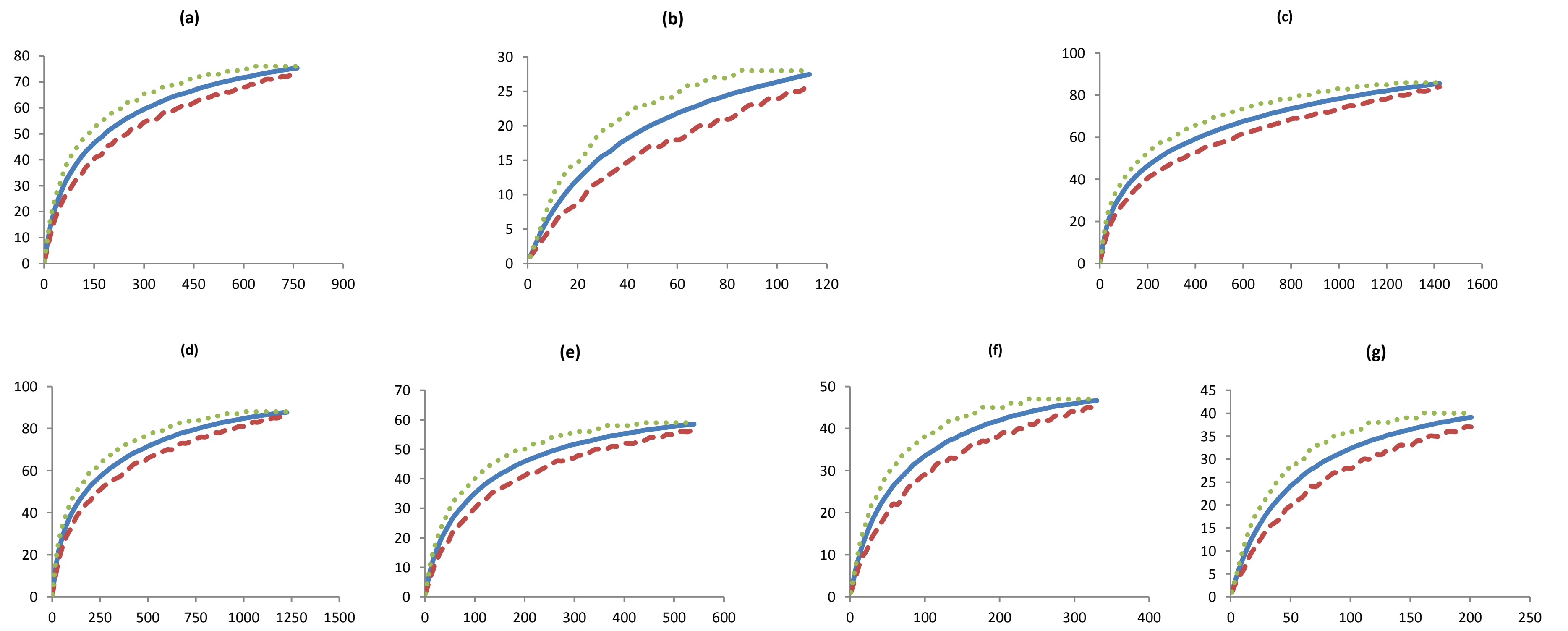


Fig. 5.14 Predicted sample based rarefaction curves (EcoSim Version 7.72) for the bird species showing richness verses abundance at (a) Agricultural land, (b) Casuarina plantations, (c) Forest land, (d) Grassland, (e) Homegardens, (f) Mango plantations and (g) Mangrove forest in the monsoon season. 1) Expected species richness values (solid lines) 2) 95% confidence interval lower bound values (square dots) 3) 95% confidence interval upper bound (round dots).

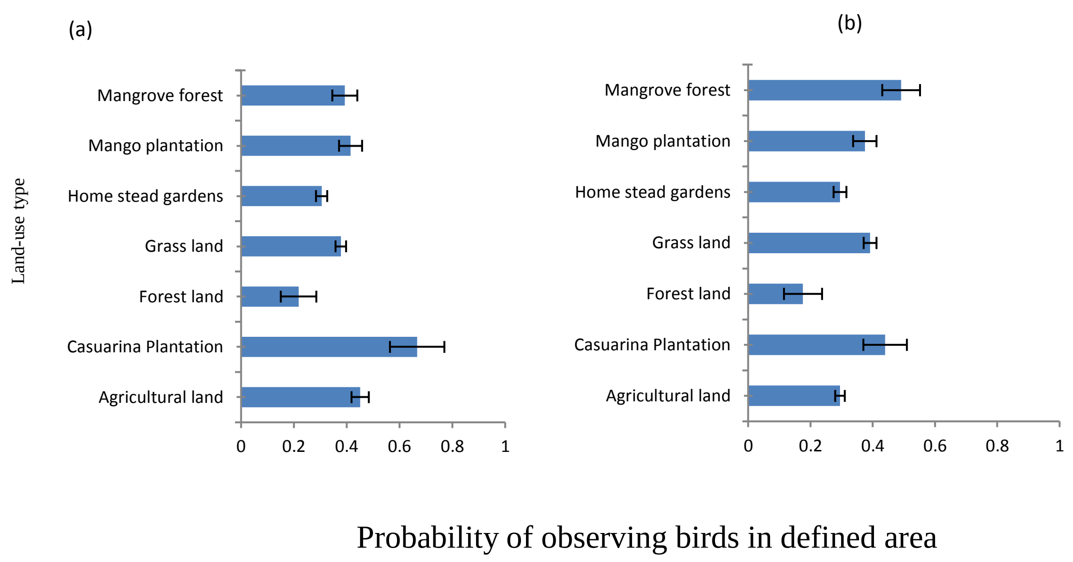


Fig. 5.15: Probability of observing the birds in dry (a) and monsoon (b) season bird survey at different land-use / habitat.

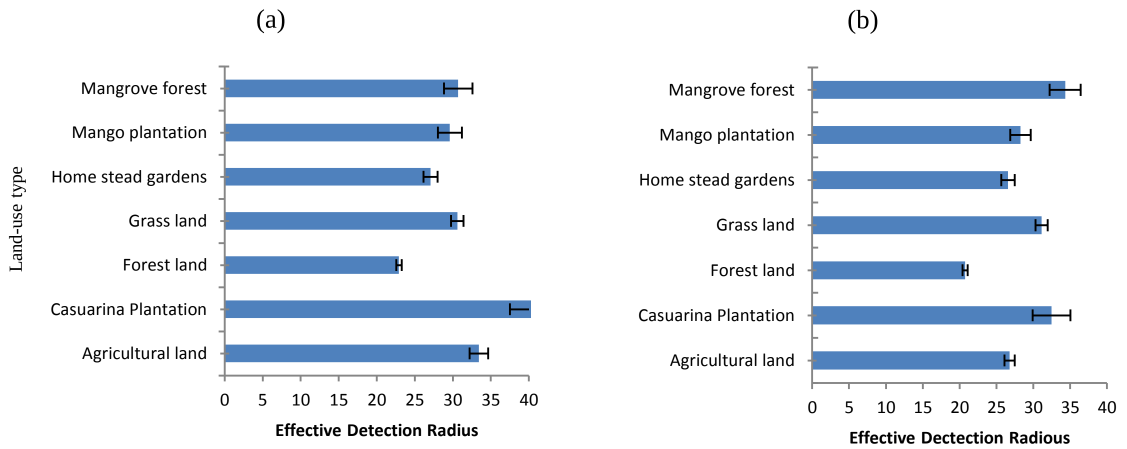


Fig. 5.16: Effective detection radius for point transects bird survey in the dry (a) and monsoon (b) season at different land-use.

The maximum effective detection distance was recorded at all land-use type in the dry season (Fig. 5.16). In the dry season, the highest effective detection radius was measured at the casuarina plantation site (41m) and least (23m) at forest land-use. However, in monsoon season it ranges between 33m at the casuarina plantation and 21m at forest land-use. EDR was slightly increased for mangrove forest site in monsoon season than the dry season (Table 5.3).

5.5.8 Effective cluster size and encounter rate:

The data of mean cluster size is represented in Table 5.5 indicates that there is not significant seasonal variation in the mean cluster size at different land-use types. The mean cluster size was highest at grassland in the dry and monsoon season (2.1 and 2.3, respectively). However, the least mean cluster size was recorded at mango plantation (1.6) and the casuarina plantation sites (1.4) in the dry and monsoon season, respectively.

Table 5.3: Comparison of effective cluster size of avifauna in the dry and monsoon season in different land-use types

	Dry season			**Monsoon season**		
Land-use type	**n**	**ES (SE±)**	**% CV**	**N**	**ES (SE±)**	**% CV**
Agricultural land	384	1.79 (6.53E-02)	3.64	405	1.96 (8.59E-02)	4.38
Casuarina Plantation	85	1.67 (0.1097)	6.55	68	1.41 (9.69E-02)	6.88
Forest land	874	1.84 (3.65E-02)	1.98	752	1.93 (4.35E-02)	2.25
Grassland	556	2.10 (7.61E-02)	3.64	555	2.25 (6.99E-02)	4.29
Homegardens	256	1.77 (8.39E-02)	4.75	275	1.89 (7.11E-02)	3.77
Mango plantation	161	1.63 (6.43E-02)	3.93	187	1.71 (7.38E-02)	4.31
Mangrove	117	1.76 (9.01E-02)	5.11	121	1.56 (8.02E-02)	5.14

Where, n = number of detections, ES= Mean cluster, SE± = Standard error and CV = Covariance.

The results of the encounter rate (n/k) shown in Fig. 5.17 indicates that there is no variation in the encounter rate at different land-use types in the dry and monsoon season bird survey. An overall encounter rate value varies between 4.0 and 5.7. In the dry season the encounter rate was highest at the casuarina plantation (5.7) followed by forest land (5.0) and lowest at mango plantation site (4.02). However, in monsoon season the highest encounter rate was recorded at homegarden (5.0) followed by mangrove forest (4.8) and it was found to be the lowest in the forest land-use type (4.3). Fig. 5.17 indicates that encounter rate was higher at the casuarina plantation and forest land-use in the dry season survey, while it decreased in monsoon season. For all other land-use encounter rate increased in monsoon season survey.

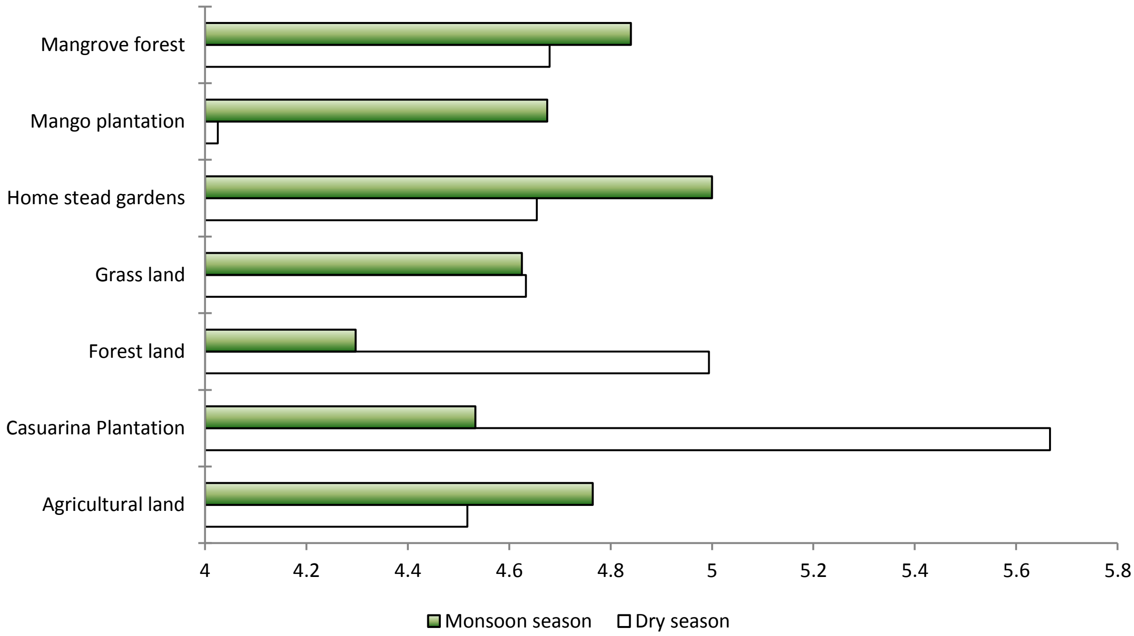


Fig. 5.17: Encounter rate at different land-use types in the dry and monsoon season bird survey

5.5.9 Bird density ha^{-1}

The results on bird density estimates per hectare are shown in Fig. 5.18 (a-b). The average bird density (34 individual's ha^{-1}) was recorded during investigation period in both seasons. It is observed that mean bird density per hectare was higher in monsoon season (36 individual's ha^{-1}) than the dry season survey (31 individual's ha^{-1}). It is evident that the high bird density per hectare was recorded at forest land-use type (61.5 individual's ha^{-1}) in monsoon season. In the dry season bird survey the highest bird density per hectare was estimated at forest land-use type (55.8 individual's ha^{-1}) followed by homegarden (35.7) and lowest was recorded at the casuarina plantation site (18.3 individual's ha^{-1}) followed by agricultural land-use type (23.1 individual's ha^{-1}).

On other had in the monsoon season the highest bird density per hectare was estimated for forest land (61.5 individual's ha^{-1}) followed by the homegarden (42.5 individual's ha^{-1}) and agricultural land-use type (41.4 individual's ha^{-1}). While, the least density was recorded at the casuarina plantation site (19.2 individual's ha^{-1}) followed by mangrove forest site (20.4 individual's ha^{-1}). It is observed that there was drastic increase in bird density per hectare at agricultural land in monsoon season (23.1 to 41.4 individual's ha^{-1}). The results also indicate that the bird density at mangrove forest site decreased in monsoon season (27.9 to 20.4 individual's ha^{-1}).

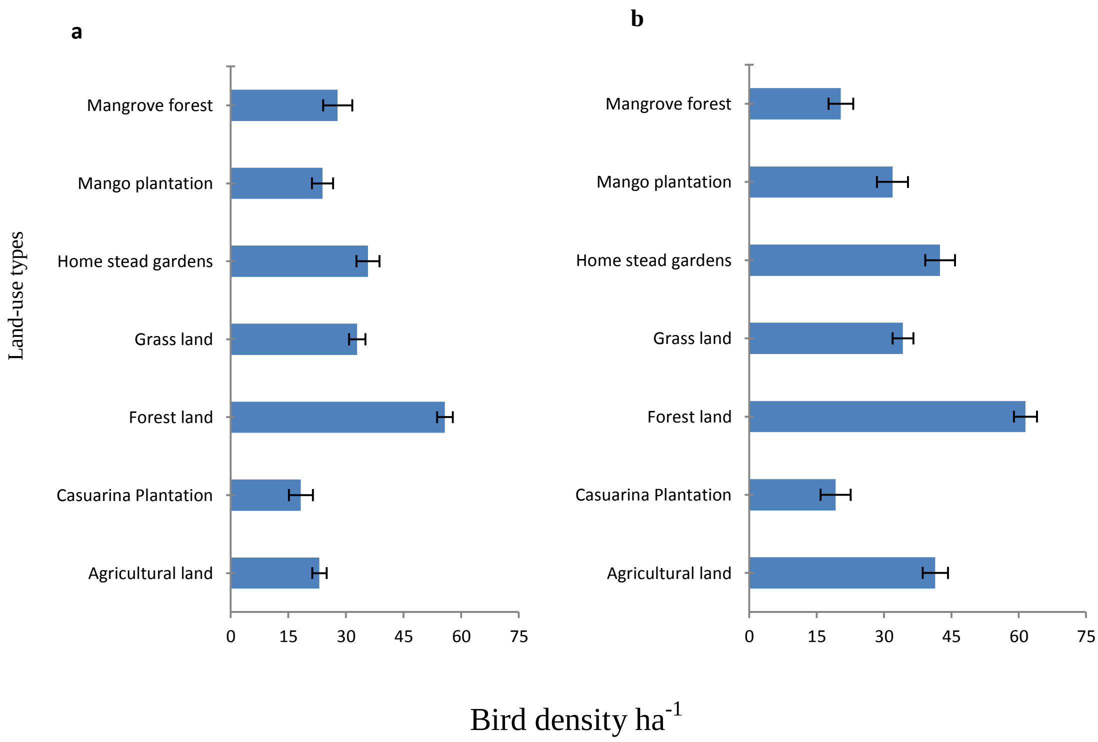


Fig. 5.18: Comparison of bird density ha^{-1} in the dry (a) and monsoon (b) season point transect survey at different land-use types

The results presented in Fig. 5.19 to 5.25 shows the corresponding estimated probability density function (PDF) of detected distances, super imposed over the histogram of actual distance data at different land-use in the dry and monsoon season, with corresponding confidence interval level for the best MCDS model.

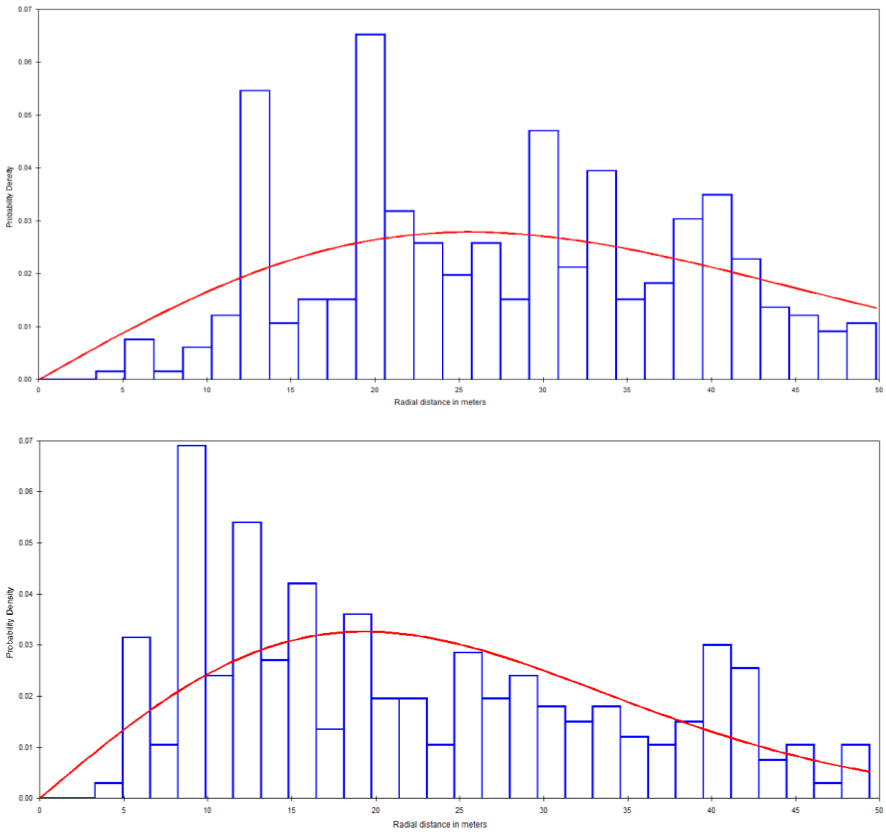


Fig. 5.19: Showing comparison between dry and monsoon season detection distances in agricultural land bird survey.

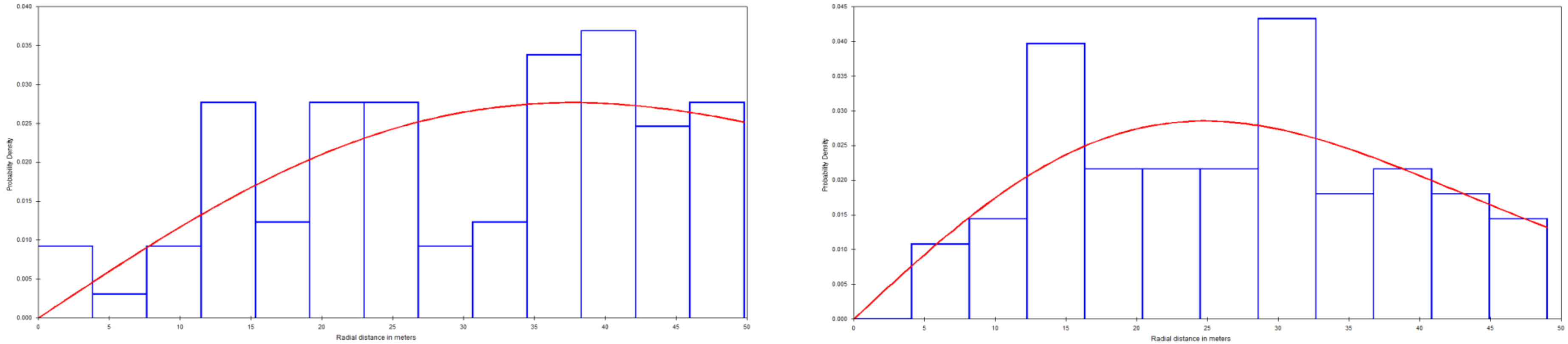


Fig. 5.20: Showing comparison between dry and monsoon season detection distances in casuarina plantation bird survey

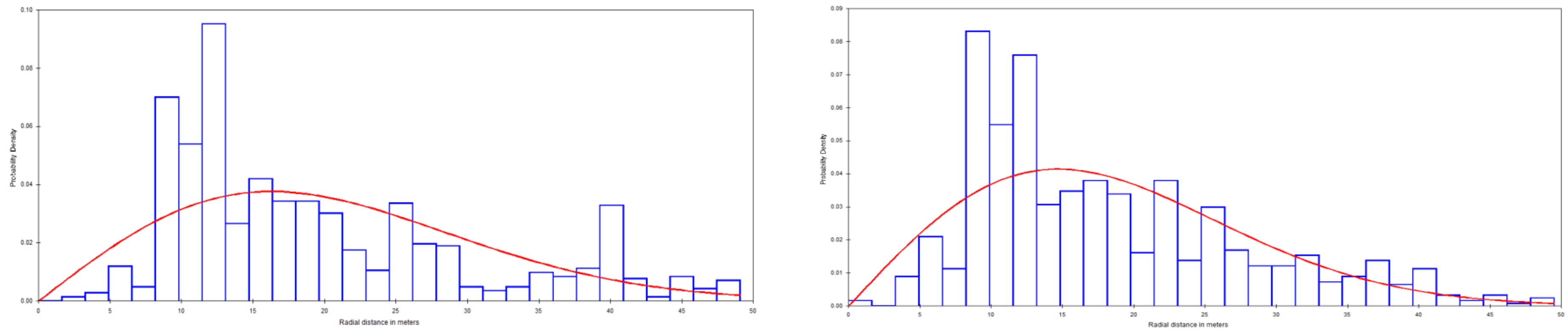


Fig. 5.21: Showing comparison between dry and monsoon season detection distances in forest land bird

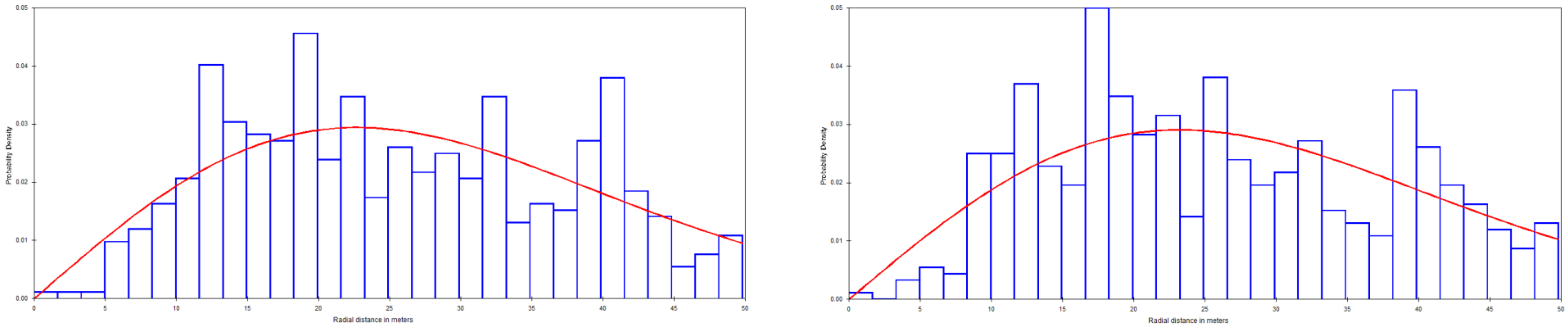


Fig. 5.22: Showing comparison between dry and monsoon season detection distances in grassland bird survey

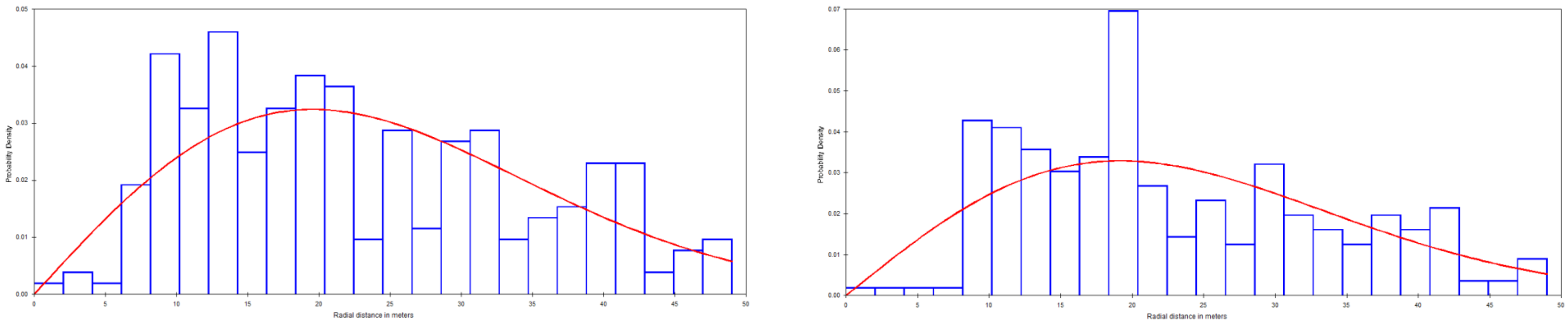


Fig. 5.23: Showing comparison between dry and monsoon season detection distances in homegarden bird survey

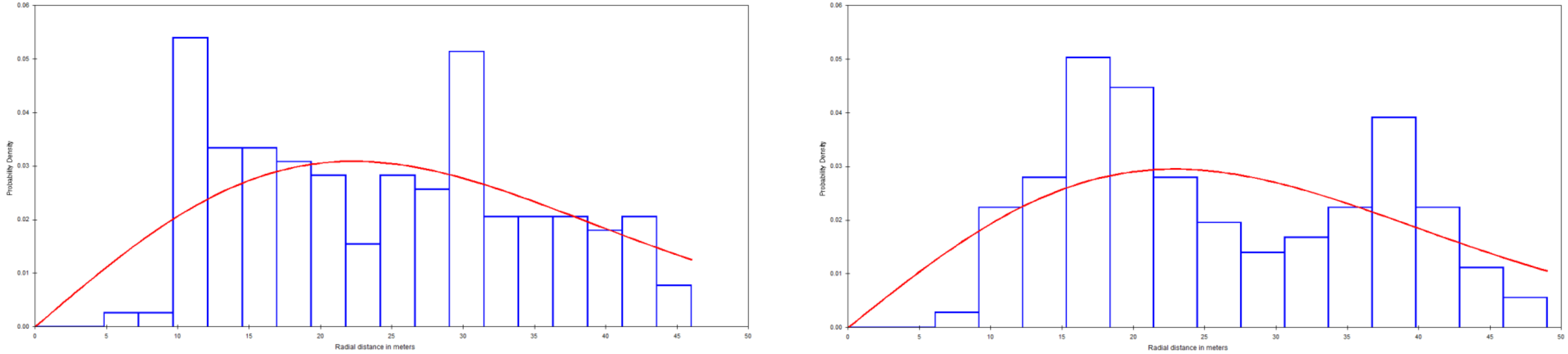


Fig. 5.24: Showing comparison between dry and monsoon season detection distances in mango plantation bird survey

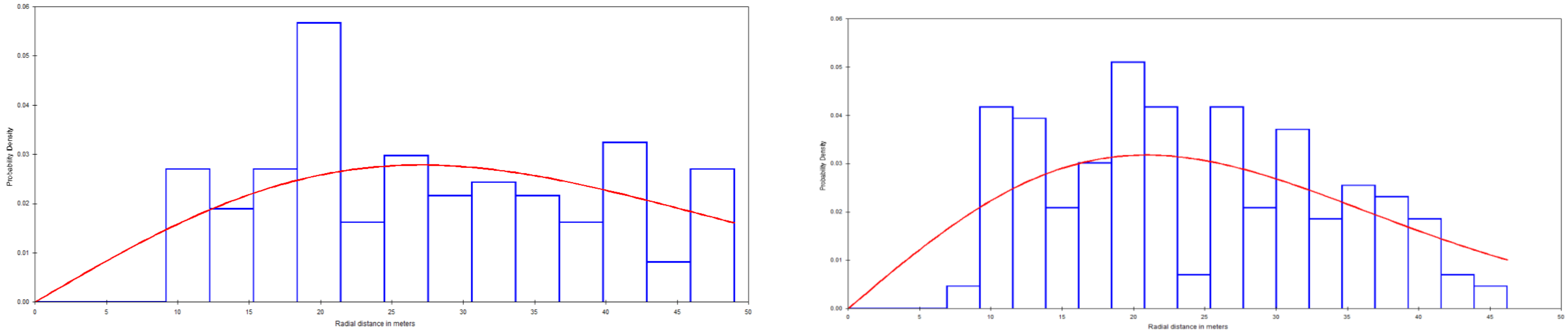


Fig. 5.25: Showing comparison between dry and monsoon season detection distances in grassland bird survey

Table 5.4: Comparison of abundance and detection probability of avifauna by land-use types investigated in the dry season survey.

	Dry season				Monsoon season			
Land-use	**Abundance**	**SE±**	**% CV**	**Detection probability/ha**	**Abundance**	**SE±**	**% CV**	**Detection probability/ha**
Agricultural land	1541	125.77	8.16	79.7	2764	187.9	6.8	57.6
Casuarina Plantation	215	36.5	16.67	83.3	227	39.62	17.45	82.7
Forest land	7659	282.08	3.68	70.7	8445	349.44	4.14	70.3
Grassland	3103	200.96	6.48	67.5	3224	220.27	6.83	60.1
Homegardens	1543	128.84	8.35	66.6	1835	144.55	7.88	75.8
Mango plantation	751	85.27	11.35	86.7	1002	108.81	10.86	83.1
Mangrove	547	74.84	13.68	79.1	400	53.76	13.44	84.1

5.5.10 Comparison of dominance of the species at different land-use:

The study revealed that the most common dominant species in the study area are jungle Crow (*Corvus macrorhynchos*), baya Weaver (*Ploceus philippinus*), brahminy Kite (*Haliastur Indus*), red wattled Lapwing (*Vanellus indicus*), spotted Dove (*Streptopelia chinensis*), Indian Myna (*Acridotheres tristis*), rose ringed-parakeet (*Psittacula krameri*), red whiskered Bulbul (*Pycnonotus jocosus*), red vented Bulbul (*Pycnonotus cafer*), Indian pied Hornbill (*Anthracocerous coronatus*), large gray Babbler (*Turdoides malcolmi*), black Drongo (*Dicrurus macrocerus*), small Bee-eater (*Merops orientalis*), jungle bush Quail (*Perdicula asiatica*), black shouldered Kite (*Elanus caeruleus*), Indian house Crow (*Corvus splendens*), cattle Egret (*Bubulcus ibis*) etc. The photographs of the some common bird species found in the study area are shown in Appendix. 8.32. The species like Malabar Trogon (*Harpactes fasciatus*), spotted Owlet (*Athene brama*), Indian Peafowl (*Pavo cristatus*), Hoopoe (*Upupa epops*), white breasted Waterhen (*Amaurornis phoenicurus*), black Bulbul (*Hypsipetes leucocephalus*), Indian pied Wagtail (*Motacilla maderaspatensis*), red Munia (*Amandava amandava*), yellow fronted Barbet (*Megalaima flavifrons*), purple Sunbird (*Nectarinia asiatica*), painted Spourfowl (*Galloperdix lunulata*), tickells blue Flycatcher (*Cyornis tickelliae*), white spotted fantail Flycatcher (*Rhipidura albicollis*), Eurasian blackbird (*Turdus merula*), common Kestrel (*Falco tinnunculus*), rosy Starling (*Sturnus roseus*), night Heron (*N. nycticorax*), Indian Pitta (*Pitta brachyuran*), little Egret (*Egretta garzetta*) etc are less abundant and less dominant species in the study area. It was observed that some species with high dominance in the dry season never show dominance in the monsoon season at same land-use. The study revealed that jungle Crow (*Corvus macrorhynchos*) is the most dominant bird species at agricultural land and homegarden site in the dry season survey, while baya Weaver (*Ploceus philippinus*) in monsoon season survey. Brahminy Kite (*Haliastur Indus*) was the most dominant species at the casuarina plantation site in the dry and monsoon season survey. At forest land-use type, jungle Crow (*Corvus macrorhynchos*) exhibit higher dominance in the dry and monsoon season point transect survey. In dry season red wattled Lapwing (*Vanellus indicus*) was the most abundant and dominant bird species at grassland site, however baya Weaver (*Ploceus philippinus*) contribute highest dominance in monsoon season. Red wattled Lapwing (*Vanellus indicus*) and large gray Babbler (*Turdoides malcolmi*) represents high dominance at mango plantation site in the dry and monsoon season, respectively. Jungle Crow (*Corvus macrorhynchos*) was the leading dominant bird at mangrove forest in the dry season, while large gray Babbler (*Turdoides malcolmi*) in monsoon season bird survey. Some species occurred occasionally throughout the study area.

5.5.11 Diversity and evenness indices:

We calculated Shannon Weaver index of diversity, Simpson's index of dominance, Simpson's index of diversity, species evenness, Sorenson's quantitative index of similarity and Jaccard's index of similarity to determine the seasonal distribution patterns of diversity at different land-use types. The data on bird species diversity indices, evenness and similarity indices for the seven land-use types in the dry and monsoon season survey are presented in Fig. 5.26 to 5.29 and Table 5.5 to 5.6.

5.5.12 Shannon Weaver index of diversity (H')

The results for Shannon Weaver indices of diversity are depicted in Table 5.5 showed that the indices values ranges between 2.90 and 3.73. The mean seasonal variation in Shannon diversity indices was significant at seven land-use types (Fig. 5.26). The mean species diversity was higher (3.68) at agricultural land followed by grassland (3.66) and Forest land-use types (3.60); however there was no significant difference. It denotes that there is more species diversity and less competition between species. The lowest mean value of Shannon Weaver index (3.01) was observed at casuarina plantation land-use indicates that low species diversity and high completion between species. It is also observed that there was no significant difference in bird species diversity at the casuarina plantation, mango plantation, mangrove and homegarden land-use types.

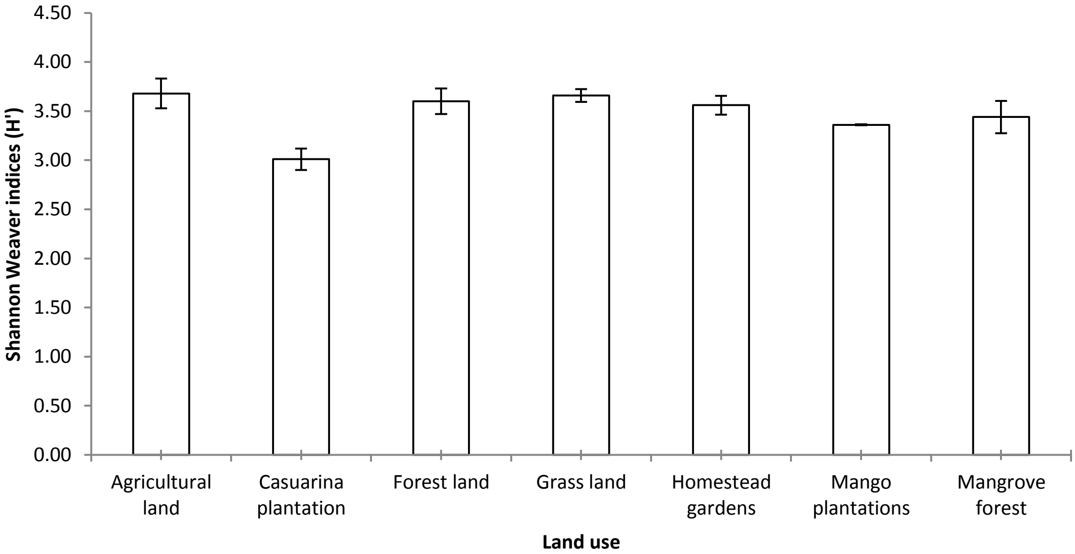


Fig. 5.26: Shannon Weaver indices of species diversity at different land-use types. Error bar shows SE (±).

The highest value of the Shannon Weaver index (3.73) was recorded at forest land and grassland in the dry season and monsoon season bird survey, respectively and it proves that there is high bird species diversity. Table 5.5 illustrates that except agricultural land and grassland habitats the species diversity decreased in the monsoon season than the dry season. The minimum Shannon Weaver diversity indices values 3.12 and 2.90 were recorded at casuarina plantations in the dry and monsoon season respectively, which symbolize that there is low bird species diversity.

Table: 5.5: Comparison of richness and diversity indices of avifaunal communities by land-use types in dry season bird survey.

Season	Land-use type	Species richness	Abundance (N)	Shannon Weaver index (H')	Simpsons index (D)	Simpsons index (1-D)	Species evenness (E)
Dry season	Agricultural land	73	689	3.67	0.035	0.96	0.86
	Casuarina plantation	36	158	3.12	0.063	0.93	0.87
	Forest land	78	1635	3.73	0.033	0.97	0.86
	Grassland	71	1163	3.6	0.038	0.96	0.84
	Homegardens	62	452	3.66	0.036	0.96	0.89
	Mango plantations	43	267	3.36	0.047	0.95	0.89
	Mangrove forest	50	223	3.61	0.034	0.97	0.92
	Average	**59**	**655**	**3.54**	**0.04**	**0.96**	**0.88**

Season	Land-use type	Species richness	Abundance (N)	Shannon Weaver index (H’)	Simpsons index (D)	Simpsons index (1-D)	Species evenness (E)
Monsoon season	Agricultural land	76	795	3.7	0.034	0.97	0.86
	Casuarina plantation	28	120	2.9	0.079	0.92	0.87
	Forest land	86	1456	3.47	0.052	0.95	0.78
	Grassland	88	1251	3.73	0.035	0.96	0.83
	Homegardens	59	567	3.47	0.046	0.95	0.85
	Mango plantations	47	348	3.37	0.049	0.95	0.88
	Mangrove forest	40	224	3.28	0.054	0.95	0.89
	Average	**61**	**680**	**3.42**	**0.05**	**0.95**	**0.85**

5.5.13 Simpson's index of dominance (D) and diversity (1-D)

The seasonal variation in Simpsons indices of dominance and Simpsons indices of diversity at different land-use types are showed in Table 5.6. It is observed that there was significant difference in dominance index values between agricultural and casuarina plantation. The highest mean Simpsons index of dominance value (0.071) was recorded at casuarina plantations followed by mango plantation (0.048), mangrove forest (0.044), forest land (0.042), homegarden (0.041), grassland (0.37) and lowest at agricultural land (0.034), see Fig. 5.27. All values of dominance index tend to zero it means that there is high species diversity. However, the species diversity in the study area was decreased from agricultural land, grassland, homegarden, forest land, mangrove forest, mango plantation to casuarina plantation (Fig. 5.27).

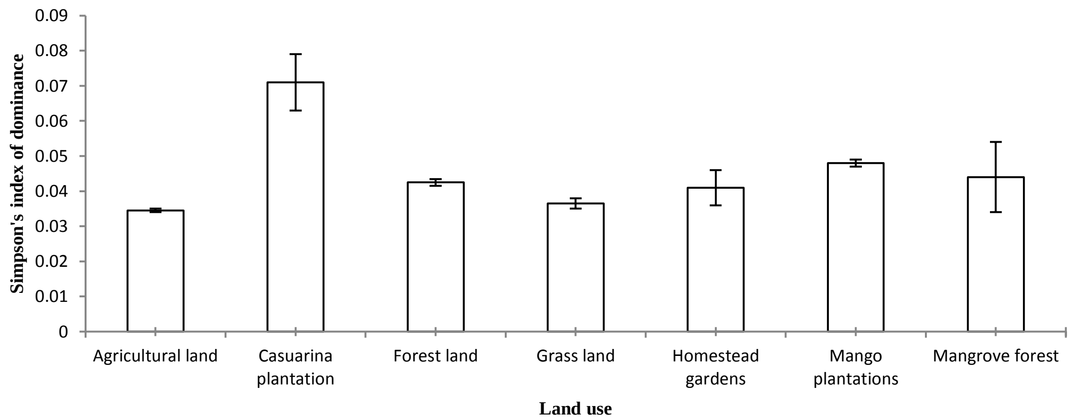


Fig. 5.27: Simpson's index of dominance at the study area. Error bars shows SE (±).

In the dry season bird survey the dominance index was highest (0.063) at casuarina plantation which indicates that there is low bird species diversity, however the lowest (0.033) dominance value indicates high species diversity at forest land followed by 0.034, 0.035, 0.036, 0.038, 0.047 at mangrove forest, agricultural land, homegarden, grassland and mango plantation land-use types, respectively. In case of monsoon season survey, the dominance index was also highest at casuarina plantation. However, the lowest values

0.034 and 0.035 were recorded at agricultural land and grassland, respectively, which indicates that there is high species diversity. The results in Table 5.5 denotes that the dominance index value decrease for agricultural land and grassland from the dry season to monsoon season shows that species diversity was higher in monsoon season than the dry season in these both land-use types. However, for other land-use types the species diversity decrease in monsoon season. In contrast, the Simpson's index of diversity is the inverse of Simpson's index of dominance. It is concluded that higher the value of Simpson's index higher the diversity of the community is (Fig. 5.29).

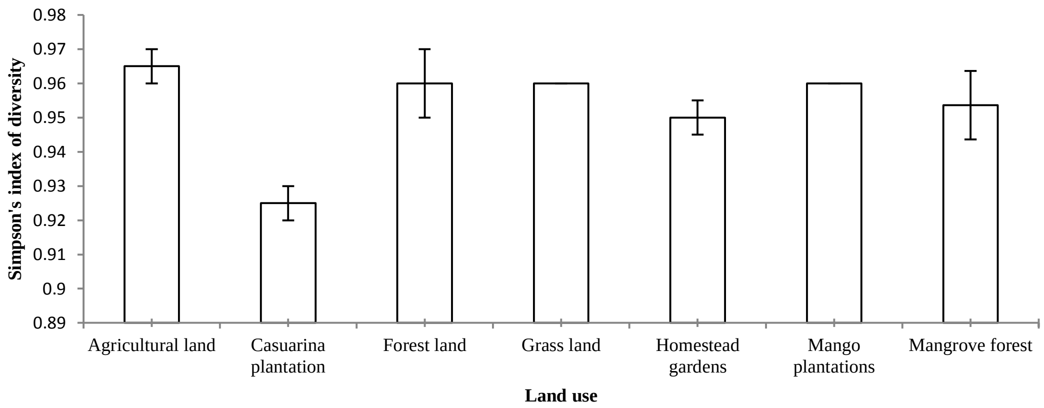


Fig. 5.28: Simpson's index of diversity at different land-use types. Error bars shows SE (±).

The species evenness measures the variance in abundance among the species at a given site. It falls between 0 and 1, where a value of 1 indicates that the species abundance are all equal (i.e. variance in abundance is 0) and the value tends to 0 when they are highly unbalanced (i.e. variance is indefinitely large). The results indicate that evenness values ranges from 0.78 to 0.92 (Table 5.5 and Fig. 5.29).

The mangrove forest showed highest value of evenness (0.92) in the dry season that means less variance and species are equally abundant. The lowest evenness value (0.78) was recorded for forest land in monsoon season, which indicates that there is relatively high variance in species abundance than any other land-use. Seasonal variation in species evenness between all land-use types was not significant in both seasons. The mean species evenness values were ranged from 0.82 between 0.90 for all land-use in both season bird surveys. There was high variance in species evenness at forest land-use followed by grassland, agricultural land casuarina plantation and homegarden land-use types. However, there was high evenness in species distribution at mangrove forest followed by mango plantation land-use type. It is observed that there is no variance in abundance among the species at all land-use types in both seasons except forest land-use in monsoon season survey (Fig. 5.29).

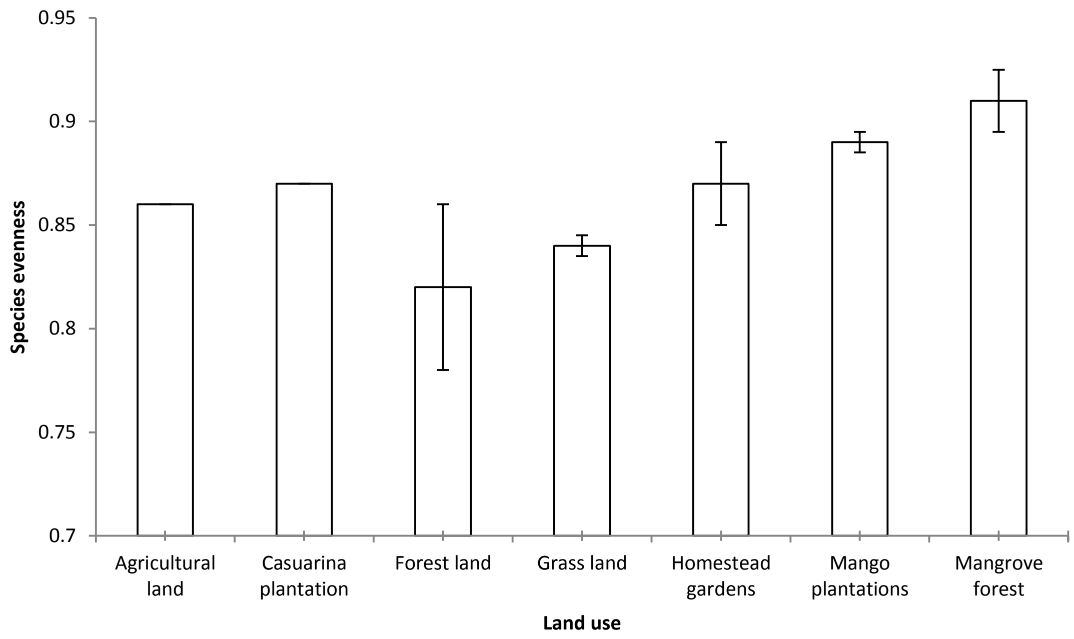


Fig. 5.29: Comparison of bird species evenness between seven land-use types. Error bars shows SE (±).

5.5.14 Sorenson's quantitative and Jaccard's similarity index

These indices of similarity are based solely on presence-absence data of bird assemblage between any two communities or population. Higher indices values indicate low bird diversity. Overall in the dry and monsoon season bird survey the values of the percent similarity indices vary greatly between 40 and 79 percent (Table 5.6). It is observed that the percent Sorenson's similarity values were highest within all land-use in the dry and monsoon season exhibit low diversity in bird community. The Sorenson's quantitative index values indicated that the agricultural land in the dry season and forest land in monsoon season as well as forest lands in the dry and monsoon season had most similar bird communities (79%). That means these land-uses have less diversity in bird community. While, agricultural land in the dry season and casuarina plantation in monsoon season had least similar (40%) bird communities indicates high bird diversity. We compared Sorenson's similarity indices with in season, which shows significant variation in bird communities between different land-use types (Table 5.7). In the dry season, high similarity (95%) was recorded between forest land and agricultural land bird communities, which indicates that both communities had least diversity. However, mango plantation and grassland land-use types had least similar (36%) bird communities indicates that there is high bird diversity. On other hand, overall similarity indices values decreased in monsoon season indicates increase in bird diversity between different land-use types. In monsoon season, the similarity index was higher (80%) between agricultural land and grassland indicates low bird diversity. While, only 39% similarity was recorded between forest land and casuarina plantation land-use types detects high bird diversity.

Table 5.6: Comparison similarity indices (Sorenson's quantitative index) between different land-use types using species list in the dry and monsoon season bird survey. The Values in bracket are number of species in common and total number of species at two land-uses in particular season respectively.

Season	**Monsoon season**							
	Land-use types	Agricultural land	Casuarina plantation	Forest	Grassland	Homegardens	Mango plantation	Mangrove
Dry season	Agricultural land	64 (52, 110)	50 (25, 76)	79 (63, 96)	75 (60, 101)	73 (48, 84)	67 (40, 80)	62(35, 78)
	Casuarina plantation	40 (21, 84)	75 (24, 40)	48 (29, 93)	48 (30, 94)	59 (28, 67)	53 (22, 61)	58 (22, 54)
	Forest land	68 (52, 102)	47 (25, 81)	79 (65, 99)	76 (63, 103)	72 (49, 78)	66 (41, 84)	61 (36, 82)
	Grassland	65 (48, 99)	47 (23, 75)	74. (58, 99)	75 (60, 99)	71 (46, 84)	64 (38, 80)	61 (34, 77)
	Homegardens	74 (51, 87)	53 (24, 66)	73 (54,94)	71(53, 97)	76 (46, 75)	68 (37, 72)	65 (33, 69)
	Mango plantations	59(35, 84)	51 (18, 53)	62 (40, 89)	58 (38, 93)	61 (31, 71)	71 (32, 58)	65 (27, 56)
	Mangrove forest	65 (41, 85)	56 (22, 56)	60 (41, 95)	65 (45, 93)	66 (36, 73)	68 (33, 64)	71 (32, 58)

Table 5.7: Comparison of percentage similarity within the dry and monsoon season between different land-use types using 'species list' (Sorenson's quantitative index). The Values in bracket are number of species in common and total number of species in particular land-use respectively.

Season		Monsoon season						
	Land-use	Agricultural land	Casuarina plantation	Forest	Grassland	Homegardens	Mango plantation	Mangrove
Dry season	Agricultural land	1	42 (22, 82)	75 (61, 101)	80 (66, 98)	74 (50, 85)	70 (43, 80)	57 (33, 83)
	Casuarina plantation	61 (33, 76)	1	39 (22, 86)	41 (24, 92)	51 (22, 65)	53 (20, 55)	59 (20, 48)
	Forest land	95 (72, 79)	60 (34, 80)	1	77 (67, 107)	63 (46, 99)	63 (42, 91)	49 (31, 95)
	Grassland	88 (63, 81)	58 (31, 76)	93 (69, 80)	1	73 (54, 93)	64 (43, 92)	55 (35, 93)
	Homegardens	86 (58, 77)	67 (33, 65)	88 (61, 78)	83 (55, 78)	1	77 (41, 65)	69 (34, 65)
	Mango plantations	69 (40, 76)	61 (24, 55)	68 (41, 80)	36 (36, 78)	67 (35, 70)	1	62 (27, 60)
	Mangrove forest	78 (48, 75)	65 (28, 58)	77 (49, 79)	76 (46, 75)	82 (46, 66)	71 (33, 60)	1

` The Jaccard's similarity values always ranges between 0 and 1. Seasonal variation in Jaccard's similarity indices was significant between different land-use type, which ranges from 0.25 to 0.66 (Table 5.8). The coefficient of Jaccard's similarity index indicated that forest land site in the dry and monsoon as well as agricultural land site in the dry season and forest land site in monsoon season had the most similar bird communities (0.66), while the casuarina plantation site in the dry season and agricultural land site in monsoon season had least similar (0.25)

Table 5.8 indicates that the similarity indices vary greatly between different land-use types in the dry season, which, ranges from 0.41 to 0.91. Forest land and agricultural land sites (0.91) exhibit most similar bird communities followed by grassland and forest land sites (0.86) which indicate lower bird diversity. However, least indices value (0.41) was recorded between grassland and Casuarina plantation site indicate higher bird diversity. On other hand in the monsoon similarity indices values ranges between 0.24 and 0.67 (Table 5.9).

In monsoon season the similarity indices values decreased than the dry season indicate that increase in bird diversity. It is observed that grassland, agricultural land sites (0.67) had most similar bird species followed by homegarden, and mango plantation sites (0.63) indicate that low diversity in bird communities. While least similarity index value (0.24) between forest land and the casuarina plantation sites indicate high dissimilarity in bird community.

Table 5.8: Comparison of Jaccard's similarity index within the dry and monsoon season between different land-use types using 'species list'. The Values in bracket are number of species observed only in Land-use type A and number of species observed only in Land-use type B in particular season.

Season		Monsoon season						
	Land-use	Agricultural land	Casuarina plantation	Forest	Grassland	Homegardens	Mango plantation	Mangrove
Dry season	Agricultural land	0.47 (21, 37)	0.33 (48, 3)	0.66 (10, 20)	0.59 (13, 28)	0.57 (25, 11)	0.50 (33, 7)	0.45 (38, 5)
	Casuarina plantation	0.25 (8, 55)	0.60 (12, 4)	0.31 (7, 57)	0.32 (6, 58)	0.42 (8, 31)	0.36 (14, 25)	0.41 (14, 18)
	Forest land	0.51 (26, 24)	0.31 (53, 3)	0.66 (13, 21)	0.61 (15, 25)	0.56 (10, 29)	0.49 (37, 6)	0.44 (42, 4)
	Grassland	0.48 (23, 28)	0.31 (47, 5)	0.57 (8, 32)	0.61 (11, 28)	0.55 (25, 13)	0.48 (33, 9)	0.44 (37, 6)
	Homegardens	0.59 (11, 25)	0.36 (38, 4)	0.57 (8, 32)	0.55 (9, 35)	0.61 (16, 13)	0.51 (25, 10)	0.48 (29, 7)
	Mango plantations	0.42 (8, 41)	0.34 (25, 10)	0.45 (3, 46)	0.41 (5, 50)	0.44 (12, 28)	0.55 (11, 15)	0.48 (16, 13)
	Mangrove	0.48 (9, 35)	0.39 (28, 6)	0.43 (9, 45)	0.48 (5, 43)	0.49 (14, 23)	0.52 (17, 14)	0.55 (18, 8)

Table 5.9: Comparison of Jaccard's similarity index within the dry and monsoon season between different land-use types using 'species list'. The Values in bracket are number of species observed only in land-use type A and number of species observed only in land-use type B in a given season.

Season		**Monsoon season**						
	Land-use	Agricultural land	Casuarina plantation	Forest land	Grassland	Homegardens	Mango	Mangrove
Dry season	Agricultural land	1	0.27 (54, 6)	0.60 (15,	0.67 (22,	0.59 (9, 26)	0.54 (4, 33)	0.40 (7, 43)
	Casuarina plantation	0.43 (40, 3)	1	0.24 (64, 6)	0.26 (64, 4)	0.34 (37, 6)	0.36 (27, 8)	0.42 (20, 8)
	Forest land	0.91 (1, 6)	0.43 (44, 3)	1	0.63 (21,	0.46 (13, 40)	0.46 (5, 44)	0.33 (9, 55)
	Grassland	0.78 (8, 10)	0.41 (40, 5)	0.86 (2, 9)	1	0.58 (5, 34)	0.47 (4, 45)	0.38 (5, 53)
	Homegardens	0.75 (4, 15)	0.51 (29, 3)	0.78 (1, 16)	0.71 (7, 16)	1	0.63 (6, 18)	0.52 (6, 25)
	Mango plantations	0.53 (3, 35)	0.44 (19, 12)	0.51 (2, 37)	0.46 (7, 35)	0.50 (8, 27)	1	0.45 (13, 20)
	Mangrove forest	0.64 (2, 25)	0.48 (22, 8)	0.62 (1, 29)	0.61 (4, 25)	0.70 (4, 16)	0.55 (17, 10)	1

5.6 Discussion

Seasonal variation in bird species structure, composition, distribution, richness and diversity was quantified in different land-use types in the Konkan coast region of India. The scope of the study includes as wide selection of homogeneous habitats within the regional moist-forest habitat. The study showed that the avifaunal structure, composition, distribution, species richness and diversity vary with season and different land-use types.

The two seasons were selected in order to capture variation in the presence of regional and migratory bird species. These patterns of variations found seem to be a response of various factors like season, vegetation and land-use changes. Our study showed a rich assemblage of bird species at the agricultural land, forest land, grassland and homegarden sites investigated. This study revealed only a few known migratory species at the grassland site, but there were large differences in the most numerous species between the two seasons.

5.6.1 Point transects method

Point transect method has been commonly used for sampling avian distribution and abundance (Etterson *et al*., 2009). In the point transect method, the observer travels along transects and stops at predefined spots, allow the birds to settle, and then all the birds seen or heard during a predetermined time, ranging, at the extremes from 2 to 20 minutes are recorded (Sutherland *et al*., 2004). If the observer stands at one place, it is possible to count the birds seen and heard. It is a simplest method and if repeated over several places can be used to assemble a list of species in the study area (Bibby *et al*., 2000). The point transect method is based on cues both visual and acoustic to avoid the major biases that often affects estimated densities from standard point transect sampling (Buckland, 2006).

Point transect method is suited to dense habitats such as forest and scrub where access is restricted and where birds may be attracted to the presence of observers at the counting stations (Sutherland *et al*., 2004). However, in work presented here the effective detection radius was lowest in the forest habitat, and highest in the more structurally simple habitat types such as grasslands and casuarina plantations, suggested that visibility plays as important role in the bird estimates. Bibby *et al*., (2000) suggested that a well spaced series of points in an area would provide more representative data than a few transect. Transects were set out in a way to cover more of the ground and divided into sections for recording birds and habitats.

In this study, a 500 meter long transects and five equidistance sample points along transect was selected because bird identification was improved if more time was available at each point. In a single morning 5 points of a single transect were visited. Obviously, an adequate level of identification skill and field guide (Pande *et al*., 2003) was helpful during bird survey. The area surveyed is proportional to the square of distance of the furthest bird from the observer.

Kissling and Garton (2006) demonstrated various point count methods to determine the bird densities. They observed that single observer fixed radius count method produces low density estimate in comparison with single-observer-variable-circular-plot and paired-observer-variable-circular-plot, and recommended paired-observer-variable-circular-plot for precise estimates of density.

5.6.2 Bird species structure, composition and distribution

Structurally bird assemblage varied with season and with land-use. The species composition of avian species counted during the dry and monsoon seasons was significantly different. The avifaunal analysis revealed that the study area is the home for

114 bird species, however, this results are very interesting than working plan of Ratnagiri forest sub-division, Chiplun which demonstrates only 36 bird species in the whole division (Takalkar, 2002). Thus, the bird species richness in our study indicates 68% more species, which is a small part (450 km^2) of the Ratnagiri forest sub-division Chiplun. Our study revealed that area contains 22%, 16 %, 23% and about 27% of bird species identified by Daniels (1992), Besten (2008), Gunawardene *et al*., (2007) and Pande *et al*., (2003), respectively. The result showed that highest number of bird species was counted in monsoon season (113) and the lowest in the dry season (83). The number of encounters decreased in monsoon season; however, the total number of birds detected increased. The reason behind this was addition of new species and the big cluster size of the most abundant species. In the dry season, the birds found dispersed and cluster size was small. It is revealed that in the dry season species richness was low than compared to the monsoon season but overall species abundance was higher. The fact that 72% (82 spp.) of the total number of species counted were common to both the dry and monsoon season, suggest that these birds are native to the environment and the habitats. On other hand in the monsoon, 27% (31) bird species seems to be migratory in nature and might responsible for the high species richness in the monsoon season. It was also noticed that out of the total 114 bird species, only 9% (10 spp.) bird species counted were common to all land-types in both season indicating that there is a constant variation in bird assemblage at the different land-use types. A large number of bird assemblage's diverse bird species is an indication of less competition due to differing niche requirements (Pianka, 1974).

If the distribution of the individual species is considered the species such as jungle crow, baya weaver, brahminy kite, red wattled lapwing, spotted dove, Indian myna, rose ringed-parakeet, red whiskered bulbul, red vented bulbul, Indian pied hornbill, large gray babbler, black drongo, small bee-eater, jungle bush quail, black shouldered kite, Indian house crow and cattle egret were found all over the study area. some species like black kite, crested honey buzzard, crested hawk eagle, crested serpent eagle, grey-headed fish-eagle, little cormorant, night heron, white-bellied sea-eagle, white-breasted waterhen, brown fish owl, common sandpiper, eurasian curlew, large cuckoo shrike, river tern, sirkeer malkoha, whimbrel and Indian shag were only distributed over the costal site and near estuaries. The remainder of the species reported were found in wide range of habitats in the study area. However, the bird species such as Indian peafowl, lesser golden woodpecker, heart spotted woodpecker, emerald dove and Indian grey hornbill were found only in the area of low level of human disturbances.

An overall analysis by family showed the family Accipitridae (10 spp.) dominants the avifauna of the study site followed by Muscicapidae (6 spp.), Columbidae, Sturnidae and Cuculidiae (5 spp. each) followed by Phasianidae, Hirundinidae, Alaudidae, Ardeidae, Pycnonotidae and Scolopacidae (4 spp. each). It is evident that although Accipitridae family is dominant family in the study area, it was observed that most of the species belonging to this family were less abundant and less occurred frequently. In both the dry and monsoon season, the family Accipitridae scored a high number of species, but the abundance and density of these bird species is low. Four species of this family belong to Schedule-I of the Indian Wildlife Protection Act, 1972. Among them, Grey-Headed Fish-Eagle is declared as globally near threatened and the White-Rumped Vulture is a critically endangered species (IUCN, 2011).

Detectability of birds varies in all land-use categories in both seasons. The birds are more easily spotted at grassland, Mango plantation, the casuarina plantation and mangrove forest than forest land-use and homegarden sites. It is possible that some birds were not tallied in dense vegetation in forest land-use and homegarden site. Each land-use was located near water body (sea, river, and estuary); therefore, species preferring habitats close to water bodies expected to occur in all land-use types.

Our results suggest that the probability of detecting a bird species at different land-use types was higher in the dry season. The high detection probability is probably due to the better conditions for fieldwork. However, the low probability of detecting bird species in monsoon season might be related to climatic condition, and dense vegetation. The outcomes revealed that species richness was high in monsoon season where probability of detecting a bird species was low. It is concluded that less abundant species are more difficult to detect and detectability of some species vary with habitat or behaviour (Dorazio *et al*., 2006). Detectability depends on observer's skill (Boulinier *et al*., 1998). It has been argued that patterns of changes in detection through time of season vary among species (Skirvin, 1981). Similarly effective detection distance was highest in the dry season and decrease in the monsoon season for all land-use except the mangrove forest sites. However, the average detection distance lies in the centre of the point transect. It is assumed that the probability of detection is high at the centre of the plot. (Buckland *et al*., 1993) and it decrease in a non-linearly with distance from the observer, and is species dependant (Verner, 1985). Current evidences suggest that many factors like weather, habitat structure, phenology, background noise, anthropogenic noise; time of the day and observers skills affects the detectability during bird counts (Alldredge *et al*., 2007; Simons *et al*., 2007; Pacifici *et al*., 2008; Etterson *et al*., 2009). The Kolmogorov-Smirnov statistic provides a means of testing whether a set of observations are from some completely specified continuous-distribution (Lilliefors, 1967). The MCDS analysis estimates showed considerable variation in detection probabilities at different land-use types. However, estimates of detection probability are reasonably similar, which indicates that observer and time of the day probably account for most of the variation in detection probabilities.

Similarly Marques *et al*., (2007) studied MCDS model and suggested that it is increasingly used to increase precision of density estimates for different land-use or habitats.

5.6.3 Bird Species richness and density

At the regional scale the potential bird species richness of the studied land-use types in the dry season represents 73% (83 spp.) from the potential species richness in monsoon season (113 spp.). Only one bird species (Red Rumped Vulture) was recorded at grassland site in the dry season, which found neither in any other land-use nor in the monsoon season.

In rarefaction analysis, the species accumulation curves showed that species richness was significantly richer in forest land, grassland and agricultural land site than homegarden, mango plantation, the casuarina plantation and mangrove forest sites. Loehle (2005) interpreted that higher the curves there is high species richness. It suggests that less rich habitats could be an important in conservation of avian community. The Species richness is the actual number of species present in a given area or in a given sample. It is an indicator of the relative wealth of species in a community. Species number per sample measures richness and it is the most basic and general diversity measurement (Peet, 1974). It is stated that species richness is a fundamental measurement of community and regional diversity (Gotelli and Colwell, 2001; Dorazio *et al*., 2006). Estimating species richness is the vital step of many field studies conducted in community ecology and is of crucial concern when dealing with the conservation and management of biodiversity (May, 1988; Colwell and Coddington, 1994; Bouliner *et al.*, 1998). However, species richness estimation depends on relative abundance distribution and sampling intensity (Brose *et al*., 2003).

In our study sample based rarefaction curve were constructed from an empirical species-by-sample matrix. A number of authors have stated that sample based rarefaction curves provides a realistic estimate of number of species to be found in sets of real-world samples (Colwell and Coddington, 1994; Chazdon *et al*., 1998; Gotelli and Colwell, 2001; Colwell *et al*., 2004). Many ecologists suggested that species richness in a species assemblage is a significant measure of biodiversity and species accumulation curves have been used for quantitative comparison among species assemblage (Bunge and Fitzpatrick, 1993; Colwell and Coddington, 1994; Mao and Colwell, 2005; Mao *et al*., 2005).

Our results showed that the bird density per hectare changed in the different land-use types between the dry and monsoon season. Royle *et al*., (2004) suggested habitat or land-use co-variate affects abundance and detectability. They also concluded that the potential bias in the density estimate was due to potential heterogeneity of land-use types or habitats. The seasonal variations in bird density were due to great number of regional bird species present during the dry and monsoon season. In addition, the seasonal changes in bird assemblage may be due to temperature and humidity fluctuations or the alteration of rainy and dry period. Similar conclusions were made in Argentina stating that the seasonal variation in bird assemblage might be due to low winter temperatures (Herrera, 1981) or the alteration of rainy and dry periods (Poulin *et al*., 1992). The high density in monsoon season might be due to availability of food and habitat.

Our investigation revealed that the high bird density was recorded at forest land-use type. The surprising result was the drastic increase in agricultural land bird density and decrease in mangrove bird density in monsoon season. In the dry season most of the agricultural land remain un-cultivated and temperature rose too greatly. The high summer temperatures, might be reason the bird species prefer the more sheltered forest or homegarden habitats or habitats near water bodies. In contrast, in the monsoon season the croplands are cultivated and food availability is high. Higher availability may be the reason why some bird species prefer to move from other land-uses to croplands in the dry season. Another reason for increase in monsoon season bird species richness and density may be due to migratory bird species. However, after forest land-use type the homegardens had the highest the bird density and but was stable in both seasons. This may be due to continuous supply of food and shelter to bird community. Many researchers suggested that individual birds of the many tropical bird species frequently move over large areas to follow temporal and spatial changes in food resources (Blake *et al*., 1990; Loiselle and Blake, 1990; Stiles, 1985). Loiselle and Blake (1992) theorized that the variation in abundance and richness at given site may have different implications for species ability to survive after disturbance or habitat loss. Similarly, in our study area the wetlands, open barren lands are changed to shrimp farming and human settlement, respectively. This might be the reason for moving bird communities to the forest land and the homegarden sites in search of food and shelter. Jayapal *et al*., (2009) studied avian communities in tropical deciduous forest of Central India and concluded that bird assemblage in forest land is associated with availability of a wide choice of food plant species.

5.6.4 Bird diversity

In terms of distribution, only ten bird species were found to be co occurring at all land-use types in both the seasons. The diversity index scores at different land-use types indicate comparable variation in bird diversity. The high value of Shannon Weaver Index indicates the most diverse habitat. The study revealed that agricultural and, grassland and forest land-use types have high bird diversity comparative to other land-use types. However, high bird diversity was recorded at forest land-use in the dry season and grassland in the monsoon season. The bird biodiversity was decreased in all land-use types in monsoon season except agricultural land and grassland sites. Overall, the agricultural land had the highest Shannon Weaver index of bird diversity followed by grassland, forestland and homegarden land-use categories. The comparison of the similarity indices indicates more heterogeneity in species assemblage between different land-use types within and between two seasons. The species diversity indices and evenness of different land-use types during the study period indicates that the forest land, agricultural land and grassland-use types had the highest species diversity and evenness. The large size of these land-use types compare to other sites might contribute to highest bird diversity and evenness.

A significant seasonal change of avian diversity and richness at different land–use types suggests that the bird species of the Konkan coast of Western Ghats have dynamic seasonal movements including some long distance migrants. It is apparent, as 72% of total bird species recorded was common in both seasons. The seasonal movements of species for food searching might bring about such fluctuations (Chettri *et al*., 2001). Few studies on birds in India argued that the principal differences among different land-use sites were due to human pressure resulting in vegetation structure and composition (Block and Brennan, 1993; Chettri *et al*., 2001).

5.6.5 Bird conservation management and monitoring

The current study indicates that the study area is rich in bird diversity. The land-use systems such as forests, homegarden and grassland showed high species richness. However, land-use systems such as agricultural land, mangrove, mango plantations and casuarina plantations are characterized by low species richness. The current research suggests that there crucial need to conserve this land-scape in order to reduce threat to bird diversity. Our findings also indicate that the current knowledge of bird community structure should be integrated into conservation decision making under different land-scape levels for different bird bird communities. An avifaounal diversity analysis of bird community structure resulted in identification of 114 bird species and most of the bird species are highly dependent on the specific land-use. We propose that the birds to be integrated as a monitoring parameter in future bird monitoring projects in the Konkan coast of Maharashtra state of India. Our list of the bird species will also provide baseline to reserve some important bird areas for conservation of the bird communities. Further, the government authorities must be aware about importance of buffer zones for the conservation of bird communities in the region.

If the human and anthropogenic disturbances increase in future, then there would be the danger of bird species homogenization. Therefore, in order to maintain diverse bird composition there is need for conservation measures and care should be taken to minimize the human disturbances in the area over a period of time. The bird communities in the Konkan coast of Maharashtra need considerable conservation interest due to high densities of the specific species. Further, disappearance of the forest, mangrove, homegardens and casuarina plantations in the study area necessitates the highest priority conservation action of the remaining intact vegetational groups and an attempt should needed to to preserve the unique biodiversity of thes vegetation types. The current study showed occurrence of rare and less abundant species listed by IUCN. Low richness of these bird species in the area leads to conclude that this group of the species should be focused for conservation in order to prevent their decline or disappearance at the regional scale.

In India, there are number of evidences of the establishment of network of protected areas for conservation of wildlife (Sundaramoorthy, 2008-2009: Kumar, 2011). In order to conserve bird diversity several Indian foresters are engaged in afforestation and reforestation programmes that are ecologically better suited to harbour the native bird communities (Kumar, 2011). Kumar (2011) suggested that forest management significantly altered structure of bird communities in Himalayan region. Sundaramoorthy, (2008-2009) reported that in India, wildlife-related crimes are controlled by three major legislations: Wildlife (Protection) Act, 1972, Customs Act, 1962 and Export and Import policy of India Foreign Trade (Development and Regulation) Act, 1992. The other related Acts used are the Indian Penal Code - 1860, Code of Criminal Procedure – 1974, Prevention of Cruelty of Animals Act – 1960 and Arms Act – 1959. There is crucial need to implement the all llegislative laws in order to conserve wildlife biodiversity in the Konkan coast of Maharashtra.

5.7 Conclusion

This study documents a 114 bird species occurring in Konkan Coast of the Western Ghats. It is concluded that the study site exhibits diverse habitats types and rich in bird species. Only few bird species are restricted to specific land-use types. The majority of bird species seen were restricted to grassland, forest land and agricultural land-use types. The investigation reflects that the majority of the bird species use a variety of available land-use types in entire study area. The wide variety of the bird species like hornbills, woodpeckers, warblers, drongos, flycatchers, kingfishers, starlings, crows and kites indicates richness and diversity of the bird species in the study area. Our study highlights the importance of conducting and documenting bird diversity at different land-use type. It is important to carry out repeated inventories of the Konkan coast in order to track regional and global changes in population of bird species. Although ornithological knowledge of the Western Ghats is significant, understanding the avifaunal diversity is still important for conservation planning and restoring ecosystems in long term management. We therefore suggest further systematic and long term avian survey to document changes in overall species richness and diversity in Konkan coast of Western Ghats.

The avifauna of the Konkan coast of Western Ghats in Maharashtra state is facing the threats of rapid economic development and deforestation. It is important to formulate future research needs of avifaunal diversity in the Konkan coast of the Western Ghats in such a way that can clearly discriminate between different factors and human disturbances in determining the avifaunal diversity level at different land-use types. There is the need for increasing the level of scientific collaboration in avian diversity studies in Konkan coast of Western Ghats.

We suggest that standardization in distance sampling and point transect method is a useful tool for avian biodiversity assessment and species richness in the Konkan coast of Western Ghats. If the present trends of land-use changes continue in the near future, the knowledge of about the effects of land-use changes on avifauna will be important to conservationist and ecologist. Being an ecological indicators as well as aesthetic reasons it is important to understand how they are affected by human induced land-use changes. Therefore, it will help for better conservation planning of avifauna of the study area in the future.

6 GENERAL DISCUSSION AND CONCLUSION

Biodiversity and C sequestration are integral part of ecosystem services therefore studies on this aspects attracting attention from ecologist and scientist worldwide. With increasing human pressures on the environment, these ecosystem services act as powerful incentives to conserve nature (Balmford *et al*., 2002). Wallace (2007) has stated the opinion that the concept of ecosystem services offers an important opportunity to develop a framework to underpin the wise utilization of biodiversity and other natural resources. Gardner, *et al*., (2009) synthesised prospectus of tropical forest diversity and pointed out that the future of tropical forest biodiversity is uncertain and it depends on the effective management of human-modified landscapes. Tropical forest ecosystems support at least two-thirds of the Earth's terrestrial biodiversity and supply significant local, regional and global human benefits through the provision of economic goods and ecosystem services.

The present study indicated that the quadrate method, loss-on-ignition and point transect survey are reliable tools for analysis of floral diversity, soil C content and bird diversity, respectively. The use of EstimateS 8.2.0 software application seems to be very important to estimate species richness and construction of the species accumulation curves. Further, Distance 6.0 release 2 software programme is effective and accurate for determination of bird density, abundance, detection probabilities, encounter rates and effective detection radius.

6.1 Vegetation analysis

In order to analyse the floristic richness and diversity of the south Konkan coast of Maharashtra we selected major land-use types such as the forests, casuarina plantations, homegardens and mangroves. A total of 410 plant species were recorded in the south Konkan Coast of Maharashtra, this is about 10.25% of the species reported in the flora of the Western

Ghats (Nayar, 1996). The forest vegetation showed highest species richness and diversity. The forest vegetation is home for 268 plant species in present study. While, the floristic composition of the forest is similar to the tropical moist deciduous forest ecosystem described by Ramesh *et al.*, (2010), as evident by the presence of a large number of species like, *Terminalia paniculata, Acacia catechu, Aegle marmelos, Ailanthus excelsa, Artocarpus heterophyllus, Bombax ceiba, Buchanania lanzan, Calycopteris floribunda, Carissa carandas, Caryota urens, Celastrus paniculatus, Derris scandens, Emblica officinalis, Ficus benghalensis, Garcinia indica, Gloriosa superba, Gmelina arborea, Grewia micrococos, Ixora brachiata, Jasminum malabaricum, Leea indica, Lantena camera, Macaranga peltata, Mallotus philippensis, Mangifera indica, Memecylon umbellatum, Michelia champaca, Pongamia pinnata, Sterculia urens, Syzygium cumini, Tamarindus indica, Tectona grandis, Terminalia paniculata, Zanthoxylum rhetsa, Ziziphus rugosa*.

The homegarden in our study are composed of 206 plant species, this richness values is in range between 155 and 328 as recorded by Kumar (2011) at different sites in central Kerala. The species composition of the homegardens showed affinity with the flora of homegardens in central Kerala as described by (Kumar, 2011), which consists of the species like *Careya arborea, Carica papaya, Cocos nucifera, Annona reticulata, Annona squamosa, Areca catechu, Artocarpus heterophyllus, Bauhinia variegata, Delonix regia, Ficus hispida, Ficus elastica, Ficus religiosa, Holarrhena pubescens, Leucaena leucocephala, Mangifera indica, Michelia champaca, Moringa oleifera, Murraya koenigii, Psidium guajava, Syzygium cumini, Terminalia elliptica , Tectona grandis, Helicteres isora, Hibiscus rosa-sinensis, Jatropha curcas, Justicia adhatoda, Heliconia species, Musa paradisiaca,* and many other shrubs, herbs and climbers. It has been concluded that the traditional homegardens are the human made system that stimulates the natural forest in structure and function, and being a multi-layered canopy system homegardens are suited maintaining high genetic diversity, which makes the ecosystem highly efficient in harnessing space, soil nutrients, water and energy

(Jose and Shanmugaratnam, 1993). The composition and structure of the homegarden may be depends on the personal preferences of its owner. In Indonesia and India, it has been reported that over centuries of cultural and biological transformations homegardens represent the accrued wisdom and insights of farmers. The peoples managed the multi-layered agro-ecosystem without access to exogenous inputs, capital, or scientific skills (Nair and Kumar, 2006). The casuarina monocultures were studied to determine under storey species richness and diversity. The monocultures composed of 40 plant species (7 shrubs, 18 herbs and 13 climbers). *Calotropis procera, Sonchus oleraceus, Sonchus asper, Achyranthes aspera, Ipomoea pes-caprae, Hemidesmus indicus, Tylophora dalzellii and Cucumis setosus* was most dominated the flora. The study revealed that monocultures showed low species richness compared to the forest and homegarden vegetation. However, all species were common to forest vegetation.

It has been argued that the mangrove species diversity is higher in India than Latin America and Africa. The west coast of India is home for 33 mangrove species. However, the ecological investigations so poor, therefore it is difficult to get correct information on the species richness and diversity (Upadyay *et al*., 2002). Banerjee *et al*., (1989) reported 116 species in mangrove, which includes 59 mangrove species, 47 algae and 10 sea grasses. Our study reported 12 true mangrove and 14 mangrove associate species. The number of true mangrove species is comparatively lower compared to the reports of the MMF, India (2010). The result revealed that *Sonneratia caseolaris, Avicennia officinalis, Excoecaria agallocha (L.), Aegiceras corniculatum, Rhizophora mucronata* and *Acanthus ilicifolius* are the most dominant mangrove species. The highest number of species belongs to the Rhizophoraceae family. The mangroves are characterized by high soil salinity and recently this unique coastal ecosystem diversity is most threatened due to anthropogenic activities, expanding human population and unsustainable economic development (Upadyay *et al*., 2002). The mangroves are considered as most complex ecosystem in nature. The long-term approach for monitoring the impacts of land-use and climate change is a prerequisite as the mangrove vegetation is closely linked with fishery resources, sea grasses and coral reef ecosystems adjacent to them. Shrimp farming and the intensive coconut plantations in wetlands generating pressure on mangrove vegetation in the study area.

6.2 Soil organic carbon storage experiment

A study on analysis of C storage was carried out in order to determine organic matter and carbon stocks under different land-use types in the study area. The major factor influencing on the soil organic matter and carbon storage are vegetation, climate and the soil properties (Post and Kwon, 2000; Magdoff and Weil, 2004; Collard and Zammit, 2006; Hobley and Willgoose, 2010). The forest ecosystem C dynamic is the part of global C cycles that involves many temporal pools and biogeochemical processes (Beedlow *et al*., 2004). The forests soils stores highest C in the study area. In general, forest ecosystems, organic matter in the soil is a complex product from the decomposition of crop residues, roots, organic acids, living or dead organisms and the substances synthesised from their breakdown products (Brady, 1974; Johnson *et al*., 1995). The results of our investigation indicated similar order of magnitude, suggesting possibility of dominant role of litter, fine root and microbial activities in soil organic carbon storage. However, the litter, root decomposition and microbial activities were not included in the present study. The significant variation was observed in organic matter content between different land-use soils in the study area. The tropical plant species and tropical forests exhibit faster rates of organic matter decomposition and nutrient turnover compared with other forest types (Kumar and Jose, 1992). Therefore, this could be the reason for higher soil organic matter and carbon content in forest soils than other land-use soils in the study area. It has been argued that the tropical forests have higher soil C contents than other types of vegetation (Noordwijk *et al*., 1997). Similarly in present study, forest soils showed significantly high variation in *SOC* content compared to the casuarina plantation, agricultural land, grass land, homegarden and mangrove soils. However, no significant difference was observed between forest and mango plantation soils. After forest vegetation the mango plantations showed highest C storage this could be due to external inputs of organic and inorganic fertilizers. Several researchers have studied soil organic carbon storage in tropical moist deciduous forest ecosystems in India, and reports indicate the soil organic carbon in top 50 cm depth ranges between 8.9 and 177 t C ha^{-1} (Yadav and Sharma, 1968; Jose and Koshy, 1972; Rajamannar and Krishnamoorthy, 1978; Banarjee *et al.*, 1981 and 1990; Singh *et al.*, 1882; Singh and Singh, 1991; Singhal *et al.*, 1982; Das and Roy, 1982; Singh and Datta, 1983; Prasad *et al.*, 1985, 1986; Sharma *et al.*, 1985; Totey *et al.*, 1986a and 1986b, Narain *et al.*, 1990; Banarjee and Sharma, 1990; Srivastava *et al.*, 1991; Mongia and Bandopadhyay, 1992; Raina *et al.*, 1999; Chhabara *et al.*, 2003). Pawar and Mehta (1999) studied sandy loam-loam soils in swamp forest of Kankan coast (Kerala) and reported that they contain 93.3 to 153.9 t/ha soil organic carbon. The soil organic carbon in Sundarban mangrove vegetation ranges between 37.7 and 67.4 t/ha (Bandopadhyay, 1986). Many researchers showed that tropical tree plantations have been characterized by relatively small carbon sink (Montagnini and Porras, 1998; Shepherd and Montagnini, 2001; Schroeder, 1992; Losi *et al.*, 2003). The study showed that homegardens has potential to store C in soil as homegardens are structurally similar to natural forest. The few reports on agro-forestry systems on soil carbon storage in India revealed that the carbon storage depends on land-use types and ecological conditions (Smiley and Kroschel, 2008; Fassbender *et al.*, 1991; Takimoto *et al.*, 2008; Haile *et al.*, 2009).

6.3 Bird diversity analysis

The avifaunal investigation revealed 114 bird species found during the study period. Significant seasonal variation in bird abundance, density, richness and diversity were recorded in different land-use types. The highest number of birds were recorded at the forest land (33% of the total) followed by the grassland site (26% of the total), suggests that these habitats provide habitat for many birds in the study area. Birdlife International declared the Western Ghats together with the adjacent coastal areas of Kokan Goa, Karnataka, Kerala, and the Deccan Plateau, as an ecological zone of global importance (Pande *et al.*, 2003). Being Endemic Bird Area it supports a vast spectrum of birdlife. However, the area is under huge pressure from human interference. Near about forty four bird species found in Western Ghats are now are listed the Red Data Book as critical, endangered, vulnerable and near threatened species (Pande *et al.*, 2003). The tropical birds are dependent on the forest canopy for nesting or foraging (Thinh, 2006), and this may be the reason for high species richness and diversity at forest land in the study area.

Next to the forest habitat, high species richness recorded at the grassland sites due to shrub layer, which provides breeding or feeding sites for most of the tropical birds. Orians (1969) suggested that fewer than 15% bird species use the low shrub layer in tropical forest. However, in structurally poor grasslands a shrub layer may be an important structural element. Despite of the impressive bird diversity detected at the study site, it is necessary to point out that not all species reported present at all land-use types. This is very important because variance in bird composition associated with land-use and its influence on other aspects of the environment. Allen and O'Connor (2000) concluded that the land-use and other environmental aspects inter-related to such an extent and it was difficult to quantify their independent associations with the regional bird distribution. In the dry season 23% and in the monsoon season 14% bird species were common at all land-use type. This interesting outcome of the investigation denotes co-occurrence of the bird species at different land-use types. Tallies of these more frequent and large numbers were attributed mainly to the large folks of the birds. This study demonstrated that the forest land and grassland sites provide habitat for many bird species. Species richness in monsoon season seems to be increased due to migratory species like Common Sandpiper, Pied crested cuckoo, Eurasian Curlew, River Tern, Whimbrel, etc. Some of the bird species were sighted only occasionally in few numbers throughout the study area. Among recorded bird species 27% (31 spp.) of the bird species that were tallied in the monsoon season were not seen in the dry season.

Our investigation revealed that the high bird density was recorded at forest land-use type. The surprising result was the drastic increase in agricultural land bird density and decrease in mangrove forest site bird density in monsoon season. In the dry season most of the agricultural land remain un-cultivated and temperature rose too greatly. The high summer temperatures, might be reason the bird species prefer the more sheltered forest or homegarden habitats or habitats near water bodies. In contrast, in the monsoon season the croplands are cultivated and food availability is high. Higher availability may be the reason why some bird species prefer to move from other land-uses to croplands in the dry season. Another reason for increase in monsoon season bird species richness and density may be due to migratory bird species. The avifauna detected in the study area is the only about quarter as diverse as that of the whole Western Ghats (114 *v.* 500 known species). It is apparent that the sampling efforts (number of point transects) carried out in this study did not reveal all the species present in all land-use types. However, the records provide a useful indication of the relative levels of bird diversity in agricultural land, the casuarina plantation, forest land-use, grassland, homegarden, mango plantation and mangrove forest habitats. The difference in number of species occurred between different land-use types may not be as large if the same sapling efforts had been made at each land-use type. More species were recorded on each subsequent sampling effort. However, it is obvious that higher sampling efforts in the casuarina plantation and mangrove forest sites would not add more species due to comparatively small patch size of these land-use types. Our findings are consistent with the conditions of McIntyre (1995) where; the larger habitat areas (forest land. Grassland, agricultural land and homegardens) supported more species and individuals on an average than smaller patches (casuarina, mangrove and mango plantation) because they might possessed more diverse matrix of microhabitats including more food sources, nesting sites, and refugia from predators or compositors.

6.4 Conservation measures with reference to the Indian forest lows and acts

The first step towards the conservation of the biodiversity of the selected study site is to follow guideline of Indian Forest (Conservation) act, 1980. This guideline explains approval of the central government to start project on forest and non forest land involved. Therefore, the central government has right to decide to start project and work should not start without approval of central government on forest and non forest land for release forest as well as non forest land for the projects under the act has been given.

6.5 Land-use planning and mitigating measures:

As already discussed, the land-use change pattern, deforestation, industrialization, natural calamities, shrimp farming, construction, encroachment by human to forest and non forest area for settlement, chira mining and installation of the thermal, hydro and nuclear power projects are the major problems in Konkan coast of Maharashtra. The effective land-use planning and mitigating measures are important for management of environmental hazards and loss of biodiversity. Therefore, we recommend following land-use planning and mitigating measures.

1. The central, state as well as local government must adopt comprehensive planning (inventories, policies and implementation) and greater attention must be given to environmental hazard reduction and biodiversity conservation in the region.

2. The Government forest department should be strict to stop illegal tree felling and actions should be taken according to Indian forest law.
3. To undertake watershed development programmes
4. The attention must be given to the vegetation management and soil conservation.
5. The priority must be given to preserve the mangrove vegetation along the coastal zone.
6. Restoration of the coastal belt of casuarina plantation is an urgent need.
7. Protection of flying foxes habitat located in the mangrove vegetation.
8. There is need to create awareness among the peoples about the environmental hazards, advantages of the conservation of natural resources and land-use planning.
9. The study region of the Konkan coast of Maharashtra has adequate ecological, faunal, floral, geomorphological, natural, or zoological significance. Therefore it is special need to declare sanctuaries or national parks or protected areas by Government notification for the purpose of protecting, propagating or development of wildlife or its environment.
10. Some of the areas are rich in bird diversity therefore we recommend to declare such areas as bird sanctuaries in the region.
11. We recommend to protect forest and open areas should be cover with mango plantation to bring more areas under green cover.
12. It is crucial need to undertake afforestation programme on open areas, coastal strips and along road side.
13. It is needed to strengthen the forest act and the person, institution or company who breaks the laws should be punished according to forest act.
14. In Konkan coast of Maharashtra the homegardens are the unique Agroforestry system and a mean of in situ conservation of agricultural and forest biodiversity by farmers

especially using farm practices. Therefore, management of the homegardens for the conservation of biodiversity and natural resources is crustily needed.

15. The site selected for the proposed nuclear power plant is complex land covering grassland, mangrove, farmland, forest, Kevada vegetation, mango plantation. This reflects that the area is ecologically significant and similarly the area is home for rare birds and mammals. Therefore, currant study suggests that before installation of the nuclear power plant Central and state government need to think to stop the land breaking and ultimately the project.

6.6 Research cost

The whole research work was carried out by me with one assistant (helper). The research work cost was includes travel from Bangor (United Kingdom) to the study site at Jaitapur Konkan Coast of Maharashtra (India), local visits, official visits, vehicle, map preparation, equipments required during studies, weather data, soil analysis and one assistant. The total data was collected in 300 working days. The working days required for the vegetation analysis were 125 days, for soil data collection and analysis were 120 days and for bird survey 206 days. The total estimated cost for whole research work was 8 lakh INR (10,000.00 GBP). The cost involved under different heads is shown in Table 6.1.

Table 6.1: Showing total cost involved during the research work

Item	**Cost in INR**	**Cost in GPB**
General expenses		
Digital camera	9,600.00	120.00
Accommodation and food during study period	50,000.00	625.00
Travel from UK to India	96,000.00	1200.00
Local travel expenses	10,500.00	131.25
Visit to Forest Survey of India, Dehradun	10,000.00	125.00
Assistant (Helper)	30,000.00	375.00
Maps including study site and sampling locations	1,00,000.00	1250.00
Printing report and internet	24,000.00	300.00
Forest cover map (Forest Survey of India)	2,000.00	25.00
Vehicle hired (two wheeler)	60,000.00	750.00
Bird survey		
Fuel for vehicle	57,600.00	720.00
Binocular	30,000.00	375.00
Rangefinder	44,500.00	556.25
Soil study		
soil augur	1,300.00	16.25
Fuel for vehicle	5,000.00	62.50
Soil storage bags and other material	3,500.00	43.75
Soil analysis	1,80,000.00	2250.00
Vegetation analysis		
Fuel for vehicle	35,000.00	437.50
Wooden verneer calliper	10,000.00	125.00
Weather data	5,000.00	62.50
Measuring tape	5,000.00	62.50
Rope	1,000.00	12.50
Ravi Multimeter	30,000.00	375.00
Total cost involved	**8,00,000.00**	**10,000.00**

6.7 Overall conclusions

The result of the present study showed that the study area is one of the most biodiversity rich sites, which provide habitats for 410 plant (136 tree spp., 72 shrub spp., 130 herb spp. and 72 climber spp.) and 114 bird species. The study revealed that the soils of the area stores high amounts of organic C. This indicates that the area is very important for providing the ecosystem services of biodiversity and C sequestration. Overall the forests showed highest floral species richness and diversity. As part of the study area is also proposed site for the ever biggest nuclear power plant in India, it is crucial to conserve biodiversity for the sake of our own curiosity and aesthetic evaluation. It has been concluded that the establishment of protected area and nature reserve or wildlife sanctuary is a primary means of biodiversity conservation. Some areas of the region also undergoing rapid conversion of forests to mango plantations, agricultural land and human settlement, therefore awareness about the impact of the future land-use change and advantages of conservation is very important. The study make aware that there is a need for conservation measures particularly where the forests are becoming degraded or converted in to other land-use types. The mangrove forests are also unique habitats in need of protection. The wetlands and swamps in the area are used for shrimp farming, or converted to coconut plantations; therefore special attention should be given to conserve mangrove biodiversity, as these habitats are suited for most of mangrove plant species, fishery, bats and bird species. The protective shelterbelts of casuarina monocultures are comparatively old plantations and are degraded due to human activities and natural calamities. Therefore urgent needs to protect existing stands and to manage these monocultures through afforestation programme. The forest soils have considerably huge potential to store carbon. The study indicates high tree density in forests and mangroves are an indicator of higher C sequestration in soil. The conservation of the existing resources will help in maintaining the soil organic carbon stocks and thus will significantly contribute to mitigating the problem of global warming.

The research findings on floral analysis of different land-use types suggest that the region is ecologically and ethno-botanically rich. The wide variety of floral and avian species indicates the high species richness and diversity in the south Konkan coast of Maharashtra. The region is prone to drastic anthropogenic land-use changes such as deforestation, conversion to agriculture, industrialization (especially, nuclear power generation), shrimp farming, construction works and chira mining. This study provides a basis for developing measures for the conservation and management of natural resources in south Konkan coast of Maharashtra.

In summer season or dry period the area look like waste and barren land but in rainy season the area covers with variety of ground flora, which seems to be unique and suppose no elsewhere found it. Thus, the seasonal variations are sharply detectable. Beside floral insight, I recognized that the area is home for many mammals, reptiles and bird species. Among the various future impacts, the most pronounced and serious impact will occur in the first stage of the project construction. Of course, the groundbreaking and installation of power plant will displace and damage the floral and faunal diversity at proposed site. There may be displacement of the natural heritage and livelihood. Not only the power project is the issue but also other human activities such as land-use conversion for agriculture, slash and burn agriculture, road construction, “Chira” mining, shrimp farming, conversion of wetlands for coconut plantation, conversion of forest land to mango plantations, illegal tree felling and clearing vegetation for human settlement are the other factors which are big concerns for ecologist and Government (Fig. 6.1).

Thus, the rate of conversion of current land-use to another land-use is visible in the area and it may lead to loss of biodiversity and will affect entire ecosystem services. Again, it is true that problems with establishing nuclear power project, energy supply and use are related not only to global warming, but also to such environmental concerns as air pollution, acid rain, stratospheric ozone depletion, forest destruction, and emission of radioactive substances. As per as environmental problems concerned there are many evidences, which suggest that the future will be negatively impacted if human being keep degrading the environment in this way. The present study conclude that land clearing, land breaking, nuclear power project installation will affect the floral and faunal biodiversity as well as carbon balance. Therefore, the study suggests that the nuclear power project should not be started on the site for future environmental health and safety, public health and security and to avoid future hazards of loss of biodiversity in the south Konkan coast of Maharashtra state.

6.8 Future research opportunities

Recently, population explosion, industrial development and over exploitation of natural resources in the Konkan coast is burning issue at national and international level. In the present study, an attempt has been carried out to analyze floristic diversity, soil C storage, and avifaunal diversity. However, studying the whole biodiversity and total C storage is beyond the scope of the thesis. Further major future research opportunities could be as follow

1. Long term monitoring effect of land-use changes on floral and faunal diversity
2. Long term monitoring effect of land-use changes on above ground, belowground and C storage.
3. There is huge scope to undertake studies on diversity of mammals, reptiles, fishes, insects, soil organisms and algae.
4. The vast scope in determine the above and below ground biomass in the forests, homegardens, casuarina plantations, mango plantations, mangroves and grasslands.
5. Study the economic and potential of the C sequestration (cost benefit) under major land-use in the south Konkan coast of Maharashtra.
6. Evaluation of major ecosystem services in the study area.

6.9 Future recommendation for similar work in coastal region

If any student or ecologist wanted to do similar piece of research work, I will suggest him some following important things to do.

1. There is huge scope to undertake studies on diversity of mammals, reptiles, fishes, insects, soil organisms and algae.
2. We suggest him to use both quadrate method and remote sensing for comparing the vegetation structure composition.
3. We recommend that he must use distance sampling technique for avifaunal study. Further, priority should be given for long term investigations on seasonal changes of avifaunal communities and migration.
4. One who want to do same piece of work he must need create awareness among the people, involving local communities and government bodies to avoid loss of biodiversity and concentration must be given on conservation of specific floral or avifaunal species of having conservation importance.
5. We suggest undertaking the studies on carbon sequestration and assessment of ecosystems in the region will be a vast scope.

7 REFERENCES

AAAS., 1995. Proceedings on human population and water, fisheries, and coastal areas: Science and Policy Issues Symposium, American Association for the Advancement of Science, Washington, DC.

Abella, S. R. and Zimmer, B. W., 2007. Estimating organic carbon from loss-on-ignition in northern Arizona forest soils. Soil Science Society of America Journal, 71 (2): 545-550.

Abu-Khader, 2009. Recent advances in nuclear power: A review. Progress in Nuclear Energy, 51: 225-235.

Ahmedullah, M. and Nayar, M. P., 1986. Endemic plants of the Indian region, Volume 1, Peninsular India. Botanical Survey of India, Calcutta.

Ajtay, G. L., Ketner, P. and Duvigneaud, P., 1979. Terrestrial primary production and phytomass. In: Bolin, B., Degens, E. T., Kempe, S., Ketner, P., (Eds.), The Global Carbon Cycle (SCOPE 13).Wiley, Chichester, UK, pages 129-182.

Alcorn, J. B., 1992. Indigenous agroforestry systems in the Latin American tropics. Pages 203-218. In Altieri, M. A. and Hecht, S. B., eds., Agro-ecology and small farm development. CRC Press, Boston.

Ali, M. A. S., Asokan, S., Manikannan, R, and Radhakrishnan, P., 2011. Checklist and nesting patterns of avifauna in and around Mayiladuthurai region, Tamil Nadu, India. JoTT Short Communication, 3 (6): 1842-1850.

Ali, S., Ripley, S.D., 1983. Handbook of Birds of India and Pakistan, Compact Edition. Oxford University Press, New Delhi.

Allaby, M., 2006. *Biomes of the World: Tropical Forests.* Chelsea House, New York.

Alldredge, M. W., 2007. A Field Evaluation of Distance Measurement Error in Auditory Avian Point Count Surveys. Journal of Wildlife Management, 71(8): 2759-2766.

Alldredge, M. W., Simons, T. R. and Pollock, K. H., 2007. Factors affecting aural detections of songbirds. Ecological Applications, 17: 948-955.

Allen, A. P., O'Connor, R. J., 2000. Interactive effects of land use and other factors on regional bird distributions. Journal of Biogeography, 27 (4): 889-900.

Almeida, M. R., 1996-2009. Flora of Maharashtra. Vol. I – V, Orient Press, Mumbai.

Amichev, B. Y. and Galbraith, J. M., 2004. A revised methodology for estimation of forest soil carbon from spatial soils and forest inventory data sets. Environmental Management, 33 (1): S74-S86.

Amthor, J. S. and Huston, M. A., 1998. Terrestrial ecosystem response to global change: a research strategy. Oak Ridge National Laboratory, Oak Ridge, Report ORNL/TM-1998/27.

Amundson, R., 2001. The carbon budget in soils. Annual Review of Earth and Planetary Sciences, 29: 535-562.

Anand, M. O., Krishnaswamy, J., Kumar, A. and Bali, A., 2010. Sustaining biodiversity conservation in human-modified landscapes in the Western Ghats: Remnant forests matter. Biological Conservation, 143: 2363-2374.

Anderson, S. H., 1970. The avifaunal composition of Oregon white oak stands. The Condor, 72: 417- 423.

Andrade, F. V., Schaefer, C. E. G. R., Correa, M. L. T. and Mendonça, E. S., 2004. Carbon stocks in Brazilian Latosols (Oxisols) from different morpho-climatic regions and management systems. Communications in Soil Science and Plant Analysis, 35: 2125-2136.

Anitha, K., Joseph, S., Chandran, R. J., Ramasamy, E.V. and Prasad, N., 2010. Tree species diversity and communitee composition in a human-dominated tropical forest of Western Ghats biodiversity hotspot, India. Ecological Complexity, 7: 217-224.

Anon. 1997. The Wildlife (Protection) Act, 1972, 4th updated edition, Wildlife (Protection) Amendment Act, Government of India, 2002 Natraj Publishers, Dehradun. Also available online at http://moef.nic.in/ accessed 14 December 2011.

Anon., 1976. Geology of the Ratnagiri district, Maharashtra. *Geological Survey of India, 125th Anniversary Publication, pages:* 1–8.

Ansari, Z. A., Jagtap, T. G., Coutinho, F. B., Charulata, S. and Gaidhane, D. M., 2003. Impact of climate change on mangrove forests along the southern west coast: a case study from Kasargod, Kerala, India. In: Proceedings of the Workshop Vulnerability and Adaptations due to Climate Change on Indian Agriculture, Forestry and Natural Ecosystem, Ravindranath, N. H., Sharma, S,, Garg, A., Bhattacharya, S. and Murthy, I. (eds.) NATCOM Publication, New Delhi, India. pp. 136–149.

Arias-Gonza´lez, J. E., Acosta-Gonza´lez , G., Membrillo, N., Garza-Pe´rez , J. R. and Castro-Pe´rez, J. M., 2011. Predicting spatially explicit coral reef fish abundance, richness and Shannon-Weaver index from habitat characteristics. Biodiversity Conservation, DOI 10.1007/s10531-011-0169-y

Arora, R. K., 1964. Phytogeographical notes on the humid tropical flora of India - World distribution and analysis of the woody dicotyledonous flora of Western Ghats and Assam. Journal of the Indian Botanical Society, 43: 220-228.

Arun, P. R., 2008. The Super-Mega Nuclear Power complex at Jaitapur The last nail on Konkan, Nuclear Free India, 1, Issue 2 pages: 5-9.

Ashutosh, S., Pandey, D., Kaur, T. and Bajpai, R.K., 2010. Knowledge-based remote sensing and GIS approach for forest type mapping in Kathua district, Jammu and Kashmir. Tropical Ecology, 51 (1): 21-29.

Atmanand, A., Gupta, K. and Raman, R., 2009. Energy and sustainable development - An Indian Perspective. World Academy of Science, Engineering and Technology, 54: 128-133.

Ayyappan , N. and Parthasarathy, N., 2001. Patterns of tree diversity within a large-scale permanent plot of tropical evergreen forest, Western Ghats, India. Ecotropica, 7: 61-76.

Ayyappan, N. and Parthasarathy, N., 1999. Biodiversity inventory of trees in a large-scale permanent plot of tropical evergreen forest at Varagalaiar, Anamalais, Western Ghats, India. Biodiversity and Conservation, 8: 1533-1554.

Azariah, J., Azariah, H., Gunasekaran, S. and Selvam, V., 1992. Structure and species distribution in Coringa mangrove forest, Godavari Delta, Andhra Pradesh, India. Hydrobiologia, 247: 11-16.

Babu, K. S., Jose, D. and Gokulapalan, C., 1982. Species diversity in a Kerala homegarden. Agroforestry Today, 4: 15.

Baccini, A., Goetz, S. J., Walker, W. S., Laporte, N. T., Sun, M., Sulla-Menashe, D., Hackler, J., Beck, P. S. A., Dubayah, R., Friedl, M. A., Samanta, S. and Houghton, R. A., 2012. Estimated carbon dioxide emissions from tropical deforestation improved by carbon-density maps. Nature Climate Change, 2: 182-185.

Bahuguna, V. K., 1999. Forest fire prevention and control strategies in India. International Forest Fire News, 20: 5-9.

Ball, D. F., 1964. Loss-on-ignition as an estimate of organic matter and organic carbon in non-calcareous soils. Journal of Soil Science, 15: 84-92.

Ball, J.B., 2001. Global forest resources; history and dynamics. The forests handbook. Oxford, UK: Blackwell science.

Balmford A., Bruner, A., Cooper P., Costanza R., Farber, S., Green, R. E., Jenkins, M., Jefferiss, P., Jessamy, V., Madden, J., Munro, K., Myers, N., Naeem, S., Paavola, J., Rayment, M., Rosendo, S., Roughgarden, J., Trumper, K. and Kerry Turner, R., 2002. Economic reasons for conserving wild nature. Science, 297: 950-953.

Balvanera, P., Daily, G. C., Ehrlich, P. R., Ricketts, T. H., Bailey, S. A., Kark, S. and Perera, H., 2001. Conserving biodiversity and ecosystem services. Science, 291 (5511): 2047.

Bandyopadhya, A. K., 1986. Soil and water characteristics of the mangrove forest of Sunderban. Indian Forester, 112 (1): 58-67.

Banerjee, L. K., Sastry, A. R.K. and Nayar, M. P., 1989. Mangroves in India. Identification manual. Botanical survey of India, Calcutta, p 113

Banerjee, S. K., Nath, S., and Banerjee, S. P., 1986. Phytosociology and soil characteristics of forests in the Eastern Himalayas. International Journal of Tropical Agriculture, 4:116-125.

Banerjee, S. P. and Sharma, S. D., 1990. Soil characteristics of chandars of eastern Uttar Pradesh. Indian Forester, 116: 723-729.

Banerjee, S. P., Mathur, K. C. and Sharma, S. D., 1990. Soils of south Kheri forests of Uttar Pradesh. Indian Forester, 116 (6): 479-486.

Banerjee, S. P., Sharma, S. D. and Gairola, S. K., 1981. Soil characteristics of sal forest-chander ecotone in South Kheri. Indian Forester, 107 (8): 492-499.

Bart, J., and Herrick, J., 1984. Diurnal timing of bird surveys. Auk, 101:384-387.

Bates, R. S. P., Lowther, E. H. N., 1952. Breeding Birds of Kashmir. Oxford University Press, Bombay.

Batjes, N. H., 1996. Total carbon and nitrogen in the soils of the world. European Journal of Soil Science, 47: 151-163.

Bawa, K. S., Joseph, G. and Setty, S., 2007. Poverty, biodiversity and institution in forest-agriculture ecotones in the Western Ghats and Eastern Himalaya ranges of India. Agriculture Ecosystems and Environment, 121: 287-295.

Beedlow, P. A., Tingey, D. T., Phillips, D. L., Hogsett, W. E., and Olszyk, D. M., 2004. Rising atmospheric CO2 and carbon sequestration in forests. Frontiers in Ecology and the Environment 2: 315-322.

Beedy, E. C., 1981. Bird communities and forest structure in the Sierra Nevada of California. The Condor, 83: 97-105.

Beehler, B. C., Krishna Raju, K. S. R. and Shahid Ali. 1987. Avian use of man-disturbed forest habitats in the Eastern Ghats, India. IBIS, The International Journal of Avian Science, 129:197-211.

Behera, B., 2010. Biodiversity. ENVIS Newsletter, CES, Volume 21, peges 8.

Behera, S. K. and Misra, M. K., 2006. Floristic and structure of the herbaceous vegetation of four recovering forest stands in the Eastern Ghats of India. Biodiversity and Conservation, 15: 2263-2285.

Bengtsson, L and Enell, M., 1986. Chemical analysis. In Berglund, B. E. (ed.), Handbook of Holocene Palaeoecology and Palaeohydrology. John Wiley and Sons Ltd., Chichester, 423–451

Bernoux, M., Graça, P. M. A., Cerri, C. C., Fearnside, P. M., Feigl, B. J. and Piccolo, M. C., 2001. In The biogeochemistry of the Amazon Basin; McClain, M. E., Victoria, R. L. and Richey, J. E., Ed. Oxford University Press: New York, NY, Pages: 165-184.

Bertel, E., 2005. Nuclear energy and the security of energy supply. Facts and opinions, NEA News 2005, No. 23 (2): 4-7.

Besten, J. W. den, 2008. Birds of India and the Indian Subcontinent, New Delhi.

Bhadwal, S. and Singh, R., 2002. Carbon sequestration estimates for forestry options under different land-use scenarios in India. Current Science, 83 (11): 1380-1386.

Bhagwat, S. A., Kushalappa, C. G., Williams, P. H., Brown, N. D., 2005. The Role of Informal Protected Areas in Maintaining Biodiversity in the Western Ghats of India. Ecology and Society, 10 (1): 8.

Bharucha, F. R. and Shankarnarayan, K. A., 1958. Studies on the Grasslands of the Western Ghats, India. Journal of Ecology, 46 (3): 681-705

Bhat, D. M., Naik, M. B., Patagar, S. G., Hegde, G. T., Kandade, Y. G., Hegde, G. N., Shastri, C. M., Shetti, D. M., Furtado, R. M., 2000. Forest dynamics in tropical rain forests of Uttara Kannada district in Western Ghats, India. Current Science, 79: 975-985.

Bhattacharya, S.C. and Jana, C., 2009. Renewable energy in India: historical developments and prospectus. Energy, 34: 981-991.

Bhattacharyya, T., Pal, D. K., Velayutham, M. V., Chandran, P., Mandal, C., 2005. Total carbon stock in Indian soils: issues, priorities and management. In: Land Resource Management for Food Environment security (International Conference on Land Resource Management). Soil Conservation Society of India, New Delhi, pp. 1–46.

Bhuyan, P., Khan, M. L. and Tripathi, R. S., 2003. Tree diversity and population structure in undisturbed and human-impacted stands of tropical wet evergreen forest in Arunachal Pradesh, Eastern Himalayas, India. Biodiversity Conservation, 12: 1753-1773.

Bianchi, S. R., Miyazawa, M., Oliveira, E. L. de, and Pavan, M. A., 2008. Relationship between the Mass of Organic Matter and Carbon in Soil. Brazil Brazilian Archives of Biology and Technology, 51(2): 263-269.

Bibby, C. J., Burgess, N. D. and Hill, D. A., 2000. Bird Census Techniques, 2nd edition. London, Academic Press.

Bibby, C. J., Collar, N. J., Crosby, M. J., Heath, M. F., Imboden, C., Johnson, T. H., Long, A. J., Stattersfield, A. J. and Thiergood, S. J., 1992. Putting biodiversity on the map: Priority areas for global conservation. ICBP, Cambridge, United Kingdom.

Bibby, C., Burgess, N. D. and Hill, D. A., Bird Census Techniques, Academic Press, London, 1992.

Bilgrami, K. S. 1995. Concept and Conservation of Biodiversity. CBS Publishers and distributors, Delhi.

BirdLife International 2004. Threatened Birds of the World 2004. CD-ROM. Cambridge, UK: BirdLife International.

Birdlife International, 2010. Birds on the IUCN Red List. Available at http://www.birdlife.org/action/science/species/global_species_programme/red_list.html

Birdlife International, 2010. Conserving the world's birds: key facts and Figures. Available online at http://www.birdlife.org/action/science/species/index.html

Bisby, F., Roskov, Y., Culham, A., Orrell, T., Nicolson, D., Paglinawan, L., Bailly, N., Appeltans, W., Kirk, P., Bourgoin, T., Baillargeon, G., Ouvrard, D., eds (2012). Species 2000 and ITIS Catalogue of Life, 30th May 2012. Digital resource at www.catalogueoflife.org/col/. Species 2000: Reading, UK.

Blake, J. G., Stiles, F. G, and Loiselle, B. A., 1990. Birds of La Selva Biological Station: Habitat use, trophic composition, and migrants. Pages 161–182 in Four Neotropical Rainforests (A. H. Gentry, Ed.). Yale University Press, New Haven, Connecticut.

Blankespoor, G. W., 1991. Slash-and-burn shifting agriculture and bird communities in Liberia, West Africa. Biological Conservation, 57: 41-71.

Block, W. M., and Brennan, L. A., 1993. The habitat concept in ornithology: theory and applications. Current Ornithology, 11: 35-91.

Bock, C. E. and Jones, Z. F., 2004. Avian habitat evaluation: should counting birds count? Forntiers in Ecology and the Environment, 2 (8): 403-410.

Bolin, B., Degens, E. T., Duvigneaud, P., and Kempe, S., 1979. The global biogeochemical carbon cycle. In: Bolin, B., Degens, E. T., Kempe, S., and Ketner, P. (eds), SCOPE 13 - The Global Carbon Cycle, 1-56. The International Council of Scientific Unions. John Wiley and Sons, New York.

Boulinier, T., Nichols, J. D., Sauer, J. R., Hines, and J. E. and Pollock, H. K., 1998. Estimating species richness: the importance of heterogeneity in species detectability. Ecology, 79: 1018-1028.

Bradley, R. I.,Milne, R., Bell, J., Lilly, A., Jordan, C. and Higgins, A., 2005. A soil carbon and land use database for the United. Soil Use and Management, 21 (4): 363–369.

Brady, N. C., 1974. Organic matter of mineral soils. In: Buckman, H. O. and Brady N. C., ed. The nature and properties of soils. Macmillan Publishing Co., New York, pages 137-163.

Brahim, N., M. Blavet, B. D. and Gallali, T., 2010. Tunisian soil organic carbon stocks. International Journal of Soil Science, 5: 34-40.

Breininger, D. R., Toland, B., Oddy, D. M., Legare, M. L., 2006. Land covers characterization and Florida scrub-jay (Aphelocoma coerulescens) population dynamics. Biological Conservation, 128: 169-181.

Broadbent, F. E., 1953. The soil organic fraction. Advances in Agronomy, 5: 153-183.

Brookshire, E. N.J., Hedin, L. O., Newbold, J. D., Sigman, D. M. and Jackson, J. K., 2012. Sustained losses of bioavailable nitrogen from montane tropical forests. Nature Geoscience. Published online. doi:10.1038/ngeo1372.

Brose, U, Martinez, N. D. and Williams, R. D., 2003. Estimating species richness: sensitivity to sampling coverage and insensitivity to spatial patterns. Ecology, 84: 2364-2377.

Brotons, L., Sierdsema, H. and Newson, S., 2005. Report on the workshop 'Spatial modelling of large scale bird monitoring data: towards pan-European quantitative distribution maps'. Bird Census News 18: 30–38.

Brower, J. E. and Zar, J. H., 1984. Field and Laboratory Methods for General Ecology, W. C. Brown Publishers, Dubuque, IA, 2nd edition.

Brown, J. H., 1981. Two decades of homage to Santa Roselia: towards a general theory of diversity. American Zoologist, 21: 877-888.

Brown, S., Iverson, L. R., Prasad, A. and Liu, D., 1993. Geographical distribution of carbon in biomass and soils of tropical Asian forests. Geocarto International, 4: 45-59.

Bruford, M. W., 2002. Biodiversity - evolution, species, genes in Conserving Bird Biodiversity: General Principle and their Application (eds. K. Norris and D. J. Pain) Cambridge University Press, Cambridge.

Bruun, P., 1962. Sea level rise as a cause of shore erosion. J Waterways Harbors Div Proc American Society of Civil Eng., 88: 117–130

Buckland, S. T. 2006. Point transect surveys for songbirds: robust methodologies. The Auk, 123: 345-357.

Buckland, S. T., Anderson, D. R., Burnham, K. P. and Laake J. L., 1993. Distance Sampling: Estimating Abundance of Biological Populations. Chapman and Hall, London

Buckland, S. T., Anderson, D. R., Burnham, K. P., Laake, J. L., Borchers, D. L. and Thomas. L., 2001. Introduction to distance sampling. Oxford University Press, New York, USA.

Buckland, S. T., Marsden, S. and Green, R. E. 2008. Estimating bird abundance: making methods work. Bird Conservation International, 18: S91-S108.

Buckland, S. T., Summers, R. W., Borchers, D. L. and Thomas, L., 2006. Point transect sampling with traps or lures. Journal of Applied Ecology, 43: 377-384.

Bunge, J. and Fitzpatrick, M., 1993. Estimating the number of species; a review. Journal of the American Statistical Association, 88: 364-373.

Butchart, S. H. M., et al., 2010. Global Biodiversity: Indicators of Recent Declines. Science, Volume 328 (5982): 1164-1168.

Cahill, A. J., Walker, J. S. and Marsden, S. J. 2006. Recovery within a population of the Critically Endangered citron-crested cockatoo Cacatua sulphurea citrinocristata in Indonesia after 10 years of international trade control. Oryx , 40: 161- 167.

Calvo, L., and J. Blake. 1998. Bird diversity and abundance on two different shade coffee plantations in Guatemala. Bird Conservation International, 8: 297-308.

Canterbury, G. E., Martin, T. E., Petit, D. R., Petit, L. J. and Bradford, D. F., 2000. Bird communities and habitat as ecological indicators of forest condition in regional monitoring. Conservation Biology, **14**: 544-558.

Carnery, K. M. and Matson, P. A., 2006. The Influence of Tropical Plant Diversity and Composition on Soil Microbial Communities. Microbial Ecology, 52(2): 226-238.

Ceccolini, L., 2002. The homegardens of Soqotra island, Yemen: an example of agro-forestry approach to multiple land-use in an isolated location. Agro-forestry Systems, 56: 107-115.

Cerri, C. E. P., Coleman, K., Jenkinson, D.S., Bernoux, M., Victoria, R. and Cerri, C. C., 2003. Modelling soil carbon from forest and pasture ecosystems of Amazon. Brazilian Soil Science Society of America Journal, 67: 1879-1887.

CFA, 2010. India's forest at glance. Commonwealth Forests 2010. An overview of the forests and forestry sectors of the countries of the Commonwealth, Commonwealth Forestry Association, 9-10.

Champion, H. G. and Seth, S. K., 1968. A Revised Survey of Forest Types of India. Manager of Publications, Government of India, Delhi, India, Pages 402.

Chandrashekara, U. M. and Sankar, S., 1998. Ecology and management of sacred groves in Kerala, India. Forest Ecology and Management, 112: 165-177.

Chandrashekara, U. M., and Ramakrishnan, P. S., 1994. Successional patterns and gap phase dynamics of a humid tropical forest of the Western Ghats of Kerala, India: ground vegetation, biomass, productivity and nutrient cycling. Forest Ecology and Management, 70 (1-3): 23-40.

Chao, A., Chazdon, R. L.,Colwell, R. K. and Shen, T., 2005. A new statistical approach for assessing similarity of species composition with incidence and abundance data. Ecology Letters, 8: 148-159.

Chapman, A. D., 2009. Numbers of Living Species in Australia and the World, 2nd edition, Government of Australia, Department of the Environment, Wate, Heritage and the Arts, Canberra. Available online at www.environment.gov.au/biodiversity/abrs/publications/other/species-numbers/

Chari, G. N., Marwar, S. A., Bobade, G. P., Kulkarni, G. A. and Bhagwatkar, D. A., 1975. Geology and Mineral Resources of Maharashtra. Nagpur, India: Directorate of Geology and Mining.

Chari, K. B., Abbasi, S. A. and Ganapathy, S. 2003. Ecology, habitat and bird community structure at Oussudu lake: towards a strategy for conservation and management. Aquatic Conservation: Marine and Freshwater Ecosystems, 13: 373-386.

Chase, M. K., Kristan, W. B., Lynam A. J., Price M. V. and Rotenberry J. T., 2000. Single species as indicators of species richness and composition in California coastal sage scrub birds and small mammals. Conservation Biology, 14: 474-487

Chase, T. N., Pielke, R. A., Kittel, T. G. F., Nemani, R. R. and Running, S. W., 1999. Simulated impacts of historical land cover changes on global climate change in northern winter. Climate Dynamics, 16: 93-105.

Chaturvedi, R. K., Raghubanshi, A. S. and Singh, J. S., 2001. Carbon density and accumulation in woody species of tropical dry forest in India. Forest Ecology and Management, 262, Issue 8: 1576-1588.

Chazdon, R., Colwell, R., Denslow, J., and Guariguata, M. 1998. Statistical methods for estimating species richness of woody regeneration in primary and secondary rain forests of NE Costa Rica, p. 285-309. In Dallmeier, F. and Comiskey, J. (eds.), Forest Biodiversity Research, Monitoring and Modelling, Conceptual Background and Old World Case Studies. Parthenon Publishing, Paris.

Chen, X. and Li, B., 2003. Change in soil carbon and nutrient storage after human disturbance of a primary Korean pine forest in Northeast China. Forest Ecology and Management, 186: 197-206

Chettri, N., Deb, D. C., Sharma, E., and Jackson, R., 2005. The relationship between bird communities and habitat: A study along a trekking corridor of the Sikkim Himalaya. Mountain Research and Development 25(3): 235-244

Chettri, N., Sharma, E., Deb, D. C., 2001. Bird community structure along a trekking corridor of Sikkim Himalaya: a conservation perspective. Biological Conservations, 102: 1-16.

Chhabra, A., Palriab, S. and Dadhwal, V. K., 2003. Soil organic carbon pool in Indian forests. Forest Ecology and Management, 173, Issues 1-3: 187–199.

Christanty, L., 1990. Home gardens in tropical Asia, with special reference to Indonesia. In: Landauer K, Brazil M (eds) Tropical home gardens. The United Nations University, Tokyo, Japan, pp 9-20

Christensen, B. T. and Malmros, P . A., 1982. Loss-on-ignition and carbon content in a beech forest soil profile. Holarctic Ecology, 5: 376-380.

Cincotta, R. P., Wisnewski, J., Engelman, R., 2000. Human population in the biodiversity hotspots. Nature , 404: 990-992.

Clarke, W. C., and Thaman, R. R., 1993. Agroforestry in the Pacific islands: Systems for sustainability. United Nations Press, New York.

Cochran, R. L., Collins, H. P., Kennedy, A. Bezdicek, D. F., 2007. Soil carbon pools and fluxes after land conversion in a semiarid shrub-steppe ecosystem. Biology and Fertility of Soils, 43: 479-489.

Cochran, W. G., 1977. Sampling techniques (3 rd ed.). New York: John Wiley & Sons.

Collard, S. J. and Zammit, C., 2006. Effects of land-use intensification on soil carbon and ecosystem services in Brigalow (Acacia harpophylla) landscapes of southeast Queensland, Australia. Agriculture, Ecosystems and Environment, 117: 185-194.

Collard, S. J. and Zammit, C., 2006. Effects of land-use intensification on soil carbon and ecosystem services in Brigalow (Acaciaharpophylla) landscapes of southeast Queensland, Australia. Agriculture, Ecosystems and Environment, 117: 185-194.

Colwell, R. K., 2009. EstimateS: Statistical estimation of species richness and shared species from samples. Version 8.2.0 User's Guide and application published at http://purl.oclc.org/estimates.

Colwell, R. K., and J. A. Coddington., 1994. Estimating terrestrial biodiversity through extrapolation. Philosophical Transactions of the Royal Society of London, 345: 101-118.

Colwell, R. K., Mao, C. X. and Chang, J., 2004. Interpolating, extrapolating and comparing incidence based species accumulation curve. Ecology, 85 (10): 2717-2727.

Condit, R., Pitman, N. C. A., Leigh, E. G., Chave, J., Terborgh, J., Foster, R. B., 2002. Beta-diversity in tropical forest trees. Science, 295, 666-669.

Connell, J. H. and Lowman, M. D., 1989. Low-diversity tropical rainforests: some possible mechanisms for their existence. American Naturalist, 134: 88-119.

Cooke, T., 1901-1908. The flora of the Presidency of Bombay, Vol. I-II, London B.S.I, reprint 1958 Calcutta.

Coomes O.T. and Ban N. 2004. Cultivated plant species diversity in a home garden of an Amazonian peasant village in northeastern Peru. Economic Botany, 58: 420 - 434.

Cornell, H. V., 1999. Unsaturation and regional influences on species richness in ecological communities: a review of theevidence. Ecoscience, 6: 303–315.

Council on Foreign Relations, 2011. The Global climate change regime. updated on November 2011. online publication by Council on Foreign Relations, available at www.cfr.org

Curtis, J. T., 1959. The Vegetation of Wisconsin. An Ordination of plant communities, University Wisconsin press, Madison Wisconsin, 657 pp.

Curtis, J. T., and McIntosh, R. P., 1950. The Interrelations of Certain Analytic and Synthetic Phytosociological Characters. Ecology, 31:434-455.

Daily, G. C., 1997. Nature's Services: Societal Dependence on Natural Ecosystems. Island Press, Washington, DC.

Daily, G. C., Ehrlich, P. R. and Sanchez-Azofeifa, G. A., 2001. Countryside biogeography: use of human-dominated habitats by the avifauna of southern Costa Rica. Ecological Applications, 11:1-13.

Daniels, R. J. R., 1989. A conservation strategy for the birds of the Uttara Kannada district. PhD Thesis. Indian Institute of Science, Bangalore.

Daniels, R. J. R., 1992. Geographical distribution patterns of amphibians in the Western Ghats, India. Journal of Biogeography, 19: 521-529.

Daniels, R. J. R., Joshi, N. V., and Gadgil, M., 1990. Changes in bird fauna of Uttara Kannada, India, in relation to changes in land-use over the past century. Biological Conservation, 52: 37-48

Daniels, R. J., Joshi, N. V. and Gadgil, M., 1992. On the relationship between bird and woody plant species diversity in the Uttara Kannada district of south India. Proceedings of the National Academy of Science of the United States of America, 89: 5311-5315.

Daniels, R.J.R., Gadgil, M. and Joshi, N.V., 1995. Impact of human extraction on tropical humid forests in the Western Ghats in Uttara Kannada, South India, Journal of Applied Ecology, 32: 866-874.

Danserean, P., 1968. The continuation concept of vegetation responses. Botanical Review, 34: 253-332.

Das, A., Krishnaswamy, J., Bawa, K. S., Kiran, M. C., Srinivas, V., Samba Kumar, S. and Karanth, K. U., 2006. Prioritization of conservation areas in the Western Ghats, India. Biological conservation, 133: 16-31.

Das, D. K., 1975. Clay Minerals in Some Forest Soils. Indian Agriculture, 19: 373–381.

Das, S. N. and Roy, B. B., 1982. Characterisation and classification of some upland soils. Indian Forester, 108 (10): 660-668.

Das, T. and Das, A. K., 2005. Inventorying plant biodiversity in homegardens: a case study in Barak Valley, Assam, North- East India. Current Science, 89 (1):155-163

Davidar, P., Puyravaud, J. P. and Leigh, E. G., 2005. Changes in rain forest tree diversity, dominance and rarity across a seasonality gradient in the Western Ghats, India. Journal of Biogeography, 32:493-501.

De Vos, B., Van Meirvenne, M., Quataert, P., Deckers, J., Muys, B., 2005. Predictive quality of pedo-transfer functions for estimating bulk density of forest soils. Soil Science Society of America Journal, 69: 500-510.

Dean, W. E. Jr., 1974. Determination of carbonate and organic matterin calcareous sediments and sedimentary rocks by loss onignition: Comparison with other methods. Journal of Sedimentary Petrology, 44: 242-248.

Demey, R., 2006. Chapter 7: A Rapid Survey of the Birds of the Boké Préfecture, Northwestern Guinea. *A Rapid Biological Assessment of Boké Préfecture, Northwestern Guinea.* RAP Bulletin of Biological Assessment, *pp.* 137-140

Deng, F., Zang, R. and Chen, B., 2008. Identification of functional groups in an old-growth tropical montane rain forest on Hainan Island, China. Forest Ecology and Management, 255: 1820-1830.

Denman, K. L., et al., 2007. In Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, ed Solomon, S., et al. (Cambridge University Press, Cambridge, U.K.) pp 499-588.

Deshmukh, S., 1994. Methods of studying mangrove vegetation, conservation of mangrove forest and genetic resources. In: Deshmukh V, Balaji V (eds) A training manual, pp 225–235

Dhadwal, V. K., Pandya, N. and Vora, A. B., 1998. Carbon cycle for Indian forest ecosystem: a priliminary estimate. In Subbaraya, B. H., Rao, D. P., Desai, P. S., Manikiam, R. P., (Eds) Global change studies: Scientific results from ISRO-GPB. ISRO, Banglore, Pages: 411-430.

Dhase, S., Kotangale, J. P., Chaudhary, P. R. and Wate, S. R. 2009. Diversity of birds at Pannipat refinery, Haryana (India). Environmental Monitoring Assessment, 158: 1-8.

Díaz, S., Fargione, J., Chapin, F. S., Tilman, D., 2006. Biodiversity loss threatens human well-being. PLoS Biology, 4 (8): e277.

Dierick, D. and Holscher, d., 2009. Species-specific tree water use characteristics in reforestation stands in the Philippines. Agricultural and Forest Meteorology, 149:1317-1326.

Dinesh, R., Chaudhuri, S. G., Ganeshamurthy, A. N. and Pramanik, S. C., 2004. Biochemical properties of soils of undisturbed and disturbed mangrove forests of South Andaman (India). Wetlands Ecology and Management, 12: 309-320.

Dixon, R. K., Brown, S., Houghton, R. A., Solomon, A. M., Trexler, M. C., Wisniewski, J., 1994. Carbon pools and fluxes of global forest ecosystems. Science, 263: 185-190.

Donato, C. D., Kauffman, J. B., Murdivarso, D., Kurnianto, S., Stidham, M. and Kanninen, M., 2011. Mangroves among the most carbon-rich forests in the tropics. Nature Geosciences, 4: 293-297.

Dorazio, R., M., Royle, J. A., Soderstrom, B. and Glimskar, A., 2006. Estimating species richness and accumulation by modelling species occurrence and detectability. Ecology, 87 (4): 842-854.

Duttaa, R. K. and Agrawal, M., 2001. Litterfall, litter decomposition and nutrient release in five exotic plant species planted on coal mine spoils. Pedobiologia, 45, Issue 4: 298-312.

ECCM., 2002. Climate change, carbon and forests: Some general guidelines for credible carbon offset projects, ECCM technical document no 6. The Edinburgh Centre for Carbon Management, Pages 9.

Echeverria, C., Coomes, D., Salas, J., Rey-Benayas, J.M., Lara, A. and Newton, A. 2006. Rapid deforestation and fragmentation of Chilean temperate forests. Biological Conservation, 130: 481-494.

Ehrlich, P.R. and Pringle, R.M., 2008. Where does biodiversity go from here? A grim business-as-usual forecast and a hopeful portfolio of partial solutions. Proceedings of the National Academy of Science of the United States of America, 105 (1): 11579-11586.

Ehrlich, P.R., Ehrlich, A.H., 1981. Extinction: the Causes and Consequences of the Disappearance of Species. Ballantine Books, New York.

Elliot, D., 2007. Nuclear or not? Does nuclear power have a place in sustainable energy future? Palgrave Macmillan, Basingstoke.

Ellison, A. M. and Farnsworth, E. J., 2000. Mangrove communities. In: Bertness, M. D., Graines, S. D and Hay, M. E., (eds). Marine communityecology. Sinauer Associates, Sunderland.

Ellison, J. C., 1989. Pollen analysis of mangrove sediments as a sea level indicator: Assessment from Tongatapu, Tonga. Palaeogeography, Palaeoecology and Palaeoclimatology, 74: 327-341.

Emadi, M. M., Baghernejad, G. and Emadi, M., 2008. Effect of shifting cultivation on distribution of nutrient elements and carbohydrates within water-stable aggregates in Northern Iran. Pak. J. Biol. Sci., 11: 195-201.

Environmental Justice Foundation, 2006. Mangroves: Nature's defence against Tsunamis- A report on the impact of mangrove loss and shrimp farm development on coastal defences. Environmental Justice Foundation, London, UK.

Estrada, A., R. Coates-Estrada, and Meritt, D. Jr., 1997. Anthropogenic landscape changes and avian diversity at Los Tuxtlas, Mexico. Biodiversity and Conservation, 6: 19-43.

Etterson, M. A., Niemi, G. J. and Danz, N. P., 2009. Estimating the effects of detection heterogeneity and overdispersion on trends estimated from avian point counts. Ecological Applications, 19: 2049-2066.

Falloon, P., Jones, C. D., Cerri, C. E., Al-Adamat, R., Kamoni, P., Bhattacharyya, T., Easter, M., Paustian, K., Killian, K., Coleman, K. and Milne, E., 2007. Climate change and its impact on soil and vegetation carbonstorage in Kenya, Jordan, India and Brazil. Agriculture, Ecosystems and Environment, 122: 114-124.

Fang, J. Y., Chen, A. P., Peng, C. H., Zhao, S. Q., and Ci, I. J., 2001. Changes in forest biomass carbon storage in China between 1949 and 1998. Science, 292: 2320-2322.

FAO, 2001. Soil carbon sequestration, world soil resources reports, Paris, France.

FAO, 2011. State of the world's forests 2011. Rome, Italy. (Available online at http://www.fao.org/docrep/013/i2000e/i2000e00.htm)

Farquharson R. J., Schwenke G. D. and Mullen J. D., 2003. Should we manage soil organic carbon in Vertosols in the northern grains region of Australia? Australian Journal of Experimental Agriculture, 43: 261-270.

Fassbender, H.W., Beer, J., Henveldop, J., Imbach, A., Enriquez, G., Bonnemann, A., 1991. Ten-year balance of organic matter and nutrients in agro-forestry systems at CATIE Costa Rica. Forest Ecology and Management, 45: 173-183.

Fearnside, P. M., 2004. Are climate change impacts already affecting tropical forest biomass? Global Environmental Change, 14: 299-302.

Feng, S., Hu, Q. and Qian, W., 2004. Quality control of daily meteorological data in China, 1951-2000: A new dataset. International Journal of Climatology, 24: 853-870.

Fergusan, C. D., 2007. Nuclear Energy: Balancing benefits and risk. Council of Foreign Relation, CRS No. 28.

Fernandes, E. C. M. and Nair, P. K. R., 1986. An evaluation of the structure and function of tropical homegardens. Agricural Systems, 21: 279-310.

Field, C., Behrenfeld, M., Randerson, J. And Falkoski, P., 1998. Primary production of the biosphere: integrating terrestrial and oceanic components. Science, 281: 237-240.

Fisher, R. A., Corbet, A. S. and Williams C. B. 1943. The relation between the number of species and the number of individuals in a random sample of an animal population. Journal of Animal Ecology, 12: 42-58.

Fjeldsa, J., 1999. The impact of human forest disturbance on the endemic avifauna of the Udzungwa Mountains, Tanzania. Bird Conservation International, 9: 47-62.

FOI, 2005. Flowers of India. Website http://www.flowersofindia.in/

Frank, B., 2005. Invited perspective: Impact of global change on plant diversity and vice versa: Old and new challenges for vegetation scientist. Journal of Vegetation Science, 16: 613-616.

Frank, E and Habel, J. C., 2011. Biodiversity hotspots: Distribution and protection of conservation priority areas. Springer - Verlag Berlin, Heidelberg. Pages 546. DOI 10.1007/978-3-642-20992-5.

Fraterrigo, J. M., Turner, M. G., Pearson, S. M. and Dixon, P., 2005. Effects of past land-use on spatial heterogeneity of soil nutrients in southern Appalachian forests ecological monographs. The Ecological Society of America, 75: 215-230.

FSI, 2009. India State of Forest Report, Forest Survey of India, Ministry of Environment and Forest, Dehradun, India. The complete India State of Forest Report, 2009 is also available to download online at http://www.fsi.nic.in/sfr_2009.htm

Fuller, G. D., 1935. The Life Forms of Plants and Statistical Plant Geography: Being the Collected Papers of Raunkiaer. Ecology, 16 (1): 111-113.

Fuller, R.J. and Langslow, D. R. 1984. Estimating numbers of birds by point counts: how long should counts last? Bird Study, 31: 195-202.

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

Gajaseni, J. and Gajaseni, N., 1999. Ecological rationalities of the traditional homegarden system in the Chao Phraya Basin, Thailand. Agroforestry Systems, 46: 3-23.

Galford, G. L., Melillo, J. M., Kicklighter, D. W., Cronin, T. W., Cerri, C. E. P., Mustard, J. F. and Cerri, C. C., 2010. Greenhouse gas emissions from alternative futures of deforestation and agricultural management in the southern Amazon. PNAS, 107 (46): 19649-19654.

Ganesh, T., Ganesan, R., Soubadradevy, M., Davidar, P. and Bawa, K. S., 1996. Assessment of plant biodiversity at a mid-elevation evergreen forest of Kalakad-Mudanthurai Tiger reserve, Western Ghats, India. Current Science, 71: 379-92.

Gaonkar, H. (1996) Butterflies of the Western Ghats, Including Sri Lanka: A biodiversity assessment of at threatened mountain system. Centre for Ecological Sciences, Bangalore India; 86p.

Gardner, T. A., Barlow, J., Chazdon, R. L., Ewers, R., Harvey, C. A., Peres, C. A. and Sodhi, N., 2009. Prospects for tropical forest biodiversity in a human-modified world. Ecology Letters, 12: 561-582.

Gaston K. J., 2000. Global patterns in biodiversity. Nature, 405 (6783): 220-226.

Gaston, A. J., 1973. Methods for estimating bird populations. Journal of Bombay Natural History Society, 72: 271-283.

Ge, X. J., Zang, L. B., Yuan, Y. M., Hao, G. and Chiang, T. Y., 2005. Strong genetic differentiation of the East-Himalayan Megacodon stylophorus (Gentianaceae) detected by Inter-Simple Sequence Repeats (ISSR). Biodiversity and Conservation, 14 (4): 849-861

Geissen, V., Sánchez-Hernández, R., Kampichler, C., Ramos-Reyes, R., Sepulveda-Lozada, A., Ochoa-Goana, S., Jong, B. H. J. de., Huerta-Lwanga a, E. and Hernández-Daumas, S., 2009. Effects of land-use change on some properties of tropical soils. An example from Southeast Mexico. Geoderma, 151: 87-97.

Ghate, U., Joshi, N. V. and Gadgil, M., 1998. On the patterns of tree diversity in the Western Ghats of India. Current Science, 75: 594-603.

Gibbons, D. W. and Gregory, R. D., 2006. Birds. Pages: 308-350. In Sutherland, W. J., edition. Ecological census techniques – a handbook. 2nd edition. Cambridge, UK: Cambridge University Press.

Gibson, L., Lee, T. M., Koh, L. P., Brook, B. W., Gardner, T A.,, Barlow, J., Carlos, A., Peres, Corey, J. A., Bradshaw, Laurance, W. F., Lovejoy, T. E. and Sodhi, N. S., 2011. Primary forests are irreplaceable for sustaining tropical biodiversity. Nature, 478: 378-381.

Gimaret-Carpentier, J., Pélissier, R., Pascal, J.-P. *and* Houllier, F., 1998. Sampling strategies for the assessment of tree species diversity. Journal of Vegetation Science, 9*:* 161-172*.*

Giriraj, A., Murthy,M. S. R., Ramesh, B. R. and Dutt, C. B. B., 2009. A method of assessing evergreen habitats using phytodiversity and geospatial techniques in tropical rain forest of Sothern Western Ghats (India). Ecological Research, 24: 749-760.

Gleason, H. A., 1929. The significance of Raunkiaer's law of frequency. Ecology, 10: 406-408

Gliman, E. L., Ellison, J., Duke, N. C and Field, C., 2008. Threats to mangroves from climate change and adaptation options: A review. Aquatic Botany, 89 (2): 237-250.

Global Biodiversity Information Facility. 2010. Class: Aves. GBIF Data Portal, GBIF Open Geospatial Consortium services. Available online at www.gbif.org

Gol, C., 2009. The effects of land use change on soil properties and organic carbon at Dagdami river catchment in Turkey. Journal of Environmental Biology, 30(5): 825-830.

Gomez-Pompa, A., 1996. Three levels of conservation by local people. Pages 347-356 in E Di Castri and T. Youn~s, eds., Biodiversity, science and development: Towards a new partnership. CAB International, Wallingford, UK.

Gopal, B. and Chauhan, M., 2006. Biodiversity and its conservation in Sundarban mangrove forest ecosystem. Aquatic Science, 68: 338-354.

Gotelli, N. J. and Entsminger, G.L., 2011. EcoSim: Null models software for ecology. Version 7. Acquired Intelligence Inc. and Kesey-Bear. Jericho, VT 05465. http://garyentsminger.com/ecosim/index.htm

Gotelli, N. J., and Colwell, R. K., 2001. Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. Ecology Letters 4: 379-391.

Goto, N., Sakoda, A. and Suzuki, M., 1994. Modelling of soil carbon dynamics as a part of carbon cycle in terrestrial ecosystems. Ecological Modelling, 74: 183-204

Gould, W. A., González, G. and Carrero-Rivera, G., 2006. Structure and composition of vegetation along an elevational gradient in Puerto Rico. Journal of Vegetation science, 17:653-664.

Gourbiere, F. and Debouzie, D., 1995. Spatial distribution and estimation of forest floor components in a 37-year-old casuarina equisetifolia (forst.) plantation in coastal Senegal. Soil Biology and Biochemistry, 27 (3): 297-304.

Grace, P. R., Ladd, J. N. Skjemstad, J. O., 1994. The effect of management practices on soil organic matter dynamics. In: Pankhurst, C. E., Dube, B. M., Gupta, V. V. S. R. and Grace, P. R., (Eds) Soil Biota-management in sustainable farming systems. CSIRO Australia, pages: 163-171.

Greenberg, R. S., Marra, P. P., 2005. Birds of Two Worlds: The Ecology and Evolution of Migration. John Hopkins University Press, Baltimore.

Greenberg, R., Bichier, P. and Sterling, J., 1997_b. Bird populations in rustic and planted shade coffee plantations of Eastern Chiapas, Mexico. Biotropica, 29: 501-514.

Greenberg, R., Bichier, P., Angon, A. C. and Reitsma, R., 1997_a. Bird populations in shade and sun coffee plantations in Central Guatemala. Conservation Biology, 11:448-459.

Greer, A., Victoria N. and Fisman, D., 2008. Climate change and infectious diseases in North America: the road ahead. Canadian Medical Association, 178 (6) doi: 10.1503/cmaj.081325.

Gregorich, E. G., Drury, C. F. and Baldock, J. A. 2001. Changes in soil carbon under long-term maize in monoculture and legume-based rotation. Canadian Journal of Soil Science, 81: 21-31.

Gregory, R. D. and A. van Strien. 2010. Wild bird indicators: using composite population trends of birds as measures of environmental health. Ornithological Science, 9: 3-22.

Grimett, R., Inskipp, C. and Inskipp, T., 1999. Birds of the Indian subcontinent. Delhi: Oxford University Press.

Grimett, R., Inskipp, T. and Allen, R., 2005. Birds of South India. New Delhi.

Grimm, N. B., Faeth, S. H., Golubiewski, N. E., Redman, C. L., Wu, J. G., Bai, X. M. and Briggs, J. M. 2008. Global change and the ecology of cities. Science, 319: 756-760.

Grover, R. B. and Chandra, S., 2006. Scenario for growth of electricity in India. Energy Policy, 34: 2834-2847.

Guan, D., Wu, J., Zhao, X., Han, S., Yu, G., Sun, X and Jin, G. 2006. CO2 fluxes over an old, temperate mixed forest in northeastern China. Agricultural and Forest Meteorology, 137: 138-149.

Gujar, A. R., Ambre, N. V., Mislankar, P. G. and Iyer S. D. 2010. Ilmenite, Magnetite and Chromite Beach Placers from South Maharashtra, Central West Coast of India. Resource Geology, 60 (1): 71-86.

Gujar, A. R., Anguswamy, N. and Rajamanickam, G. V., 2009. Provenance Signature of Pre-Cambrian and Mesozoic Rocks in the Nearshore Placers of Konkan, Central West Coast of India. Marine Georesources and Geotechnology, 27 (2): 115-131.

Gujar, A. R., B. Nagendranath, and R. Banerjee. 1988. Marine minerals: The Indian perspective. Mar. Min. 7:317-350.

Gujar, A. R., P. G. Mislankar, and N. V. Ambre. 2004. Coastal placers of Konkan Maharashtra, their distribution, mineralogy and geomorphic environment of formation. Indian Journal of Geomorphology, 9:123-130.

Gullison, R. E., Frumhoff, P. C., Canadell, J. C., Field, C. B., Nepstad, D. C., Hayhoe, K., Avissar, R., Curran, L. M., Friedlingstein, P., Jones, C. D. and Nobre, C., 2007. Tropical forests and climate policy. Science 316: 985-986.

Gunawardene, N. R., Dulip Daniels, A. E., Gunatilleke, I. A. U. N., Gunatilleke, C. V. S., Karunakaran, P. V., Geetha Nayak, K., Prasad, S., Puyravaud, P., Ramesh, B. R., Subramanian, K. A., Vasanthy, G., 2007. A brief overview of the Western Ghats-Sri Lanka biodiversity hotspot. Current Science, 93, 1567-1572.

Guo, L. B. and Gifford, R. M., 2002. Soil carbon stocks and land-use: a meta analysis. Global change Biology, 8: 345-360.

Gupta, M. B., Vijayan, L., Sandaliyan, S. and Sridharan, N. 2011. Status of Wetlands and Wetland Birds in Coimbatore, Trichy, Perambalore and Thiruvarur Districts in Tamil Nadu, India. World Journal of Zoology, 6 (2): 154-158.

Gupta, O. P. and Shukla, R. P., 1991. The composition and dynamics of associated plant communities of sal plantations. Tropical Ecology, 32: 296-309.

Gutzwiller, K. J. and Barrow, W. C., 2002. Does Bird Community Structure Vary with Landscape Patchiness? A Chihuahuan Desert perspective. Oikos, 98 (2): 284-298.

Hacisalihoglu, S., 2007. Determination of soil erosion in a steep hill slope with different land-use types: A case study in Mertsdorf. Journal of Environ. Biology, 28: 433-438.

Haile, S. G., Nair, P. K. R., Nair, V. D., 2008. Carbon storage of different soil-size fractions in Florida silvopastoral systems. Journal of Environmental Quality, 37: 1789-1797.

Hanson, T., Brooks, T.M., DaFonesca, G. A. B., Hoffmann, M., Lamoreux, J. F., Machlis, G., Mittermeier, C. G., Mittermeier, R. A. and Pilgrim, J. D., 2008. Essya: Warfare in Biodiversity Hotspots, Conservation biology, 23 (3): 578-587.

Hare, M. A., Lantagne, D. O., Murphy, P. G., Chero, H., 1997. Structure and tree species composition in a subtropical dry forest in Dominican Republic: comparison with a dry forest in Puerto Rico. Tropical Ecology, 38: 1-17.

Harisha, M. N. and Hosetti, B. B., 2009. Diversity and distribution of avifauna of Lakkavalli range forest, Bhadra wildlife sanctuary, Western Ghats, India. Ecoprint, 16: 21-27.

Harris, F., 2004. Conserving biodiversity resources. In: Harris, F. (Ed.), Global Environmental Issues. Wiley, Chichester. Pp. 95-113.

Hartshorn, G. S., 2001. Tropical forest ecosystems. Pages 701–710 in S. Levin, editor. Encyclopedia of biodiversity. Academic Press, New York.

Haynes, R. J., 2000. Interactions between soil organic matter status, cropping history, method of quantification and sample pre treatment and their effects on measured aggregate stability. Biology and Fertility of Soils, 30: 270-275.

Herrera, C. M., 1981. Organización temporal en las comunidades de aves. Doñana, Acta Vertebrata, 8:79-101.

Herzog, S. K., Kessler, M., and Cahill, T. M., 2002. Estimating species richness of tropical bird communities from rapid assessment data. Auk, 119: 749-769.

Heywood, V.H., 1995. Global Biodiversity Assessment. Cambridge University Press, Cambridge, UK.

Hill, M., Eames, J.C., Trai, L.T. and Cu, N., 2001. Population sizes, status and habitat associations of forest birds in Chu Yang Sin Nature Reserve, Dak Lak Province, Vietnam. Bird Conservation International, 11: 49-70.

Hinrichs, S., Nordhaus, I. and Geist, S. J., 2009. Status, diversity and distribution patterns of mangrove vegetation in the Segara Anakan lagoon, Java, Indonesia. Reginol Environtal Change, 9: 275-289

Hobley, E. and Willgoose, G., 2010. Measuring soil organic carbon stocks - issues and considerations. Symposium 1.5.1. Quantitative monitoring of soil change. 62-65. 19th WCSS, Brisbane, Australia, Published on DVD.

Hogarth, P. J., 1999. The biology of mangroves. Oxford University Press, Oxford

Hollis, J. M., Hannam, J. and Bellamy, P. H., 2012. Empirically-derived pedotransfer functions for predicting bulk density in European soils. European Journal of Soil Science, 63, Issue 1: 96-109.

Holmes, R. T. and Sherry T. W., 2001. Thirty-year bird population trends in an unfragmented temperate deciduous forest: importance of habitat change. Auk, 118: 589-609.

Holmes, R. T., Sherry, T. W., and Sturges, F. W., 1986. Bird community dynamics in a temperate deciduous forest: Long-term trends at Hubbard Brook. Ecological Monographs, 56: 201-220.

Houghton, R. A., 2003. Revised estimates of the annual net flux of the carbon to the atmosphere from the changes in land use and land management. Tellus Series B: Chemical and Physical Meteorology, 55: 38-390.

Houghton, R.A., Hackler, J.L. and Lawrence, K.T., 1999. The U.S. carbon budget: contribution from land use change. Science, 285: 574-578.

Howard, D. M., Howard, P. J. A. and Howard, D. C., 1995. A Markov Model Projection of Soil Organic Carbon Stores Following Land Use Changes. Journal of Environmental Management, 45: 287-302.

Howard, P. J. A., 1965. The carbon organic matter factor in various soil types. Oikos, 15: 229-236.

Hubbell, S. P., and Foster, R. B., 1992. Short-term dynamics of a Neotropical forest: Why ecological research matters to tropical conservation and management. Oikos, 63: 48-61.

Hughes, J. B., Daily, G. C. and Ehrlich. P. R., 2002. Conservation of tropical forest birds in countryside habitats. Ecology Letters, 5: 21-129.

Hunter, M. L., 1996. Fundamentals of Conservation Biology. Blackwell Science, Inc., Cambridge, MA 482p

Huston, M. A., 1994. Biological Diversity. Cambridge University Press, Cambridge, United Kingdom.

Huston, M.A., 1980. Soil nutrients and tree species richness in Costa Rican forest. Journal of Biogeography, 7: 147-157.

IEA, 2008. World energy outlook. International Energy Agency. Paris.

IEA., 2007. World energy outlook 2007. Paris: IEA/OECD

Ingalhalikar, S., 2001. Flowers of Sahyadri. Field guide to 500 flowers of north Western Ghats of India. Corolla Publications, Pune, India. Pages 210.

Ingalhalikar, S., 2007. Flowers of Sahyadri. Field guide to additional 1200 flowers of North Western Ghats of India, Corolla Publications, Pune, India. Pages 315.

International Commission on Radiation Units and Measurements, 2006. General sampling concepts and principles. Journal of the ICRU, Vol 6 (1): 25-34 Report 75, Oxford University Press, doi:10.1093/jicru/ndl008

IPCC, 2001. Climate Change 2001: The Scientific Basis. Summary for Policy Makers. IPCC, Cambridge University Press, Cambridge, UK, Pages: 1-21.

IPCC, 2007. Climate change 2007: the physical science basis. In: Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B., Tignor, M and Miller, H. L., eds Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom and New York: Cambridge University Press; 996.

IUCN 2011_a. IUCN Red List of Threatened Species. Version 2011.2. http://www.iucnredlist.org Downloaded on 14 November 2011.

IUCN, 2001. Iucn red list categories and Criteria: Version 3.1. Gland, Switzerland and Cambridge, UK: IUCN Species Survival Commission.

IUCN, 2010. New study shows over one fifth of the world's plants are under threat of extinction. IUCN News Release, 29 September 2010. Available online at http://www.iucnredlist.org/news/srli-plants-press-release

IUCN, 2011_b. The big plan, Ocean futures, curbing wildlife trade, Love not loss. World conservation, the magazine of the international union for conservation of nature, 41 (1): 28.

Jagtap, T. G. and Nagle, V. L., 2007. Response and Adaptability of Mangrove Habitats from the Indian Subcontinent to Changing Climate. AMBIO: A Journal of the Human Environment, 36(4): 328-334.

Jagtap, T. G., 1994. In Biodiversity in the Western Ghats: An Information Kit, World Wide Fund, India and International Institute of Rural Reconstruction, Goa, 1994, pp. 3–6.

Jagtap, T. G., Naik, S. and Nagle, V. L., 2001. Assessment of Coastal Wetland Resources of Central West Coast, India, Using LANDSAT Data. Journal of the Indian Society of Remote Sensing, 29 (3): 143-150.

Jain, S.K., 2004. Nuclear Power in India: The Fourth Revolution. An International Journal of Nuclear Power, 18 (2-3): 13-20.

Jathar, G. A. and Rahmani, A. R. 2006. Endemic birds of India. BUCEROS, ENVIS Newsletter: Avian Ecology and Inland Wetlands, BNHS, Volume.11. No.2 and 3.

Javed, S. and Kaul, R., Field methods for bird surveys, Bombay Natural History Society, Department of Wildlife Science, Aligarh Muslim University, Indian Bird Conservation Network, World Pheasant Association, 2000.

Jayapal, R., Qureshi, Q., and Chellam, R., 2009. Importance of forest structure versus floristics to composition of avian assemblages in tropical deciduous forests of Central Highlands, India. Forest Ecology and Management, 257: 2287-2295.

Jenkinson, D. S., Adams, D. E. and Wild, A., 1991. Model estimates of CO_2emissions from soil in response to global warming. Nature, 351: 304-306.

Jenny, H. and Raichaudhari, S. P., 1960. Effect of climate and cultivation on Nitrogen and orgamic matter reserves in Indian soils, ICAR, New Delhi, pages-127.

Jerdon, T.C., 1862–1864. The Birds of India. Calcutta. (2 Vols).

Jha, M. N., Pande, P., and Pathak, T. C., 1979. 'Studies on the Changes in the Physico-Chemical Properties of Tripura Soils as a Result of Jhuming. Indian Forester, 105: 436-443.

Jobbagy, E. G. and Jackson, R. B., 2000. The vertical distribution of soil organic carbon and its relation to climate and vegetation. Ecological Applications, 10: 423-436.

John, J. and Nair, M. A., 1999. Socio-economic characteristics of homestead farming in south Kerala. J. Tropical Agriculture, 37: 107-109.

Johnsingh, A. J. T., Martin, N. H., Balasingh, J. and Chelladurai, V., 1987. Vegetation and avifauna in a thorn scrub habitat in south India. Tropical Ecology, 28: 22-34

Johnson, A.W., 1972. Individuality and experimentation in traditional agriculture. Human Ecology, 1 (2): 149-160.

Johnson, C. E., Driscoll, C. T., Fahey, T. J., Siccama, T. G. and Hughes, J. W., 1995. Carbon dynamics following clear cutting of a northern hardwood forest. In Kelly, J. M. and McFee, W. W., (Eds.), Carbon Forms and Functions in Forest Soils, SSSA, Madison, WI, pp. 463–488.

Johnson, D. W., 1992. Effects of forest management on soil carbon storage. Water, Air and Soil Pollution, 64: 83-12.

Johnston, C. A., Groffman, P. and Breshears, D. D., 2004. Carbon cyclingin soil. Frontiers in Ecology and the Environment, 2: 522-528.

Jones, C., Cox, P. and Huntingford, C., 2003. Uncertainty in climate-carbon cycle projections associated with the sensitivity of soil respiration to temperature. Tellus, 55 B: 642-648.

Jones, C., Mcconnellw, C., Colemanz, K., Cox, P., Falloonz, P., Jenkinsonz, D. and Powlson, D., 2005. Global climate change and soil carbon stocks; predictions from two contrasting models for the turnover of organic carbon in soil. Global Change Biology, 11: 154-166.

Jose, A. I. and Koshy, M. M., 1972. A study of the morphological, physical and chemical characteristics of soils as influenced by teak vegetation. Indian Forester, 98: 338-345.

Jose, D. and Shanmugaratnam, N., 1993. Traditional homegardens of Kerala: A sustainable human ecosystem. Agroforestry Systems, 24, 203-213.

Joshi, H. and Ghose, M., 2003. Forest structure and species distribution along soil salinity and pH gradient in mangrove swamps of the Sundarbans. Trop. Ecol., 44(2): 197-206.

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

Joshua, J. and Johnsingh A. J. T., 1994. Impact of biotic disturbances on the habitat and population of the endangered grizzled giant squirrel Ratufa macroura in south India. Biological Conservation, 68, (1): 29-34.

Joshua, J. and Johnsingh, A. J. T., 1988. Observations on birds on Mundanthurai Plateau, Tamil Nadu. Journal of the Bombay Natural History Society, 85: 565-577.

Kadavul, K., 1999. Plant biodiversity and conservation of tropical semi-evergreen forest in the Shervarayan hills of Eastern Ghats, India. Biodiversity and Conservation, 8: 421-439.

Kale, M. P., Ravan, S. A., Roy, P. S. and Singh, S., 2009. Patterns of Carbon Sequestration in Forests of Western Ghats andStudy of Applicability of Remote Sensing in Generating CarbonCredits through Afforestation/Reforestation. Journal of Indian Society Remote Sensing, 37: 457-471.

Kamoni, P. T., Gicheru, P. T., Wokabi, S. M., Easter, M., Milne, E., Coleman, K., Falloon, P., Paustian, K., Killian, K and Kihanda, F. M., 2007. Evaluation of two soil carbon models using two Kenyan long-term experimental datasets. Agriculture, Ecosystems and Environment, 122: 95-104.

Kappelle, M., Van Vuuren, M.M.I. and Baas, P., 1999. Effects of climate change on biodiversity: a review and identification of key research issues. Biodiversity and Conservation, **8**: 1383-1397.

Karr, J. R. 1976. Within and between habitat avian diversity in African and Neotropical lowland habitats. Ecological Monographs, 46: 457-481.

Karthikeyan, S., 1983. Endemic grasses of India with anemphasis on rare, indeterminate and extinct species. Anassessment of threatened Plants of India (ed. by Jain, S. K. and Rao, R. R.), pp. 240. Botanical Survey of India, Coimbatore

Karthikeyan, S., 1996. Northern Western Ghats and North west Coast: In Hajra P.K. et al (Eds.) Flora of India Introductory Volume Part I. Botanical Survey of India, Kolkota. Pp. 375-390.

Kathiresan, K. and Bingham, B. L., 2001. Biology of mangroves and mangrove ecosystems. Advances in Marine Biology, 40: 81-251.

Kathiresan, K., 2000. A review of studies on Pichavaram mangrove, southeast India. Hydrobiologia, 430: 185-205.

Katti, M. V., 1989. Bird communities of Lower Dachigam Valley, Kashmir. MSc. (Wildlife Science) dissertation, Saurashtra University, Rajkot.

Kaul, M., Mohren, G. M. J. and Dadhwal, V. K., 2010. Carbon storage and sequestration potential of selected tree species in India. Mitig Adapt Strateg Glob Change, 15:489-510.

Keenlyside, N. S. and Ba, J., 2010. Prospects for decadal climate prediction. Wiley Interdisciplinary Reviews: Climate Change, 1 (5): 627-635.

Kehlenbeck, K. and Maass, B. L., 2006. Are tropical homegardens sustainable? some evidence from Central Sulawesi, Indonesia. In: Kumar BM, Nair PKR (eds) Tropical homegardens: a time-tested example of sustainable agroforestry. Advances in agroforestry, 3: 339-354

Kehlenbeck, K., Arifin, H. S. and Maass B. L., 2007. Plant diversity in homegardens in a socio-economic and agro-ecological context. In: Tscharntke T, Leuschner C, Zeller M, Guhardja E, Bidin A (eds) The stability of tropical rainforest margins: linking ecological, economic and social constraints of land use and conservation. Springer, Berlin, pp 297-319

Kenoyer, L. A., 1927. A study of Raunkiaer's law of frequency. Ecology, 8: 341-349.

Kepler, C. B., and Scott, J. M., 1981. Reducing bird count variability by training observers. Studies in Avian Biology 6: 366-371.

Kershaw, K.A., 1973. Quantitative and Dynamic Plant Ecology (second Edition), ELBSD and Edward Arnold, London.

Kew Royal Botanic Gardens, 2010. News, New study shows one fifth of the world’s plants are under threat of extinction, Dated 29 September 2010. Available online at: http://www.kew.org/science-conservation/search-rescue/mapping-plants/plants-at-risk/index.htm.

Khanna, P. K., Ludwig, B., Bauhus, J. and O’Hara, C., 2001. Khanna, P.K., Ludwig, B., Bauhus, J., O’Hara, C., 2001. Assessment and significance of labile organic C pools in forest soils. In: Lal, R., Kimble, J.M., Follett, R.F., Stewart, B.A. (Eds.), Assessment Methods for Soil Carbon. CRC/Lewis Publishers, Boca Raton, Florida, USA, pp. 167-182

Kharkwal, G. Rawat, Y. S., 2010. Structure and composition of vegetation in subtropical forest of Kumaun Himalaya. African Journal of Plant Science, 4 (4): 116-121.

Kharkwal, G., 2008. Distribution of Indian flora. Oaks, 4: 6.

Khoshoo, T. N. (1994) India's biodiversity: Tasks ahead. Current Science, 67 (8): 577-582.

Khumbongmayum, A. D., Khan, M., and Tripathi, R. S., 2006. Biodiversity conservation in sacred groves of Manipur, Northeast India: population structure and regeneration status of woody species. Biodiversity Conservation, 15: 2439-2456.

Kindt, R. and Coe, R. 2005. Tree diversity analysis. A manual and software for common statistical methods for ecological and biodiversity studies. Nairobi: World Agroforestry Centre (ICRAF).

King, D., 2004. Climate change science: adapt. Mitigate, or ignore? Science, 303: 176-177

Kirschbaum, M. U. F., 1995. The temperature dependence of soil organic matter decomposition and the effect of global warming on soil organic carbon storage. Soil Biology Biochemistry, 27: 753-760.

Kissling, M. L. and Garton, E. O., 2006. Estimating detection probability and density from point-count surveys: A combination of distance and double-observer sampling. Auk , 123: 735-752.

Koellner, T., Hersperger, A. M. and Wohlgemuth, T., 2004. Rarefaction method for assessing plant species diversity on a regional scale. Ecography, 27: 532-544.

Koellner, T., Sell, J. and Navarro, G., 2010. Why and how much are firms willing to invest ecosystem services from tropical forest? A comparison of international and Costa Rican firms. Ecological Economics, 69: 2127-2139

Kofron, C. P. and Chapman, A., 1995. Deforestation and bird species composition in Liberia, West Africa. Tropical Zoology, 8: 239-256.

Koley, J., Harikumar, S., Ashraf, S. A. H., Chande, S. K. and Sharma, S. K., 2006. Regulatory practices for nuclear power Plants in India. Nuclear Engineering and Design, 236: 894-913.

Komiyama, A., Eong, O. J. and Poungparn, S., 2008. Allometry, biomass, and productivity of mangrove forest: A review. Aquatic Botany, 89 (2): 128-137.

Konare, H., Yost, R. S., Doumbia1, M., McCarty, G. W., Jarju, A. and Kablan, R., 2010. Loss on ignition: Measuring soil organic carbon in soils of the Sahel, West Africa. African Journal of Agricultural Research, 5 (22): 3088-3095.

Konen, M. E., Jacobs, P. M., Burras, C. L., Talaga, B. J. and Mason, J. A., 2002. Equations for predicting soil organic carbon using loss-on-ignition for north central U.S. soils. Soil Science Society America Journal, 66:1878-1881.

Krebs, C. J., 1994. Ecology: The experimental analysis of distribution and abundance. Harper Collins, New York,

Krebs, C. J., 1999. Ecological methodology. Addison Wesley Longman, New York, pp. 1-496.

Krishna, N., 2008-2009. Wildlife in India. Econews, Volume 14 (3 and 4): 5-8.

Krishnan K. S. and Roy B. C., 1945. Titanium. Record. Geological survey of India, 76: 1-32.

Krishnan, R., Davider, P., 1996. The Shrubs of the Western Ghats (South India): Floristics and Status, Journal of Biogeography, 23 (6): 783-789.

Krishnaswamy, J. and Richter, D., 2002. Properties of advanced weathering-stage soils in tropical forests and pastures. Soil Science Society of America Journal, 66: 244-253.

Krishnaswamy, J., Bawa, K. S., Ganeshaiah, K. N. and Kiran, M. C., 2009. Quantifying and mapping biodiversity and ecosystem services: Utility of a multi-season NDVI based Mahalanobis distance surrogate. Remote Sensing of Environment, 113: 857-867.

Kumar, A., Walker, S., Molur, S. (2000): Prioritisation of endangered species. In: Singh, S., Sastry, A. R. K., Mehta, R., Uppal, V. (eds.) Setting biodiversity priorities for India. World Wide Fund for Nature, India, New Delhi. pp. 341-386.

Kumar, B. M. and Jose, K. D., 1992. Litter production and decomposition dynamics in moist decidous forest of the Western Ghats in Peninsular India. Forest Ecology and Management, 181-201.

Kumar, B. M. and Nair, P. K. R., 2004. The enigma of tropical homegardens. Agroforestry Systems, 2004, 61: 135-152.

Kumar, B. M. and Nair, P. K. R., 2006. Tropical Homegardens: A Time-Tested Example of Sustainable Agroforestry: 339-354.

Kumar, B. M., 2011. Species richness and above ground carbon stocks in the homegardens of central Kerala, India. Agriculture, Ecosystems and Environment, Accessed online doi:10.1016/j.agee.2011.01.006.

Kumar, B. M., George, S. J. and Chinnamani, S., 1994. Diversity, structure and standing stock of wood in the homegardens of Kerala in Peninsular India. Agroforestry Systems, 25: 243-262.

Kumar, B., 2009. A case study: Conservation Strategy of Biodiversity in Konkan Region of Coastal Maharashtra, India. New York Science Journal, 2 (4): 31-32.

Lal, M. and Singh, R., 2000. Carbon sequestration potential of Indian forests. Environment Monitoring and Assessment, 60: 315-327.

Lal, R., 2002. Soil carbon dynamics in cropland and rangeland. Environmental Pollution, 116: 353-362.

Lal, R., 2004. Agricultural activities and the global carbon cycle. Nutrient cycling in Agroecosystems, 70: 103-116.

Lal, R., 2005. Forest soils and carbon sequestration. Forest Ecology and Management, 220: 242-258.

Lamb, D., Erskine, P.D. and Parrotta, J.A., 2005. Restoration of degraded tropical forest landscapes. Science, 310: 1628-1632.

Lambert, F. R., 1993. Trade, status and management of three parrots in the north Moluccas, Indonesia: White Cockatoo Cacatua alba, Chattering Lory Lorius garrulus and Violet-eared Lory Eos squamata. Bird Conservation International, 3: 145-168.

Lambin, E. F, Turner, B. L., Geist, H. J., Agbola,S. B., Angelsen, A., Bruce, J. W., Coomes, O. T., Dirzo, R., Fischer, G., Folke, C., George, P. S., Homewood, K., Imbernon, J., Leemans, R., Li, X., Moran, E. F., Mortimore, M., Ramakrishnan, P. S., Richards, J. F., Skanes, H., Steffen, W., Stone, G. D., Svedin, U., Veldkamp, T. A., Vogel,C. and Xu, J., 2001. The causes of land-use and land-cover change: moving beyond the myths. Global Environmental Change, 11: 261-269.

Lambin, E. F., Baulies, X., Bockstael, N., Fischer, G., Krug, T., Leemans, R., Moran, E. F., Rindfuss, R. R., Stao, Y., Skole, D., Turner, B. L. II and Vogel, C., 1999. Land use and land use cover change (LUCC): Implementation strategy. IGBP Report No. 48, IGBP Report No.10, Stockholm, Bonn.

Lambin, E. F., Geist, H. J. and Lepers, E., 2003. Dynamics of land-use and land-cover change in tropical regions. Annual Review Environmental Resources, 28: 205-241.

Laurance, W. F., Laurance, S. G., Ferreira, L. V., Rankin-de Merona, J. M., Gascon, C. and Lovejoy, T. E., 1997. Biomass collapse in Amazonian forest fragments. Science, 278: 1117-1118.

Lavorel, S., Flannigan, M. D., Lambin, E. F., Scholes, M. C., 2007. Vulnerability of land systems to fire: interactions among humans, climate, the atmosphere, and ecosystems. Mitigation and Adaptation Strategies for Global Change, 12 (1): 1381-2386.

Lawton, J. H., et al. 1998. Biodiversity inventories, indicator taxa and effects of habitat modification in tropical forest. Nature, 391: 72-76.

Lee, C. C. and Chiu, Y. B., 2010. Nuclear energy consumption, oil prices, and economic growth: evidences from highly industrialized countries. Energy Economics, doi:10.1016/jeneco2010.07.001.

Lee, D. C. and Marsden, S. J., 2008. Increasing the value of bird-habitat studies in tropical forests: choice of approach and habitat measures. Bird Conservation International, 18: S109-S124.

Lee, D. C. and Marsden, S. J., 2008a. Adjusting count period strategies to improve the accuracy of forest bird abundance estimates from point transect distance sampling surveys. IBIS, The international Journal of Avian Science, 150: 315–325.

Lee, D. W., 1989. Canopy Dynamics and Light Climates in a Tropical Moist Deciduous Forest in India. Journal of Tropical Ecology, 5 (1): 65-79.

Lee, T. J., Lee, K. H. and Oh, K. B., 2007. Strategic environment for nuclear innovation in the next half century. Progress in Nuclear Energy, 49: 397-408.

Lemos, M. C. and Rood, R. B. 2010. Climate projections and their impact on policy and practice. Wiley Interdisciplinary Reviews: Climate Change, 1 (5): 670-682.

Lewis, S. L., 2006. Tropical forests and the changing earth ecosystem. Philosophical Transactions of the Royal Society, 361: 195-210.

Lilliefors, H. W. 1967. On the Kolmogorov-Smirnov tests for normality with mean and variance unknown. Journal of the American Statistical Association, 62: 399-402

Loehle, C., Wigley, T. B., Rutzmoser, S., Gerwin, J. A., Keyser, P. D., Lancia, R. A., Reynolds, C. J., Thill, R. E., Weih, R., White, D. Jr *and* Wood, P. B., 2005. Managed forest landscape structure and avian species richness in the south eastern US. Forest Ecology and Management, 214*:* 279-293*.*

Loiselle, B. A. and Blake, J. G., 1990. Diets of understory fruit-eating birds in Costa Rica: Seasonality and resource abundance. Studies in Avian Biology, 13: 91-103.

Loiselle, B. A. and J. G. Blake. 1992. Population variation in a tropical bird community: Implications for conservation. BioScience, 42: 838-845.

Lopez-Ulloa, M., Veldkamp, E. and de Koning, G. H. J., 2005. Soil carbon stabilization in converted tropical pastures and forests depends on soil type. Soil Science Society of America Journal, 69: 1110-1117.

Losi, C. J., Siccama, T. G., Condit, R. and Morales, J. E., 2003. Analysis of alternative methods for estimating carbon stock in young tropical plantations. Forest Ecology and Management, 184 (1-3): 355-368.

Lu, C. Y., Wong, Y. S., Tom, N. F.Y. and Berry, R., 1998. Vegetation analysis of typical mangrove swamp Lai chi wo coast Hong Kong. Chi. Journal of Oceanology and Limnology, 16 (1): 72-77.

Lunt, H. A., 1931. The carbon organic matter factor in forest soil humus. Soil Science, 22: 27-33.

MacArthur, R. H., 1965. Patterns of species diversity. Biological Review, 40: 510-533.

Macintosh, D. J. and Ashton, E. C., 2002. Review of Mangrove Biodiversity Conservation and Management. Centre for Tropical Ecosystems Research, University of Aarhus, Denmark. Pages viii+ 71.

Magdoff, F. and Weil, R. R., 2004. Soil organic matter management strategies. In: Soil Organic Matter in Sustainable Agriculture (eds. Magdoff, F. and Weil, R.R.,), 45-65. CRC Press, Boca Raton, FL.

Magnussen, S., Péllisier, R., He, F., Ramesh, R. B., 2006. An assessment of sample-based estimators of tree species richness in two wet tropical forest compartments in Panama and India. An International Journal of Forestry, 8: 417-431.

Magrini, K., Evans, C., Hoover, C., Elam, C. and Davis, M., 2002. Use of pyrolysismolecular beam mass spectrometry to characterize forest soil carbon: Method and preliminary results. Environmental Pollution, 116: S255-S268.

Magurran, A. E. and Henderson, 2003. Explaining the excess of rare species in natural species abundance distributions. Nature, 422: 714-716

Magurran, A. E., 1988. Ecological diversity and its measurement. Princeton University Press, Princeton, New Jersey, USA.

Magurran, A. E., 2004. Measuring biological diversity. Blackwell Publishing; Oxford, United Kingdom. p. 256.

Maily, D. and Margolis, H. A., 1992. Forest floor and mineral soil development in *Casuarina equisetifolia* plantations on the coastal sand dunes of Senegal. Forest Ecology and Management, 55: 259-278.

Majaliwa, J. G. M., Twongyirwe, R., Nyenje, R., Oluka, M., Ongom, B., Sirike, J., Mfitumukiza, D., Azanga, E., Natumanya, R., Mwerera, R. and Barasa, B., 2010. The Effect of Land Cover Change on Soil Properties around Kibale National Park in SouthWestern Uganda. Hindawi Publishing Corporation, Applied and Environmental Soil Science, Volume 2010, Research Article, Article ID 185689, 7 pages. doi:10.1155/2010/185689

Malhi, Y. et al. 2002 An international network to understand the biomass and dynamics of Amazonian forests (RAINFOR). Journal of Vegetation Science, 13: 439-450.

Mallah, S. and Bansal, N. K., 2009. Electricity demand and supply projections for Indian economy. International Journal of Energy Technology Policy, 7 (2): 167-179.

Mallah, S. and Bansal, N. K., 2010. Renewable energy for sustainable electrical energy system in India. Energy Policy, 38 (8): 3933-3942.

Mallah, S., 2011. Nuclear energy option for energy security and sustainable development in India. Annals of Nuclear Energy, 38: 331-336.

Mani, S. and Parthasarathy, N., 2005. Biodiversity assessment of trees in the five inland tropical dry evergreen forest of Peninsular India. Systematics and Biodiversity, 3(1): 1-12.

Mani, S., Parthasarathy, N., 2006. Tree diversity and stand structure in inland and coastal tropical dry evergreen forests of Peninsular India. Current Science, 90: 1238-1246

Manson, N. W. H., MacGillivray, K., Steel, J. B., and Wilson, J. B. 2003. An index of functional diversity. Journal of Vegetation Science, 14: 571-578.

Manuwal, D. A., 1983. Avian abundance and guild structure in two Montana coniferous forests. The Murrelet, 64:1-11.

Mao, C. X. and Colwell, R. K., 2005. Estimation of species richness: mixture models, the role of rare species, and inferential challenges. Ecology, 86 (5): 1143-1153

Mao, C. X., Colwell, R. K. and Chang, J., 2005. Estimating species accumulation curves using mixtures. Biometrics, 61:433-441.

Margules, C. R., and Pressey, R. L., 2000. Systematic conservation planning. Nature, 405: 243-253.

Marques, T. A. 2009. Distance sampling: estimating animal density. Significance, 136-137.

Marques, T. A., Thomas, L., Fancy, S. G. and Buckland, S. T., 2007. Improving estimates of bird density using multiple covariate distance sampling. The Auk, 127: 1229-1243.

Marsden, S. J., 1998. Changes in bird abundance following selective logging on Seram, Indonesia. Conservation Biology, 12: 605-611.

Marsden, S. J., 1999. Estimation of parrot and hornbill densities using a point count distance sampling method. IBIS, the International Journal of Avian Science, 141: 377-390.

Martı´nez M. L., Pe´rez-Maqueo, O., Va´zquez, G., Castillo-Campos, G., Garcı´a-Franco, J., Mehltreter, K., Equihua, M., Landgrave, R., 2009. Effects of land use change on biodiversity and ecosystem services in tropical montane cloud forests of Mexico. Forest Ecology and Management, 258: 1856-1863.

Martin, D., Lal, T., Sachdev, C. B., and Sharma, J. P., 2010. Soil organic carbon storage changes with climate change, landform and land use conditions in Garhwal hills of the Indian Himalayan Mountains. Agriculture, Ecosystems and Environment, 13 B (1-2): 64-73.

Martinsen, V., Mulder, J., Austrheim, G. and Mysterud, A., 2011. Carbon storage in low-alpine grassland soils: effects of different grazing intensities of sheep. European Journal of Soil Science, 62 (6): 822-833.

Mas, A. H. and Dietsch, T. V., 2004. Linking shade coffee certification to biodiversity conservation: butterflies and birds in Chiapas, Mexico. Ecological Applications, 14: 642- 654.

May, R. M., 1988. How many species on earth? Science, 241: 1441-1449.

McGuire, A. D., Melillo, J. M., Kicklighter, D. W. and Joyce, L. A., 1995. Equilibrium responses of soil carbon to climate change: empirical and process based estimates. Journal of Biogeography, 22: 785-796.

McIntosh, R B., 1962. Raunkiaer's "Law of Frequency", Reviewed work(s). Ecology, 43 (3): 533-535

McIntosh, R. P., 1967. An index of diversity and the relation of certain concepts to diversity. Ecology, 48: 392-404.

McIntyre N. E., 1995. Effects of forest patch size on avian diversity. Landscape Ecology, 10: 85-99.

Mehta, V. K., Sullivan, P. J., Walter, M. T., Krishnaswamy, J. and DeGloria S. D. 2008. Impacts of disturbance on soil properties in a dry tropical forest in Southern India, Ecohydrology, 1: 161-175.

Menon, M., 2010. Development Issue, Critical mass: The protest by residence of Madban and neighboring villages in Maharashtra against the Jaitapur Nuclear Power Project is ganging momentum. Frontline, 41-44.

Menon, S., and Bawa, K. S. (1997). Applications of Geographic Information Systems. (GIS), remote-sensing, and a landscape ecology approach to biodiversity conservation in the Western Ghats. Current Science, 73: 134-145.

Menyah, K. and Wolde-Rufael, Y., 2010. CO_2 emissions, nuclear energy, renewable energy and economic growth in the US. Energy Policy, 38: 2911-1915.

Metzger, J. P., and Decamps, H., 1997. The structural connectivity threshold: An hypothesis in conservation biology at the landscape scale. Acta Oecologica-International Journal of Ecology, 18 (1):1-12.

Mfilinge, P. L., Meziane, T., Bachok, Z. and Tsuchiya, M., 2005. Litter dynamics and particulate organic matter outwelling from a subtropicalmangrove in Okinawa Island, South Japan. Estuarian Coastal Shelf Science, 63: 301-313.

Michon, G., Bompard, J., Hecketsweiler, P. and Ducatillion, C., 1983. Tropical forest architectural analysis as applied to agro-forests in the humid tropic: the example of traditional village agro-forests in West Java. Agroforestry Systems, 1: 117-129.

Miegroet, H. V., Boettinger, J. L., Baker, M. A., Nielsen, J., Evans, D., Stum, A., 2005. Soil carbon distribution and quality in a montane range land-forest mosaic in northern Utah. Forest Ecology and Management, 220: 284-299.

Millat-e-Mustafa, M. D., Hall, J.B., Teklehaimanot, Z., 1996. Structure and floristics of Bangladesh homegardens. Agroforestry Systems, 33: 263-280.

Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Biodiversity Synthesis. World Resources Institute, Washington, DC.

Miller, D. A., Wigley, T. B. and Miller, K. V., 2009. Managed Forests and Conservation of Terrestrial Biodiversity in the Southern United States: Wild life management. The Society of American Foresters, Journal of Forestry, 107 (4):197-203.

Misana, S. B., Majule, A. E. and Lyaruu, H. V., 2003. Linkages between changes in land use, biodiversity and land degradation on the slopes of Mount Kilimanjaro, Tanzania. LUCID Working Paper Number 38, International Livestock Research Institute, Nairobi.

Mishra, D. K. and Singh, N. P., 2001. Endemic and Threatened Flowering Plants of Maharashtra. Botanical Survey of India, Calcutta, 196-197pp.

Misra, R., 1968. Ecology Work Book. Oxford and IBH Publishing Company, New Delhi.

Mittermeier, R. A., P., Robles-Gil, M. Hoffmann, J., Pilgrim, T., Brooks, C. G., Mittermeier, J., Lamoreux, and G. A. B. da Fonseca. 2004. Hotspots revisited. CEMEX, Mexico

MMF India, 2010. Mangroves: Soldiers of our Coasts. New Delhi, TERI, 32 pp

Mohan, S., Nair, P. K. R. and Long, A. J., 2007. An assessment of the ecological diversity of homegardens: A case study of Kerala State, India. Journal of Sustainable Agriculture, 29 (4): 135-153

Mongia, A. D. and Bandyopadhyay, A. K., 1992. Physico-chemical changes occurring in soils after clear felling for high value plantation crops. Journal of Indian Society of Soil Science, 40: 420-424.

Montagnini, F. and Porras, C., 1998. Evaluating the role of plantations as carbon sinks: an example of an integrative approach from the humid tropics. Environmental Management, 22: 459-470.

Montzka, S. A., Dlugokency, E. J. and Butler, J. H., 2011. Non- CO_2 greenhouse gases and climate change. Nature, 476: 43-50.

Morris D. W., 2003. Toward an ecological synthesis: a case for habitat selection. Oecologia, 136: 1-13.

Mudappa, D. and Raman, T. R. S., 2009. A conservation status of hornbills (Buceritidae) in the Western Ghats, India. Indian birds, 5 (4): 90-102.

Mukherjee, A., 1994. “India’s farmers could be world’s top suppliers”, Fish Farming International, 21 (7): 12-13.

Murty, D., Kirschbaum, M. U. F., Mcmurtrie, R. and Mcgilvray, H., 2002. Does conversion of forest to agricultural land change soil carbon and nitrogen: A review of the literature? Global Change Biology, 8: 105-123.

Murty, P. P., Rao, D. S., Dora, S. V. V. S. N and Narasinha Rao, M. G., 2011. Diversity and distribution of Pteridophytic flora of Punyagiri hill, Vizianagaram District AP, India. Current Botany, 2 (7): 1-4.

Muthuramkumar, S. and Parthasarathy, N., 2000. Alpha diversity of lianas in a tropical evergreen forest in the Anamalais, Western Ghats, India. Diversity and Distributions, 6: 1-14.

Myers, N., 1992. The primary source: Tropical forests and our future. W. W. Norton and Company, New York.

Myers, N., Mittermeeier, R. A., Mittelmeier, C. G., daFonsecca, G. A. B., Kent, J., 2000. Biodiversity hotspots for conservation priorities, Nature, 403: 853-858.

Naidoo, R., 2004. Species richness and community composition of songbirds in a tropical forest-agricultural landscape, Animal Conservation, 7: 93-105.

Naidoo, R., Balmford, A., Costanza, R., Fisher, B., Green, R.E., Lehner, B., Malcolom, T. R. and Ricketts, T. H., 2008. Global mapping of ecosystem services and conservation priorities. Proceedings of the National Academy of Science of the United States of America, 105 (28): 9495-9500.

Nair V. R., Mustafa, S., Mehata, P., Govindan, K., Ram, M. J. and Gajbhiye, S. N., 1998. Biological characteristics of the Vashishti estuary, Maharashtra (West coast of India). Indian Journal of Marine Science, 27:310-316.

Nair, M. A. and Sreedharan, C., 1986. Agroforestry farming systems in the homesteads of Kerala, southern India. Agroforestry Systems, 4: 339-363.

Nair, N. C. and Daniel, P., 1986. The floristic diversity of theWestern Ghats and its conservation: a review. Proceedings of Indian Academy of Science (Animal/Plant Science) Supplement, 3: 127-163.

Nair, P. K. R and Kumar, B. M., 2006. Introduction, In Kumar, B. M. and Nair, P. K. R. (eds.), Tropical Homegardens: A Time-Tested Example of Sustainable Agroforestry, 1-10.

Narain, P., Singh, R. and Singh, K., 1990. Influence of forest covers on physico-chemical and site characteristics in Dun valley. Indian Forester, 116 (11): 901-916.

Nath, P. C., Arunachalam, A., Khan, M. L., Arunachalam, K. and Barbhuiya, A. R., 2005. Vegetation analysis and tree population structure of tropical wet evergreen forests in and around Namdapha National Park, Northeast India. Biodiversity and Conservation, 14 (8): 1909-1922.

National Center for Atmospheric Research. 2005. "Climate change inevitable in 21st century: sea level rise to outpace temperature increase" http://www.ucar.edu/news/releases/2005/change.shtml.

National Research Council, 2002. Abrupt climate change: An Inevitable surprises. Washington, D.C.: National Academy Press.

Nayar, M. P., 1980. Endemic flora of Peninsular India and its significance. Bulletin Botanical Survey of India, 22: 12-23.

Nayar, M. P., 1996. Hotspots of endemic plants of India, Nepal and Bhutan. Tropical Botanic Garden and Research Institute, Thiruvananthapuram.

Naylor, R. L., Goldburg, R. J., Primavera, J. H., Kautsky, N., Beveridge, M. C. M., Clay, J., Folke, C., Lubchenco, J., Mooney, H. and Troell., M., 2000. Effect of aquaculture on world fish supplies. Nature, 405:1017-1024.

NEA, 2002. Society and Nuclear Energy; Towards a Better Understanding. OECD/NEA, Paris.

NEERI, 2010. Environmental Impact Assessment for Proposed Nuclear Power Park at Jaitapur Dist. Ratnagiri, Maharashtra (Nuclear Power Corporation of India Ltd.), Volume I, EIA main report. (Draft copy). National Environmental Engineering Research Institute, Nehru Marg, Nagpur, (Maharashtra) India. Available online at http://www.indiaenvironmentportal.org.in/files/Cover%20Page%20Vol%20I.pdf

Negi, C. S., 2005. Socio-cultural and ethno-botanical value of a sacred forest, Thal Ke Dhar, central Himalaya. Indian Journal of Traditional Knowledge, 4: 190-198.

Nelson, D .W. and Sommers, L. E., 1996. Total carbon, organic carbon, and organic matter. In: Methods of Soil Analysis, Part 2, 2nd ed., Page, A. L., et al., Ed. Agronomy. 9: 961-1010. American Society of Agronomy, Inc. Madison, WI.

Newton, I., 1995. The contribution of some recent research on birds to ecological understanding. Journal of Animal Ecology, 64: 675-696.

Nohr, H. and Jorgensen, A. F., 1997. Mapping of biological diversity in Sahel by means of satellite image analyses and ornithological surveys. Biodiversity and Conservation, 6: 545-566.

Noordwijk, M. V., Cerri, C., Woomer, P. L., Nugroho, K. and Bernoux, M., 1997. Soil carbon dynamics in the humid tropical forest zone. Geoderma, 79: 187-225.

Nuclear Power Corporation of India Limited, 2006-07. The future lies. Annual Report 2000-07. Nuclear Power Corporation of India Limited. Pages: 108. Available online at http://www.iptu.co.uk/content/trade_cluster_info/india/NPCIL_annual_report06_07.pdf

O'Connell, T. J., Jackson L. E., Brooks R. P., 2000. Bird guilds as indicators of ecological conditions in the central Appalachians. Ecological Applications, 10: 1706-1721.

Odum, E. P., 1959. Fundamentals of ecology. 2nd edition Saunders, W. B., Philadelphia, 546 p

Odum, E.P., 1983. Basic Ecology, Saunders College Publishing, Holt Saunders, Japan, 613.

Oguike, P. C. and Mbagwu, J. S. C., 2009. Variations in Some Physical Properties and Organic Matter Content of Soils of Coastal Plain Sand under Different Land Use Types. World J. Agricultural Sci., 5(1): 63.

Oosting, H. J., 1956. The study of plant communities.2nd edition, Freeman, W H. and Co., San Francisco,California: 440 p.

Orians, G. H., 1969. The number of bird species in some tropical forests. Ecology, 50: 783-801.

Pacifici, K., T. R. Simons, and K. H. Pollock. 2008. Effects of vegetation and background noise on the detection process in auditory avian point-count surveys. Auk, 125: 600-607.

Palma, C. A., Gachengo, C. N., Delve, R. J., Cadisch, G. and Giller, K. E., 2001. Organic inputs for soil fertility management in tropical agroecosystems: application of an organic resource database. Agriculture, Ecosystems and Environment, 83: 27-42.

Pande, P. K., 2005. Biomass and productivity in some disturbed tropical dry deciduous teak forests of Satpura plateau, Madhya Pradesh. Tropical Ecology, 46: 229-239.

Pande, P. K., Negi, J. D. S. and Sharma, S. C., 2002. Plant species diversity, composition, gradient analysis and regeneration behavior of some tree species in a moist temperate western—Himalayan forest ecosystem. Indian Forester, 128 (8): 869-886.

Pande, S., Tambe, S., Francis, C.M. and Sant, N., 2003. Birds of Western Ghats, Kokan and Malabar (including birds of Goa). Delhi: Oxford University Press.

Panigrahy, R. K., Kale, M. P., Dutta, U., Mishra, A., Banergee, B. and Singh, S., 2010. Forest cover change detection of Western Ghats of Maharashtra using remote sensing based visual interpretation technique. Current science, 98 (5): 657-664.

Panse, V.G. and Sukhatme, P.V., 1985. Statistical Methods for Agricultural Workers. I.C.A.R., New Delhi.

Parmesan, C. and Yohe, G., 2003. A globally coherent fingerprint of climate change impacts across natural systems. Nature, 421: 37-42.

Parrotta, J. A. 1999. Productivity, nutrient cycling, and succession in single and mixed-species plantations of *Casuarina equisetifolia*, *Eucalyptus robusta*, and *Leucaena leucocephala* in Puerto Rico. Forest Ecology Management, 124: 45-77.

Parrotta, J. A., 1995. Influence of over story composition on understory colonization by native species in plantations on a degraded tropical site. Journal of Vegetation Science, 6 (5): 627-636.

Parry, M. L., Carter, T. R. and Hulme, M., 1996. What is a dangerous climate change? Global Environmental Change, 6 (1): 1-6.

Parsons, R. and Cameron, D., 1974. Maximum plant species diversity in terrestrial communities. Biotropica, 6: 202-203.

Parthasarathy N. and Karthikeyan R., 1997. Plant biodiversity inventory and conservation of two tropical dry evergreen forests on the Coromandal Coast, South India. Biodiversity and Conservation, 6: 1063-1083.

Parthasarathy, N., 1999. Tree diversity and distribution in undisturbed and human-impacted sites of tropical wet evergreen forest in southern Western Ghats, India. Biodiversity and Conservation, 8: 1365-1381.

Parthasarathy, N., 2001. Changes in forest composition and structure in three sites of tropical evergreen forest around Sengaltheri, Western Ghats. Current Science, 80: 389-393.

Parthasarthy, N., 1983. A phytogeographic analysisof the flora of Kalakad Reserve Forest, Western Ghats. Journal of Indian Botanical Society, 67: 342-346.

Pascal, J. P. and Pelissier, R., 1996. Structure and floristic composition of a tropical rain forest in south-west India. Journal of Tropical Ecology, 12: 191-214.

Pascal, J. P., 1988. Wet evergreen forests of the Western Ghats of India. Inst. Pondichery, Trav. Sec. Sci. Tech. Tome 20.

Pascal, J. P., Ramesh, B. R. and Francheschi, D. de., 2004. Wet evergreen forest types of the southern Western Ghats, India. Tropical Ecology, 45 (2): 281-292.

Pearson, D. L., 1975. The relation of foliage complexity to ecological diversity of three Amazonian bird communities. The Condor, 77: 453-466.

Peet, R. K., 1974. The measurement of species diversity. Annual Review of Ecology and Systematics, 5: 285-307.

Pendleton, G. W., 1995. Effects of sampling strategy, detection probability, and independence of counts on the use of point counts. In: Ralph, C.J., Sauer, J.R., Droege, S. (Eds.), Monitoring Bird Populations by Point Counts, General Monitoring Bird Populations by Point Counts, Genera Station, USDA, Forest Service, Albany, CA, pp. 131-134.

Perera, A. H. and Rajapakse, R. M. N., 1991. A baseline study of Kandyanforest gardens of Sri Lanka: Structure, composition and utilization. Forest Ecology Management, 45: 269-280.

Perie, C. and Ouimet, R., 2008. Organic carbon, organic matter and bulk density relationships in boreal forest soils. Canadian Journal of Soil Science, 88: 315-325.

Peyre, A., Guidal, A., Wiersum, K. F. and Bongers, F., 2006. Dynamics of homegarden structure and function in Kerala, India. Agroforestry Systems, 66: 101.

Philips, O., et al., 1998. Changes in the carbon balance of tropical forest: evidence from long term plots. Science, 282: 439-442.

Phillips, E. A., 1959. Methods of vegetation study. Henry Holt and CO. New York. p. 318.

Pianka, E. R. 1974. Niche overlap and diffuse competition. Proceedings of the National Academy of Science of the United States of America, 71: 2141-2145. (Reprinted in 1975 in R. H. Whittaker and S. A. Levin (eds.) Niche: theory and application, Benchmark Papers in Ecology. Dowden, Hutchinson and Ross.

Pimm, S. L., Raven, P., 2000. Extinction by numbers. Nature, 403: 843–845.

Pinay, G., Barberaa, P., Carreras-Paloua, A., Fromina, N., Sonie, L., Couteauxa, M. M., Roya, J., Philippot, L. and Lensi, R., 2007. Impact of atmospheric CO_2 and plant life forms on soil microbial activities. Soil Biology and Biochemistry, 39: 33-42.

Plotkin, J. B. and Muller-Landa, H. C., 2002. Sampling the Species Composition of a Landscape: LandauSource: Ecology, 83 (12): 3344-3356.

Plumptre, A. J., 1997. Shifting cultivation along the Trans- African Highway and its impact on the understorey bird community in the Ituri Forest, Zaire. Bird Conservation International, 7: 317-329.

Post, W. M. and Kwon, K. C., 2000. Soil carbon sequestration and land-use change processes and potential. Global Change Biology, 6: 317-327.

Post, W. M., Emanuel, W. R., Zinke, P. J. and Stangenberger, A. G., 1982. Soil carbon pools and world life zones. Nature, 298: 156-159.

Poulin, B., Lefebvre, G. and McNeil, R. 1992. Tropical avian phenology in relation to abundance and exploitation of food resources. Ecology, 73: 2295-2309.

Poulsen, M. K. and Lambert, E., 2000. Altitudinal distribution and habitat preferences of forest birds on Halmahera and Buru, Indonesia: implications for conservation of Moluccan avifaunas. IBIS, The International Journal of Avian Science, 142: 566-586.

Powar, S. L. and Mehta, V. B., 1999. Characteristics of soils of Konkan coast. Journal of Indian Society of Soil Science, 47 (2): 334-337.

Powlson, D. S., Brookes, P. C. and Christensen, B. T., 1987. Measurement of soil microbial biomass provides an early indication of changes in total soil organic matter due to straw incorporation. Soil Biology and Biochemistry, 19: 159-164.

Powlson, D. S., Whitmore, A. P. and Goulding, K. W. T., 2011. Soil carbon sequestration to mitigate climate change: a critical re-examination to identify the true and the false. European Journal of Soil Science, 62: 42-55

Pragasan, L.A. and Parthasarathy, N., 2010. Landscape-level tree diversity assessment in tropical forests of southern Eastern Ghats, India. Flora, 205: 728-737

Prasad, K. G., Singh, S. B., George, M. and Singh, J., 1986. Relative effects of vegetation and rainfall on soil properties. Van Vigyan, 24 (3-4): 91-95.

Prasad, K. G., Singh, S. B., Gupta, G. N. and George, M., 1985. Studies on changes in soil properties under different vegetations. Indian Forester, 111 (10): 794-801.

Prasad, R. 1999. Joint forest management in India and the impact of state control over non-wood forest products. International Journal of Forestry and Forest Industry, 50 (198): 58–62.

Prasad, V. K., Kant, Y. and Badarinath, K. V.S., 2002. Land use changes and modelling carbon fluxes from satellite data. Advances in Space Research, 30 (11): 2511-2516.

Pratt, L. W. 2011. Vegetation assessment of forests of Pagan Island, Commonwealth of the Northern Mariana Islands. Hawai`i Cooperative Studies Unit Technical Report HCSU- 023. University of Hawai`i at Hilo. pp 26-29

Praveen, J., and Nameer, P. O., 2009. Monitoring bird diversity in Western Ghats of Kerala. Current Science, 96: 1390-1395.

Pribyl, D. W., 2010. A critical review of the conventional SOC to SOM conversion factor. Geoderma, 156: 75-83.

Priess, J. A., Mimler, M., Klein, A. M., Schwarze, S., Tscharntke, T., Steffan-Dewenter, I., 2007. Linking deforestation scenarios to pollination services and economic returns in coffee agroforestry systems. Ecological Applications, 17 (2): 407-417.

Pullin, A. S., Knight, T. M., Stone, D. A. and Charman, K., 2004. Do conservation managers use scientific evidence to support their decision-making? Biological Conservation, 119: 245-252.

Putman, R. J., 1994. Community ecology. Chapman and Hall, NY.

Puyravaud, J. P., Davidar, P. and Laurance, W. F., 2010. Cryptic loss of India’s native forests. Science, 3 (6):390-394.

Pyke, C. R., Condit, R., Aguilar, S., and Lao, S., 2001. Floristic composition across a climatic gradient in a neotropical lowland forest. Journal of Vegetation Science, 12: 553-566.

Rahbek, C. and Colwell, R. K., 2011. Biodiversity: Species loss revisited. Nature, 473: 288-289.

Raina, A. K., Jha, M. N. and Pharsi, S. C., 1999. Morphology, miner-alogy, genesis and classification of soils of Garhwal Himalayas developed on different parent materials. Annuls of Forestry, 7 (2): 269-276.

Rajamannar, A. and Krishnamoorthy, K. K., 1978. A note on the influence of altitude on the physico-chemical characteristics of forest soils. Journal of Indian Society for Soil Science, 26 (4): 399-400.

Ralph, C. J. and Scott, M. J. (eds), 1981. Studies in Avian Biology: Estimating Numbers of Terrestrial Birds, Cooper Ornithological Society, Kansas, USA, 6: 1-630.

Ralph, C. J., 1981_a. An investigation of the effect of seasonal activity levels on avian census. Studies in Avian Biology, 6: 265-270.

Ralph, C.J., 1981_b. Terminology used in estimating number of birds. Studies in Avian Biology, 6: 577-578.

Raman T. R. S., 2001. Effect of slash-and-burn shifting cultivation on rainforest birds in Mizoram, North-east India. Conservation Biology, 15: 685-698.

Raman, T. R. S., Rawat, G. S. and Johnsingh, A. J. T., 1998. Recovery of tropical rainforest avifauna in relation to vegetation succession following shifting cultivation in Mizoram, north-east India. Journal of Applied Ecology, 35: 214-231.

Ramana, M. V. and Rao, D. B., 2010. The environmental impact assessment process for nuclear facilities: an examination of the Indian experience. Environmental Impact Assessment Review, 30: 268-21.

Ramana, M. V., 2005. Nuclear energy in India. Energy for Sustainable Development, IX (2): 35-47.

Ramanujam, M. P. and Kadamban, D., 2001. Plant biodiversity of two tropical dry evergreen forests in the Pondicherry region of South India and the role. Geographical, 10 (7): 1203-1217.

Ramasubramanian, R., Gnanppazham, L., Ravishankar, T. and Navamuniyammal, M., 2006, Mangroves of Godavari: analysis through remote sensing approach. Wetlands Ecology and Management, 14: 29-37.

Ramesh, B. R., Menon, S., and Bawa, K. S., (1997). A vegetation based approach to biodiversity gap analysis in the Agastyamalai region, Western Ghats, India. Ambio, 26: 529-536.

Ramesh, B. R., Pascal, J. P. and Francheschi, D. de, 1991. Distribution of endemic arborescent evergreen species in the Western Ghats. Pp. 20-19. In: Kerala Forest Department (ed) proceedings of the Rare, Endangered and endemic plants of the Western Ghats.

Ramesh, B. R., Venugopal, P. D., Pelissier, R., Patil, S. V., Swaminath, M. H. and Counteron, P., 2010. Mesoscale patterns in the floristic composition of forests in the Western Ghats of Karnataka, India. Biotropica, 42 (4): 435-443.

Rao, D. D., Baburajan, A., Sudheendran, V., Verma, P. C. and Hegde, A. G., 2010. Evaluation and assessment of 25 years of environmental radioactivity monitoring data at Tarapur (India) nuclear site. Journal of Environmental Radioactivity, 101: 630-642.

Rathzel, N. and Uzzel, D., 2009. Changing relations in global environmental change. Global Environmental Change, 19: 326–335.

Raunkiaer, C., 1918. Recherches statistiques sur lesformations vegetales. Biol. Medd. 1: 1-80.

Raunkiaer, C., 1934. The life forms of plants and statistical geography. Claredon, Oxford, 632p.

Ravindranath, N. H., Somashekhar, B. S., and Gadgil, M., 1997. Carbon flows in Indian forests. Climatic Change, 35: 297-320.

Rawlins, B. G., Vane1, C. H., Kim, A. W., Tye1, A. M., Kemp, S. J. and Bellamy, P. H., 2008. Methods for estimating types of soil organic carbon and their application to surveys of UK urban areas. Soil Use and Management, 24: 47-59.

Read, J. W. and Ridgell, R. H., 1922. On the use of the conventional carbon factor in estimating soil organic matter. Soil Science, 13: 1-6.

Recher, H. F., Majer, J. D. and Ganesh S., 1996. Eucalypts, arthropods and birds: on the relation between foliar nutrients and species richness. Forest Ecology and Management, 85 (1-3): 177-195.

Reddy, C. S., Shilpa, B., Giriraj, A., Reddy, K. N. and Rao, K. T., 2008. Structure and Floristic Composition of Tree diversity in Tropical Dry Deciduous Forest of Eastern Ghats, Southern AndhraPradesh, India. Asian Journal of Scientific Research, 1: 57-64.

Reid, W. V., et al. 2005. Millennium Ecosystem Assessment Synthesis Report. United Nations Environment programme. Available at www.millenniumassessment.org

Remsen, J. V., 1994. Use and misuse of bird lists in community ecology and conservation. Auk, 111: 225-227.

Renner, S. C., 2011. Bird species richness pattern in the Greater Himalayan Mountains: A general introduction. Ornithological Monographs, 70:1-9.

Rennolls, K., and Laumonier, Y., 2000. Species diversity structure analysis at two sites in the tropical rain forest of Sumatra. Journal of Tropical Ecology, 16: 253-270.

Reynolds, R. T., Scott, J. M. and Nussbaum, R. A. 1980. A variable circular-plot method for estimating bird numbers. Condor, 82: 309-313.

Richards, P. W., 2002. Composition of primary rain forest (II). In: Chazdon, R. L., Whitmore, T. C., (Eds.), Foundations of Tropical Forest Biology. The University of Chicago Press, Chicago and London, pp. 538-544.

Richter, D. D., Markewitz, D., Trumbore, S. E. and Wells, C. G., 1999. Rapid accumulation and turnover of soil carbon in a re-establishing forest. Nature, 400: 56-58.

Ricketts, T. H., Daily, G. C., Ehrlich, P. R. and Michener, C. D., 2004. Economic value of tropical forest to coffee production. Proceedings of the National Academy of Sciences of the United States of America, 101 (34): 12579-12582.

Ricketts, T. H., Regetz, J., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C., Bogdanski, A., Gemmill-Herren, B., Greenleaf, S. S., Klein, A. M., Mayfield, M. M., Morandin, L. A., Ochieng, A., Viana, B. F., 2008. Landscape effects on crop pollination services: are there general patterns? Ecology Letters, 11 (5): 499-515.

Riley, J., 2003. Population sizes and the conservation status of endemic and restricted-range bird species on Karakelang, Talaud Islands, Indonesia. Bird Conservation International, 13: 59-74.

Robertson, H. A. and Hackwell, K. R., 1995. Habitat preferences of birds in seral kahikatea *Dacrycarpus dacrydioides* (Podocarpaceae) forest of South Westland, New Zealand. Biological Conservation, 71: 275-280.

Robins, C. S., 1981. Effect of time of day on bird activity. In estimating the numbers of terrestrial birds (C. J. Ralph and J. M. Scott, Eds.). Studies in Avian Biology, 6: 275-286.

Root, T. L., Liverman, D. and Newman, C., 2007. Managing biodiversity in the light of climate change: current biological effects and future impacts. In Key Topics in Conservation Biology ed. MacDonald, D. and Service, K. pp. 85– 104. Oxford: Blackwell Publishing.

Root, T. L., Price, J. T., Hall, K. R., Schneider, S. H., Rosenzweigk, C. and Pounds, J. A., 2003. Fingerprints of global warming on wild animals and plants. Nature, 421: 57-60.

Rosenstock, S. S., Anderson, D. R., K. M., Giesen, K. M., Leukering, T. and Carter, M. F., 2002. Landbird counting techniques: Current practices and an alternative. Auk ,119: 46-53.

Rosenzweig, M. L. 1995. Species Diversity in Space and Time. Cambridge University Press, Cambridge, United Kingdom.

Ross, S. M., 1993. Organic matter in tropical soils: current condi6tions, concerns and prospects for conservation. Progress in physical geography, 17: 265-305.

Roy, B. C., 1958. Ilmenite along Ratnagiri coast, Bombay, Records. Geol. Survey of India, 87: 438-452.

Royle, J. A., Dawson, D. K. and Bates, S., 2004. Modeling abundance effects in distance sampling. Ecology, 85 (6): 1591-1597.

Sagar, R. and Sharma, G. P., 2012. Measurement of alpha diversity using Simpson index (1/λ): the jeopardy. Environmental Skeptics and Critics, 1 (1): 23-24.

Sagar, R., Raghubanshi, A. S and Singh, J. S., 2003. Tree species composition, dispersion and diversity along a disturbance gradient in a dry tropical forest region of India. Forest Ecology and Management, 186: 61-71.

Saha, S. K., Nair, P. K.R., Nair, V. D. and Kumar, B. M., 2009. Soil carbon stock in relation to plant diversity of homegardens in Kerala, India. Agroforestry Systems, 76: 53-65.

Saha, S. K., Nair, P. K.R., Nair, V. D. and Kumar, B. M., 2010. Carbon storage in relation to soil size-fractions under tropical tree-based land-use systems. Plant Soil, 328: 433-446.

Sahoo, A. K., Sah, K. D., and Gupta, S. K., 1989. Available micronutrient status of some mangrove soils of the Sunderbans. Indian Agriculture, 33, 141-146.

Sahrawat, K. L., 2005. Fertility and organic matter in submerged rice soils. Current Science, 88 (5): 735-739.

Sala, O. E., Chapin, F. S., Armesto, J. J., Berlow, E., Bloomfield, J., Dirzo, R., Huber-Sanwald, E., Huenneke, L. F., Jackson, R. B., Kinzig, A., Leemans, R., Lodge, D. M., Mooney, H. A., Oesterheld, M., Poff, N. L., Sykes, M. T., Walker, B. H., Walker, M. and Wall, D. H., 2000. Biodiversity: global biodiversity scenarios for the year 2100. Science, 287: 1770-1774.

Samra, J. S., Banerjee, S. P. and Singhal, R. M., 1985. Classification of soil biosequences in relation to vegetation I Bijnor plantation division (UP). Indian Forester, 111 (7): 525-531.

Sanchez, P. A., Sherpherd, K. D., Soule, M. J., Place, F. M. and Izac, R. J. et al., 1997. Soil Fertility Replenishment in Africa: An Investment in Natural Resource Capital. In: Replenishing Soil Fertility in Africa, Buresh, R.J., P.A. Sanchez and F. Calhoun (Eds.). SSSA and ICRAF, Madison, USA. 1-46.

Sanchez-Hernandez, C., Boyd, D. S. and Foody, G. M., 2007. Mapping specific habitats from remotely sensed imagery: Support vector machine and support vector data description based classification of coastal salt-marsh habitats. Ecological Informatics, 2: 83-88.

Sanders, H. L., 1968. Marine benthic diversity: a comparative study. American Naturalist, 102: 243-282.

Saraswathy, R., Suganya, S. and Singaram, P., 2007. Environmental impact of nitrogen fertilization in tea ecosystem. J. Environ. Biol., 28, 779-88.

Saravanakumar, A., Rajkumar, M., Sun, J., Serebiah, J. S. and Thivakaran, G. A., 2002. Forest structure of arid zone mangroves in relation to their physical and chemical environment in the western Gulf of Kachchh, Gujarat, Northwest coast of India. Journal of Coastal Conservation, 13 (4): 217-234.

Schiermeier, Q., 2011. Three-quarters of climate change is man-made. Nature News.

Schimel, D. S. 1995. Terrestrial biogeochemical cycles: Global estimates with remote sensing. Remote Sensing of Environment, 51 (1): 49-56.

Schimel, D. S., Braswell, B. H., Holland, E. A., Mc Keown, R., Ojima, D. S., Painter, Th., Patron, W. J. and Townshend, A. R., 1994. Climate, edaphic and biotic controls over storage and turnover of carbon in soils. Global Biogeochemical Cycles, 8: 279-293.

Schlesinger, W. H., 1977. Carbon balance in terrestrial detritus. Annual Review of Ecology and Systematics, 8: 51-81.

Schroeder, P. E., 1992. Carbon storage potential of short rotation tropical tree plantations. Forest Ecology and Management, 50: 31-41.

Schulte L. A. and Niemi G. J., 1998. Bird communities of early successional burned and logged forest. Journal of Wildlife Management, 62: 1418-1429.

Schulte, E. E., and Hopkins, B. G., 1996. Estimation of soil organic matter by weight loss-on-ignition. p. 21–31. In Magdoff, F.R., et al. (ed.) Soil organic matter: Analysis and interpretation. SSSA Special Publication, 46. SSSA, Madison, WI.

Schulze, E. D. and Mooney, H. A., 1993. Ecosystem Function and Biodiversity. Springer, Berlin.

Schwartz, M. L., 1967. The Brunn Theory of sea level rise as a cause of shore erosion. Journal of Geology, 75: 76-92

Scott, J. M. and Ramsey, F. L. 1981. Length of count period as a possible source of bias in estimating bird densities. In Ralph, C.J. and Scott, J.M. (eds) Estimating Numbers of Terrestrial Birds: 409–413. Studies on Avian Biology, No. 6.

Scott, J. M., Ramsey, F. L. and Kepler, C. B., 1981. Distance estimation as a variable in estimating bird numbers from vocalizations. Studies in Avian Biology 6: 334-340.

Sedjo, R. A., 2001. ‘Forest carbon sequestration: some issues for forest investments’, Discussion paper, Resources for the Future, 1-34, Washington, D.C.

Seen, D. L., Ramesh, B. R., Nair, K. M., Martins, M., Arrouayss, D. and Bourgeon, G., 2010. Soil carbon stocks, deforestation and land-cover changes in the Western Ghats biodiversity hotspot (India). Global Change Biology, 16: 1777-1792.

Shannon, C. E., and Weaver, W., 1949. The Mathematical Theory of Communication. University of Illinois Press, Urbana.

Shannon, C.E., 1948. A mathematical theory of communications. Bell System Technical Journal, 27: 379-423.

Sharma, B. D., Karthikeyan, S. and Singh N. P., 1996. Flora of Maharashtra State. Botanical Survey of India.

Sharma, P. and Rai, S. C., 2007. Carbon sequestration with land-use covers change in a Himalayan watershed. Geoderma, 139: 371-378.

Sharma, P., Rai, S. C., Sharma, R. and Sharma, E., 2004. Effects of land-use change on soil microbial C, N and P in a Himalayan watershed. Pedobiologia, 48: 83-92.

Sheikh, H-R., Biswas, S. R., Bocker, R. and Kruse, M., 2009. Mangrove community recovery potential after catastrophic disturbances in Bangladesh. Forest Ecology and Management, 257: 923-930

Shepherd, D. and Montagnini, F., 2001. Above Ground Carbon Sequestration Potential in Mixed and Pure Tree Plantations in the Humid Tropics. Journal of Tropical Forest Science, 13 (3): 450-459.

Shrestha, B. M., Sitaula, B. K., Singh, B. R. and Bajracharya, R. M., 2004. Soil Organic Carbon Stocks in Soil Aggregates under Different Land Use Systems in Nepal. Nutr. Cycl. Agroecosys., 70 (2): 201-213.

Siddiquie, H. N., Rajamanickam, G. V. and Almedia, F., 1979. Offshore placers of Ratnagiri, Konkan coast, Maharashtra, India. Mar. Min., 32: 91-118

Simons, T. R., Alldredge, M. W., Pollock, K. H. and Wettroth J. M., 2007. Experimental analysis of the auditory detection process on avian point counts. Auk, 124: 986-999.

Simpson, E. H., 1949. Measurement of diversity. Nature, 163: 688.

Singh, K., Sharma, S. K., Singhal, R. M. and Samra, J. S., 1982. A comparative study of saline-sodic, sodic and normal soils in relation. Indian Forester, 108 (7): 471-473.

Singh, L. and Singh, J. S., 1991. Species structure, dry matter dynamics and carbon flux of a dry tropical forest in India. Annals of Botany, 68: 263-273.

Singh, L., Sharma, B., Agrawal, R. and Puri, S., 2005. Diversity and dominance of tropical moist deciduous forest in Achanakmar Wildlife Sanctuary. Bulletin of Natational Institute of Ecology, 15: 1-9

Singh, N. P. and Karthikeyan, S., 2000. Flora of Maharashtra State. Vol. I, Botanical Survey India.

Singh, N. P., Lakshminarasimhan, P., Karthikeyan, S. and Prasanna, P. V., 2001, Flora of Maharashtra State. Vol. II, Botanical Survey of India.

Singh, O. P. and Datta, B., 1983. Characteristics of some hill soils of Mizoram in relation to altitude. Journal of Indian Society of Soil Science, 31: 657-661.

Singh, V. P., Mall, L. P., Garge, A. and Pathak, S. M., 1990. Mangroves-forgotten forests. Natural resources and development, pp 13–26

Singhal, R. M., Samra, J. S., Sharma, S. D., Pande, P. and Sharma, S. K., 1982. Soil biosequences of a forest land of Doon valley. Indian Forester, 108 (4): 293-299.

Skirvin, A. A., 1981. Effect of time of day and time of season on the number of observations and density estimates of breeding birds. In: Estimating numbers of terrestrial birds (Ralph, C. J. and Scott, J. M., eds.), pp. 271–274. Studies in Avian Biology, no. 6. Allen Press, Lawrence, KS.

Smiley, G. L. and Kroschel, J., 2008. Temporal change in carbon stocks of cocoa-gliricidia agroforests in Central Sulawesi, Indonesia. Agroforestry Systems, 73: 219-231.

Smith, N. J. H., Fik, T.J., Alvim, P. T., Falesi, I. C. and Serrfio, E. A. S., 1995. Agroforestry developments and potential in the Brazilian Amazon. Land Degradation and Rehabilitation, 6: 251-263.

Smol, J. P., 2012. Climate Change: A planet in flux. Nature, 483: S12-S15.

Snedaker, S. C. and Lahmann, E. J., 1988. Mangrove understorey absence: aconsequence of evolution. Journal of Tropical Ecology, 4 (3): 311-314.

Soberon, J. and Llorente, J., 1993. The use of species accumulation functions for the prediction of species richness. Conservation Biology, 7: 480-488.

Soemarwoto, O., 1987. Homegardens: a traditional agroforestry system with a promising future. Pages 157-170. In: Steppler, H.A.; Nair, P.K.R. (eds.). Agroforestry a decade of development. ICRAF, Nairobi, Kenya.

Soini, E., 2006. Bird diversity and land-use on the slopes of Mt Kilimanjaro and the adjacent plains, Tanzania. African Zoology, 41: 193-209.

Solomon, D., Fritzche, F., Lehmann, J., Tekalign, M., Zech, W., 2002. Soil organic matter dynamics in the sub humid agroecosystems of the Ethiopian highlands: evidence from natural 13C abundance and particle-size fraction. Soil Science Society of America Journal, 66: 969-978.

Solomon, S., Plattner, G-K., Knutti, R.and Friedlingstein, P., 2009. Irreversible climate change due to carbon dioxide emissions. Proceedings of the National Academy of Science of the United States of America, 106 (6): 1704-1709.

Sorensen, T. A., 1948. "A method of establishing groups of equal amplitude in plant Sociology based on similarity of species content", Det. Kong Danske Vidensk Selsk. Biol. Skr. (Copenhagen), 5 (4): 1-34.

Spellerberg, I. F., and Fedor, P. J., 2003. A tribute to Claude Shannon (1916–2001) and a plea for more rigorous use of species richness, species diversity and the "Shannon-Wiener" index. Global Ecology Biogeography, 12: 177-179.

Sreekumar, P. V. and Nair, V. J., 1991. Flora of Kerala - Grasses. Botanical Survey of India, Calcutta.

Srinivas, V. and Parthasarathy, N., 2000. Comparative analysis of tree diversity and dispersion in the tropical lowland evergreen forest of Agumbe, central Western Ghats, India. Tropical Biodiversity, 7: 45-60.

Srivastava, R., Gaikwad, S. T. and Ram, J., 1991. Characteristics and classification of some forest soils of Chandrapur district ofMaharashtra. Van Vigyan, 29 (4): 234-238.

Stattersfield, A., Crosby, M. J., Long, A. J. and Wege, D. C., 1998. Endemic Bird Areas of the World: Priorities for Biodiversity Conservation. Birdlife Conservation Series No. 7, Cambridge, UK: BirdLife International. 846pp.

Steffan-Dewenter, I. and Westphal, C., 2008. The interplay of pollinator diversity, pollination services and landscape change. Journal of Applied Ecology, 45 (3): 737-741.

Steffens, M., Kolbl, A., Uwe Totsche, K. and Kögel-Knabner, I., 2008. Grazing effects on soil chemical and physical properties in a semiarid steppe of Inner Mongolia (P.R.China). Geoderma, 143: 63-72.

Stiles, F. G., 1985. Conservation of forest birds in Costa Rica: Problems and perspectives. Pages 141-168 in Conservation of Tropical Forest Birds (Diamond. A. W. and Lovejoy, T. E., Eds.). International Council of Bird Preservation, Technical Publication No. 4, Cambridge, United Kingdom.

Stoms, D. M. and Estes, J. E., 1993. A remote sensing research agenda for mapping and monitoring biodiversity. International Journal of Remote Sensing, 14: 1839-1860.

Stork, N. E., and Samways, M. J., 1995. Inventorying and monitoring. In Heyward, V. H., (Ed.), Global biodiversity assessment (pp. 453−543). New York: Cambridge Press.

Stotz, D. F., Fitzpatrick, J.W., Parker III, T. A., and Moskovits, D. K., 1996. Neotropical Birds: Ecology and Conservation, University of Chicago Press, Chicago.

Strassburg, B. B. N., Kelly, A., Balmford, A., et al., 2010. Global congruence of carbon storage and biodiversity in terrestrial ecosystems. Conservation Letters, 3: 98-105.

Sukumar, R., Dattaraja, H. S., Suresh, H. S., Radhakrisnan, J., Vasudeva, R.,Nirmala, S. and Joshi, N. V., 1992. Long-term monitoring of vegetation in a tropical deciduous forest in Mudumalai, southern India. Current Science, 62: 608-616

Suma, K. P., 2005. Diversity of mangroves in Ernakulam District of Kerala, India. Nature Environment and Pollution Technology, 4 (3): 421-425.

Sundaramoorthy, T., 2008-2009. Wildlife conservation in India. In Krishna, N., 2008-2009. Econews, Volume 14 (3 and 4): 9-11.

Sundarapandian, S. M. and Wiener, P. S., 1997. Plant biodiversity at low-elevation evergreen and moist deciduous forests at Kodayar (Western Ghats, India). International Journal of Ecology and Environment Science, 23: 363-379.

Sutherland, W. J., Newton, I. and Green, R. H. eds., 2004. Bird Ecology and Conservation: A Handbook of Techniques. Oxford University Press, Oxford.

Svensson, S., 1980. Comparison of bird census methods. In Oelke, H. (ed.), Bird Census Work and Nature Conservation, 13-22. Dachverbandes Deutscher Avifaunisten, Göttingen. Use in discussion

Swift, M. J. and Anderson, J. M., 1993. Biodiversity and ecosystem function in agricultural systems. In: Schulze, E. D. and Mooney, H. A., (eds.) Biodiversity and ecosystem function. Springer- Verlag, Berlin, pp 15–42

Takalkar, V. G., 2002. Working plan for the forest of Ratnagiri sun-division, Chiplun for years 2002-2003 to 2011-12, Volume I and II, Government of Maharashtra State.

Takimoto, A., Nair, P. K. R. and Nair, V. D., 2008. Carbon stock and sequestration potential of traditional and improved agroforestry systems in the West African Sahel. Agriculture, Ecosystems and Environment, 125: 159-166.

Tan, Z. and Lal, R., 2005. Carbon sequestration potential estimates with changes in land use and tillage practice in Ohio, USA. Agriculture, Ecosystems and Environment, 111:140-152.

Tashimo, M. and Matsui, K., 2008. Role of nuclear energy in environment, economy, and energy issues of the 21st century- Growing energy demand in Asia and role of nuclear. Progress in Nuclear Energy, 50: 103-108.

Taylor, M. R., 2007. An evaluation of bird presence and breeding activity in regenerating coastal dune forests, Maputaland, South Africa. MSc. Zoology Thesis submiited to University of Pretoria, South Africa.

Taylor, R. C., 2006. Birds using a contemporary neo-tropical landscape: the effects of forest fragmentation and agricultural landscape structure on neo-tropical birds, PhD Thesis, Bangor University.

Ter Steege, H., Pitman, N., Sabatier, D., Castellanos, H., Der Hout, P.V., Daly, D. C., Silveira, M., Phillips, O., Vasquez, R., Andel, T. V., Duivenvoorden, J., De Oliveira, A. A., Ek, R., Lilwah, R., Thomas, R., Essen, J. V., Baider, C., Maas, P., Mori, S., Terborgh, J., Vargas, P. N., Mogollón, H., and Morawetz, W., 2003. A spatial model of tree α-diversity and tree density for the Amazon. Biodiversity Conservation, 12: 2255-2277.

Terborgh, J., S., Robinson, K., Parker III, T. A., Munn, C. A., and Pierpont, N., 1990. Structure and organization of an Amazonian bird community. Ecological Monographs, 60: 213-238.

The Hindu 25th July 2010. Jaitapur nuclear project: villagers turn down compensation.

Thinh, V. T., 2006. Bird species richness and diversity in relation to vegetation in Bavi National Park, Vietnam. Ornithological Science, 5 (1): 121-125.

Thiollay, J. M., 1995. The role of traditional agroforests in the conservation of rain forest bird diversity in Sumatra. Conservation Biology, 9: 335-353.

Thomas, C. D. and Williamson, M., 2012. Extinction and climate change. Nature, 482: E4-E5. doi:10.1038/nature10858.

Thomas, C. D., Cameron, A., Green, R. E., Bakkenes, M., Beaumont, L. J., Collingham, Y. C., Erasmus, B. F. N., Siqueira M. F., Grainger, A., Hannah, L., Hughes, L., Huntley, B., Jaarsveld, A. S., Midgley, G. F., Miles, M., Ortega-Huerta, M. A., Peterson, A. T., Phillips O. L. and Williams, S. E., 2004. Extinction risk from climate change. Nature, 427: 145-148.

Thomas, L., Buckland, S. T., Rexstad, E. A., Laake, J. L. and Strindberg, S., 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. Jour. of Applied Ecology, 47: 5-14.

Threatened Bird Forum, 2007. Threatened birds of India. In BUCEROS, ENVIS newsletter, Avian Ecology, 12 (1): 8.

Tiwari, A. K. and Singh, J. S., 1987. Analysis of forest land-use and vegetation in a part of Central Himalaya, using aerial photographs. Environmental conservation, 14: 233-44.

Tolba, M. K., El-Kholy, O. A. (Eds.), 1992. The World Environment 1972–1992: Two Decades of Challenge. Chapman and Hall, London.

Tomlinson, P. B., 1986. The botany of mangroves. Cambridge University Press, Cambridge, UK

Totey, N. G., Bhowmik, A. K. and Khatri, P. K., 1986a. Performance of Sal on soils derived from different parent materials in Shahdol forest division MP. Indian Forester, 112 (1): 18-31.

Totey, N. G., Singh, A. K., Bhowmik, A. K. and Khatri, P. K., 1986b. Effect of forest covers on physico-chemical properties of soils developed on sandstone. Indian Forester, 112 (4): 314-327.

Trujillo, W., Amezquita, E., Fisher, M. J. and Lal, R., 1997.Soil organic carbon dynamics and land use in the Colombian Savannas: Aggregate size distribution. Pages 267- 280, In: Lal, R., Kimble, J.M., Follett, R.F., Stewart, B.A. (Editors) Soil Processes and the Carbon Cycle.CRC/Lewis Press, Boca Raton, Florida.

Turner, B. L. II, Clark, W. C., Kates, R. W., Richards, J. F., Mathews, J. T. and Meyer, W. B. (Eds.), 1990. The earth as transformed by human action: global and regional changes in the biosphere over the past 300 years. Cambridge Univ. Press, Cambridge.

Turner, M. G., 2010. Disturbance and landscape dynamics in a changing world. Ecology, 91: 2833-2849.

Turner, R. K., Adger, N. and Brouwer, R., 1998. Ecosystems services value, research needs and policy relevance. Ecological Economics, 25: 61-65.

Turner, W. R., Brandon, K., Brooks, T. M., Costanza, R., Fonseca, G. A. B. da, and Portela, R., 2007. Global conservation of biodiversity and Ecosystem Services. Bioscience, 57 (10): 868-873.

Upadhaya, K., Pandey, H. N., Law, P. S. and Tripathi, R. S., 2003. Tree diversity in sacred groves of the Jaibtia hills in Meghalaya, northeast India. Biodiversity and Conservation, 12: 583-597.

Upadhyay, V. P., Ranjan, R. and Singh, J. S., 2002. Human-mangrove conflicts: The way out. Current Science, India 83: 1328-1336.

Urban, F., Benders, R. M. J. and Moll, H. C., 2009. Energy for rural India. Applied Energy, 86: S47-S57.

Urfi, A. J., 2004. Birds Beyond Watching, Universities Press, Hyderabad.

Urfi, A. J., 2010. Using Heronry Birds to Monitor Urbanization Impacts: A case study of painted stork *Mycteria leucocephala* nesting in the Delhi Zoo, India. Ambio, 39: 190-193.

Urfi, A. J., Sen, M., Kalam, A. and Meganathan, T., 2005. Counting birds in India: Methodologies and trends. Current Science, 89:1997-2003.

Vajravelu, E. and Vivekananthan, K., 1996. Southern Western Ghats- South of Goa. Flora of India: introductory volume (ed. Hajra, P. K., Sharma, B. D., Sanjappa, M. and Sastry, A. R. K.,) pp. 391–445. Botanical Survey of India, Calcutta.

Valiela, I., Bowen, J. L. and York, J. K., 2001. Mangrove Forests: One of the world's threatened major tropical environments. Bioscience, 51 (10): 807-815.

Valk, V. D. A. G., and Attiwill, P. M., 1984. Acetylene reduction in an *Avicennia marina* community in southern Australia. Australian Journal of Botany, 32: 157-164.

Van Kooten, G. C., Bulte, E. H., Sinclair, A. E. R. (Eds.), 2000. Conserving Nature's Diversity: Insights from Biology, Ethics and Economics. Ashgate Publishing, Aldershot.

Varghese, A. O. and Menon, A. R. R., 1998. Vegetation characteristics of southern secondary moist mixed deciduous forests of Agasthyamalai region of Kerala. Indian Journal of Forestry, 21 (4): 639-644.

Venu, P., 1998. A review of floristic diversity inventory and monitoring methods in India. Proceedings of Indian Academy of Science (Plant Science), 64: 281-292.

Verghese, A., In Bird Diversity and Conservation Strategies for Nineties and Beyond: Estimating Bird Numbers, Ornithological Society of India, Bangalore, 1995, pp. 77–84.

Verner, J., 1985. In Current Ornithology: Assessment of Counting Techniques (ed. Johnston, R. F.), Plenum Press, 2: 247-302.

Vitousek, P. M., Mooney, H. A., Lubchenco, J., Melillo, J. M., 1997. Human domination of earth's ecosystems. Science, 277: 494-499.

Wafar, S., Untawale, A. G. and Wafar, M., (1997). Litter fall and energy flux in a mangrove ecosystem. Estuarine, Coastal and Shelf Science, 44: 111-124.

Waisel, Y., Eschel, A. and Kafkafi, U., 1991. Plant roots: the hidden half. Marcel Dekker, New York, 948 p.

Walker, B. H., Steffen, W. E., 1996. Global Change and Terrestrial Ecosystems. Cambridge University Press, Cambridge UK.

Wallace, K. J., 2007. Classification of ecosystem services: Problems and solutions. Biological Conservation, 139: 235-246.

Waltert, M., Bobo, K. S., Sainge, N. M., Fermon, H. and Muhlenberg, M., 2005. From forest to farmland: habitat effects on afrotropical forest bird diversity. Ecological Applications, 15: 1351-1366.

Wassie, A., Sterck, F. J. and Bongers, F., 2010. Species and structural diversity of church forest in a fragmented Ethiopian Highland landscape. Journal of Vegetation Science, 21 (5): 938-948.

Watson, R., Rodhe, H., Oeschger, H. and Siegenthaler, U., 1990. Greenhouse gases and aerosols. In Climate Change: the IPCC Scientific Assessment. Eds. Houghton, J. T., Jenkins, G. J. and Ephraums, J.J. Cambridge University Press, Cambridge, Pages 1-40.

Wezel, A. and Bender, S., 2003. Plant species diversity of homegardens of Cuba and its significance for household food supply. Agroforestry Systems, 57: 37-47.

Whelan, C. J., Wenny, D. G. and Marquis, R. J., 2008. Ecosystem Services Provided by Birds. Annals New York Academy Sciences, 1134: 25-60.

Whitman, C. T., 2007. The case of nuclear power. Business Week (4050), 9/17/2007.

Whittaker, R. H., 1967. Gradient analysis of vegetation. Biological Review, 42: 207-264.

Whittaker, R. H., 1970. Communities and ecosystems. Mc Millan. NewYork, p. 162.

Whittaker, R. H., 1972. Evolution and measurement of species diversity. Taxon, 21: 213-251.

Wiens, J. A. 1989. The ecology of bird communities. Vol. 2. Processes and variations. Cambridge Univ. Press.

Wiens, J. A. and Rotenberry, J. T. 1981. Habitat associations and community structure of birds in shrub steppe environments. Ecological Monographs, 51: 21-41.

Wiens, J. A., 1992. The ecology of bird communities. Volume 1. The press of the University of Cambridge, United Kingdom. pp 543

Wilke, B. M., 2005. Determination of chemical and physical soil properties. Pages: 74-76. In Margensin, R. and Schinner, F., 2005. Manual of Soil Analysis - Monitoring and Assessing Soil Bioremediation. Soil Biology. Volume 5, Springer. DOI: 10.1007/3-540-28904-6

Williams, K. J., Ford, A., Rosauer, D. F., De Silva, N., Mittermeier, R., Bruce, C., Larsen, F. W and Margules, C., 2011. Forests of east Australia: Chapter 16: The 35th biodiversity hotspot. Pages: 277-294. In Frank, E and Habel, J. C., 2011. Biodiversity hotspots: Distribution and protection of conservation priority areas. Springer - Verlag Berlin, Heidelberg. Pages 546. DOI 10.1007/978-3-642-20992-5.

Williams, L. G., 2001. The 21st century task for nuclear safety. Nuclear Industry, 21 (7): 26-30.

Williams, M., Ryan, C. M., Rees, R. M., Sambane, E., Fernando, J. and Grace, J., 2008. Carbon sequestration and biodiversity of re-growing miombo woodlands in Mozambique. Forest Ecology and Management, 254: 145-155.

Wilson, E. O., 1988. The current state of biological diversity. In: Wilson, E.O. (Ed.), Biodiversity. The National Academic Press, Washington DC, pp. 3-88.

Wilson, E. O., 1999. The diversity of life. Reissue ed. W.W. Norton and Company, New York, NY. US.

Wojtkowski, P. A., 1993. Toward an understanding of tropical homegardens. Agrofor. Syst., 24: 215-222.

Wolde-Rufael, Y. and Menyah, K., 2010. Nuclear energy consumption and economic growth in nine developed countries. Energy Economics, 32: 550-556.

World Conservation Monitoring Centre (WCMC). 1992. Global biodiversity: status of the Earth's living resources. World Conservation Monitoring Centre, Chapman and Hall, London, UK.

Wright, A. L., Wang, Y. and Reddy, K. R., 2008. Loss-on-Ignition Method to Assess Soil Organic Carbon in Calcareous Everglades Wetlands, Communications in Soil Science and Plant Analysis, 39: 19-20, 3074-3083.

Xu, X., Liu, W. and Kiely, G. 2011a. Modelling the change in soil organic carbon of grassland in response to climate change: effects of measured versus modelled carbon pools for initializing the Rothamsted Carbon model. Agriculture, Ecosystems and Environment, 140: 372–381.

Xu, X., Liu, W., Zhang, C. and Kiely, G. 2011b. Estimation of soil organic carbon stock and its spatial distribution in the Republic of Ireland. Soil Use and Management, 27 (2): 156-162.

Yadav, J. S. P. and Sharma, D. R., 1968. A soil investigation with reference to Sal and Teak in Madhya Pradesh. Indian Forester, 94: 890-897.

Zhang, W. J., Wang, X. J., Xu, M. G., Huang, S. M., Liu, H. and Peng, C., 2010. Soil organic carbon dynamics under long-term fertilizations in arable land of northern China. Biogeosciences, 7: 409-425.

Zhou, H., Xiong, D., Yang, Z., and He, X., 2007. Effects of land use change on the ecosystem services value in the dry-hot valley. Wuhan University Journal of Natural Sciences, 12 (4): 743-748.

8 APPENDICES

8.1 Appendix I: List of the plant species recorded with their common name, botanical name, family, vegetation component type and habitat type.

Note: Where, C = Climber, H = Herb, S= Shrub, T= Tree, F = Forest, CP = Casuarina plantation, HG = Homgardens, MF = Mangrove , NA/CL = Not yet been assessed but listed in the catalogue of Life, NA/NCL = Either not yet been assessed and also not listed in the catalogue of life, LC = Least concerned, Vulnurable, DD = Data Deficient, LR = Lower risk, CD = Conservation Dependent and NT = Near Threatned.

Sr.	Vernacular Name	Common Name	Scientific Name	Family	Type	Habitat	IUCN status
1	Unknown	Unknown	-	-	C	F	-
2	Chimine	White Lady	*Thunbergia fragrans* Roxb.	Acanthaceae	C	F	NA/CL
3	Acantus Spp.		-	Acanthaceae	H	F	-
4	Nilkanth	Violet Asystasia	*Asystasia dalzelliana Santapau*	Acanthaceae	H	F	NA/NCL
5	Pivli koranti	Spiny Barleria	*Barleria cuspidate*	Acanthaceae	H	F	NA/NCL
6	Golgonda	Pin Cushion Plant	*Neuracanthus sphaerostachyus*	Acanthaceae	H	F	NA/NCL
7	Dashmuli	Blue eranthemum	*Daedalcanthus roseum*	Acanthaceae	H	F, HG	NA/NCL
8	Jambhali Koranti	Mayurpankh	*Barleria involucrate*	Acanthaceae	S	F, HG	NA/NCL
9	Adulsa	Malabar nut	*Justicia adhatoda*	Acanthaceae	S	F, HG	NA/NCL
10	Kate Koranti	Spiny Barleria	*Barleria prionitis*	Acanthaceae	S	F, HG, CP	NA/NCL
11	Aboli	Crossandra	*Crossandra infundibuliformis*	Acanthaceae	H	HG	NA/NCL
12	Marandi	Holly Mangrove	*Acanthus ilicifolius* L.	Acanthaceae	S	MF	LC

Sr.	Vernacular Name	Common Name	Scientific Name	Family	Type	Habitat	IUCN status
13	Neche	Fern	*Adianatum lunulatum*	Adiantaceae	H	F	NA/NCL
14	Ghonas pan	Snake Plant	*Sansevieria trifasciata* Prain	Agavaceae	H	HG	NA/CL
15	Kurdu/ Kombda	Cockscomb	*Celosia argentea* L.	Amaranthaceae	H	F	NA/CL
16	Aghada	Chaff-flower	*Achyranthes aspera* L.	Amaranthaceae	H	F, CP	NA/CL
17	Rajgira	Love-lies-bleeding	*Amaranthus caudatus* L.	Amaranthaceae	H	HG	NA/CL
18	Math	Green Amaranth	*Amaranthus viridis* L.	Amaranthaceae	H	HG	NA/CL
19	Nagdami	Crinum	*Crinum eleonorae* Blatt & MaCann.	Amaryllidaceae	H	F	NA/CL
20	Lili	Spider Lily	*Hymenocallis littoralis* (Jacq.) Salisb	Amaryllidaceae	H	HG	NA/CL
21	Charoli	Chironji Tree	*Buchanania lanzan* L.	Anacardiaceae	T	F	NA/NCL
22	Kaju	Cashew Nut	*Anacardium occidentale*	Anacardiaceae	T	F, HG	NA/CL
23	Moya/ Shimti	Indian Ash Tree	*Lannea coromandelica*	Anacardiaceae	T	F, HG	NA/NCL
24	Amba	Mango	*Mangifera indica*	Anacardiaceae	T	F, HG	DD
25	Bibba/ Bhilava	Marking Nut	*Semecarpus anacardium* L. f.	Anacardiaceae	T	F, HG	NA/CL
26	Ambada	Wild Mango	*Spondias pinnata*	Anacardiaceae	T	HG	NA/NCL
27	Ram phal	Netted Custard Apple	*Annona reticulate* L.	Annonaceae	T	F, HG	NA/CL
28	Shitaphal	Sugar Apple	*Annona squamosa* L.	Annonaceae	T	HG	NA/CL
29	Hirva Chafa	Green chapha	*Artabotrys hexapetalus* (L. f.) Bhandari.	Annonaceae	T	HG	NA/CL
30	Ashok	Ashok	*Polyalthia longifolia* (Sonn.) Thwaites	Annonaceae	T	HG	NA/CL
31	Ran Kothambir	Wild Corriender	*Pimpinella spp.*	Apiaceae	H	F	NA/CL
32	Raan Jira	Hairy Hogweed	*Pimpinella tomentosa*	Apiaceae	H	F	NA/CL

Sr.	Vernacular Name	Common Name	Scientific Name	Family	Type	Habitat	IUCN status
33	Pandhara kuda	Indrajao	*Holarrhena pubescens* (Buch-Ham.) Wall. ex G. Don.	Apocynaceae	S	F, HG	LC
34	Kala Kuda	Sweet Indrajao	*Wrightia tinctoria* R. Br. (Hook. f.) Pichon	Apocynaceae	S	F	LR/LC
35	Sarpagandha	Indian Snakeroot	*Rauvolfia serpentine* (L.) Benth. ex Kurz.	Apocynaceae	H	F, HG	NA/CL
36	Karvanda	Karonda	*Carissa caradas* L.	Apocynaceae	S	F, HG	NA/CL
37	Nagal Kuda	Nag Kuda	*Tabernaemontana heyneana* Wall.	Apocynaceae	T	F, HG	NA/CL
38	Sadaphuli	Periwinkle	*Catharanthus roseus* (L.) G. Don.	Apocynaceae	H	HG	LR/ Threatned
39	Tagar	Crape jasmine	*Tabernaemontana divaricata* (L.) R. Br.	Apocynaceae	S	HG	NA/CL
40	Anant	Carnation of India	*Tabernaemontana gamblei*	Apocynaceae	S	HG	NA/CL
41	Kanher	Nerium	*Nerium oleander*	Apocynaceae	T	HG	LR/CD
42	Pandra Chafa	White Plumeria	*Plumeria alba* L.	Apocynaceae	T	HG	NA/CL
43	Chapha	Plumeria	*Plumeria obtusa* L.	Apocynaceae	T	HG	NA/CL
44	Karnchafa	Lucky Nut	*Thevetia peruviana* (Pers.) K. Schum.	Apocynaceae	T	HG	NA/CL
45	Sherla	Dragon Stalk Yam	*Amorphophallus commutatus* (Schott.)	Araceae	H	F	NA/CL
46	Rukhalu	Rock Ariopsis	*Remusativa vivipara* (Roxb.) Schott.	Araceae	H	F	NA/NCL
47	Tyfani	Typhonium	*Typhonium roxburghii* Schott.	Araceae	H	F	NA/CL
48	Sap kanda	Whipcord Cobra Lily	*Arisaema tortuosum* (Wall.) Schott.	Araceae	H	F, CP	NA/CL
49	Alu	Green Taro	*Colocasia esculenta*	Araceae	H	F, HG	LC
50	Ran Suran	Wild Yam	*Amorphophallus*	Araceae	S	F, HG	NA/NCL
51	Suran	Elephant foot Yam	*Amorphophallus paeonifolius*	Araceae	S	HG	NA/NCL
52	Bherli mad	Fish Treeail Palm	*Caryota urens* L.	Arecaceae	T	F, HG	NA/CL

Sr.	Vernacular Name	Common Name	Scientific Name	Family	Type	Habitat	IUCN status
53	Supari	Areca nut	*Areca catechu* L.	Arecaceae	T	HG	NA/CL
54	Naral	Coconut	*Cocos nucifera* L.	Arecaceae	T	HG	NA/CL
55	Shidodi vel	Holostemma Creeper	*Holostemma annulare*	*Asclepiadaceae*	C	F	NA/NCL
56	Harandodi	Cotton milk plant	*Wattakaka volubilis*	*Asclepiadaceae*	C	F	NA/NCL
57	Gurmar	Gurmar	*Gymnema sylvestre* (Retz.) Schultes.	*Asclepiadaceae*	C	F, CP	NA/CL
58	Gudhuchi/ Dikvel	Tylophora	*Tylophora dalzellii*	Asclepiadaceae	C	F, CP	NA/NCL
59	Anantmul	Indian Sarsaparilla	*Hemidesmus indicus*	*Asclepiadaceae*	C	F, CP, HG	NA/NCL
60	Madar/ Rui	Rubber bush	*Calotropis gigantea* (L.) Ait.f.	Asclepiadaceae	S	F, CP, HG	NA/CL
61	Rui	Rubber bush	*Calotropis procera* (L.) Ait.f.	Asclepiadaceae	S	F, CP, HG	NA/CL
62	Kavali	Indian sarsaparilla	*Cryptolepis buchananii*	Asclepiadaceae	C	F, MF, HG	NA/NCL
63	Shatavari	Wild Asparagus	*Asparagus racemosus* Willd	*Asparagaceae*	C	F	NA/CL
64	Korphad	Aloe	*Aloe vera* (L.) Brum. f.	Asphodelaceae	S	HG	NA/CL
65	Landga	Bristly starbur	*Acanthospermum hispidum* DC.	Asteraceae	H	F	NA/CL
66	Bhamrud	Blumea	*Blumea lacera* (Brum.f.) DC.	Asteraceae	H	F	NA/CL
67	Sonkadi	Sonkadi	*Pentanema indicum* (L.) Ling.	Asteraceae	H	F	NA/CL
68	Phulkadi amri	Terrestrial orchid	*Peristylus lawii* Wight.	Asteraceae	H	F	NA/CL
69	Parngumphi	Purple Heads	*Phyllocephalum scabridum* DC.	*Asteraceae*	H	F	NA/CL
70	Dahan	Smooth Tricholepis	*Tricholepis glaberrima* DC.	Asteraceae	H	F	NA/CL
71	Lahan	Lahan	*Tricholepis radicans*	Asteraceae	H	F	NA/NCL
72	Mhatari	Spiny sowthistle	*Sonchus asper* (L.)	Asteraceae	H	F, CP	NA/CL

Sr.	Vernacular Name	Common Name	Scientific Name	Family	Type	Habitat	IUCN status
73	Mhatara	Milk thistle	*Sonchus oleraceus* L.	Asteraceae	H	F, CP	NA/CL
74	Raan modi	Devilweed	*Chromolaena odorata* L.	Asteraceae	S	F, CP	NA/CL
75	Sontar	Sonki	*Senecio bombayensis* N. P. Balkr.	Asteraceae	H	F, HG	NA/CL
76	Tilgundi	Cosmos	*Cosmos spp.*	Asteraceae	H	HG	NA/CL
77	Zendu	Marigold	*Tagetes erecta* L.	Asteraceae	H	HG	NA/CL
78	Suryaphul	Sunflower	*Helianthus annuus* L.	Asteraceae	S	HG	NA/CL
79	Tavir/ Tivar	Grey/ White Mnagrove	*Avicennia marina*	Avicenniaceae	T	MF	LC
80	Upati/ Tivar	Tivar/ Indian Mangrove	*Avicennia officinalis*	Avicenniaceae	T	MF	LC
81	Dhal terda	Handsome Flowered Balsam	*Impatiens pulcherrima*	Balsaminaceae	H	F	NA/NCL
82	Phonda Terda/	Marsh balsum	*Impatiens tomentosa*	Balsaminaceae	H	F	NA/NCL
83	Terda	Balsum plant	*Impatiens balsamina*	Balsaminaceae	H	F, CP, HG	NA/CL
84	Lal terda	Rosemary Leaved Balsam	*Impatiens oppositifolia*	Balsaminaceae	H	F, HG	NA/NCL
85	Kapru	Common Begonia	*Begonia crenata*	Begoniaceae	H	F	NA/NCL
86	Paral/ Padal	Treerumpet flower Tree	*Stereospermum CLais*	Bignoniaceae	T	F	NA/NCL
87	Kate Savar	Silk Cotton Tree	*Bombax ceiba* L.	Bombacaceae	T	F, HG	NA/CL
88	Chota kalpa	Indian Borage	*Trichodesma indicum*	*Boraginaceae*	H	F	NA/NCL
89	Trichodesma	Clasping-Leaf Borage	*Trichodesma inaequale*	Boraginaceae	H	HG	NA/NCL
90	Bokhar	Indian cherry	*Cordia dichotoma* G. Forst.	Boraginaceae	T	MF	NA/CL
91	Ananas	Pineapple	*Ananas comosus* (L.) Merr.	Bromeliaceae	H	HG	NA/CL
92	Nivdung	Prickly Pear	*Opuntia elatior*	Cactaceae	S	F, HG	NA/NCL

Sr.	Vernacular Name	Common Name	Scientific Name	Family	Type	Habitat	IUCN status
93	Ratrani	Hedge Cactus	*Cereus hildmannianus* K. Schum.	Cactaceae	S	HG	NA/CL
94	Chinchni	Feather-leaved cassia	*Cassia mimosoides* Sensu Brena.	Caesalpiniaceae	H	F	NA/CL
95	Kasvid	Coffeeweed	*Cassia occidentalis* (L.) Rose.	Caesalpiniaceae	S	F	NA/CL
96	Takla	Takala	*Cassia tora* Sensu auct.	Caesalpiniaceae	H	F, CP, HG	NA/CL
97	Lahan pivla gulmohar	Candle bush	*Cassia alata* L.	Caesalpiniaceae	S	F, HG	NA/CL
98	Apta	Bidi leaf Tree	*Bauhinia racemosa* Lam.	Caesalpiniaceae	T	F, HG	NA/CL
99	Kanchan	Orchid Tree	*Bauhinia variegate* L.	Caesalpiniaceae	T	F, HG	NA/CL
100	Bhava	Amaltash	*Cassia fistula* L.	Caesalpiniaceae	T	F, HG	NA/CL
101	Gulmohar	Flame Tree	*Delonix regia* (Hook.) Raf.	Caesalpiniaceae	T	F, HG	V
102	Chinch	Treeamarind	*Tamarindus indica* L.	Caesalpiniaceae	T	F, HG	NA/CL
103	Sagar Gota	bonduc nut	*Caesalpinia bonduc* (L.) Roxb.	Caesalpiniaceae	C	HG	NA/CL
104	Shankasur	Peacock Flower	*Caesalpinia pulcherrima* (L.) SW	Caesalpiniaceae	S	HG	NA/CL
105	Pandhara mandar	Dwarf white bauhinia	*Bauhinia acuminata* L.	Caesalpiniaceae	T	HG	NA/CL
106	Pivla Gulmohar	Copper pod	*Peltophorum pterocarpum* DC.	Caesalpiniaceae	T	HG	NA/CL
107	Khargul/ Ghol	Indian Charcoal Tree	*Trema orientalis*	Cannabaceae	T	F	NA/NCL
108	Kardal	Indian Shot	*Canna indica* L.	Cannaceae	S	HG	NA/CL
109	Nepti	Capparis	*Capparis deciduas*	Capparaceae	C	F	NA/NCL
110	Pantilvan	Celandine Spider Flower	*Cleome chelidonii*	Capparaceae	H	F	NA/NCL
111	Tilwan	Wild Spider flower	*Cleome gynandra* L.	*Capparaceae*	H	F	NA/CL
112	Papai	Papaya	*Carica papaya* L.	Caricaceae	T	HG	NA/CL

Sr.	Vernacular Name	Common Name	Scientific Name	Family	Type	Habitat	IUCN status
113	Suru	*Casuarina*	*Casuarina equisetifolia* L.	Casuarinaceae	T	F, CP, HG	NA/CL
114	Malkangni	Black Oil Plant	*Celastrus paniculatus*	*Celastraceae*	C	F	NA/NCL
115	Surangi	Surangi	*Mommea suriga*	Clusiaceae	T	F, HG	NA/NCL
116	Ratamba	Kokum	*Garcinia indica* (Thouars) Choisy.	Clusiaceae	T	F, HG	NA/CL
117	Undi/ Undal	Oil Nut Tree	*Calophyllum inophyllum* L.	Clusiaceae	T	F, MF	LR/LC
118	Nag champa	Indian rose chestnut	*Mesua ferrea*	Clusiaceae	T	HG	NA/NCL
119	Uski/ Ukshi	Paper flower climber	*Calycopteris floribunda*	*Combretaceae*	C	F	NA/NCL
120	Harda	Chebulic Myrobalan	*Terminalia chebula* (Gaertner) Roxb.	Combretaceae	T	F	NA/CL
121	Arjun	Arjun	*Terminalia arjuna*	Combretaceae	T	F, HG	NA/NCL
122	Behra	Belliric Myrobalan	*Terminalia bellirica*	Combretaceae	T	F, HG	NA/CL
123	Aine	Indian Laurel	*Terminalia elliptica*	Combretaceae	T	F, HG	NA/NCL
124	Kinjal	Flowering Murdah	*Terminalia paniculata*	Combretaceae	T	F, HG	NA/NCL
125	Badam	Indian Almond	*Terminalia catappa* L.	Combretaceae	T	HG	NA/CL
126	Nabhali	Cyanotis	*Cyanotis cristata* L.	*Commelinaceae*	H	F	LC
127	Murdannia	Dewflower	*Murdannia wightii*	Commelinaceae	H	F	NA/CL
128	Kena/ Kanpet	Day flower	*Commelina forsskalaei*	Commelinaceae	H	F, CP	NA/CL
129	Bond vel	Oval Leaved Silverweed	*Argyreia elliptica*	Convolvuaceae	C	F	NA/NCL
130	Gavel	Silky Morning Glory	*Argyreia nervosa* (Brum. f.)	Convolvuaceae	C	F	NA/CL
131	Tambarvel	Tambarvel	*Ipomoea campanulata* auct. non. L.	Convolvuaceae	C	F	NA/CL
132	Lal pungli	Scarlet Morning Glory	*Ipomoea hederifolia* L.	Convolvuaceae	C	F	NA/CL

Sr.	Vernacular Name	Common Name	Scientific Name	Family	Type	Habitat	IUCN status
133	Nili pungli	Blue Morning Glory	*Ipomoea nil* (L.) Roth.	Convolvuaceae	C	F	NA/CL
134	Wagh padi	Tiger Foot Morning Glory	*Ipomoea pes-tigridis* L.	Convolvuaceae	C	F	NA/CL
135	Nisottar	Transparent Wood Rose	*Operculina turpethum* L.	Convolvuaceae	C	F	NA/CL
136	Chand Vel	Field Bindweed	*Convolvulus arvensis* L.	Convolvuaceae	C	F, CP	NA/CL
137	Nikhari/ Malghanti	Tiny Morning Glory	*Ipomoea eriocarpa* R.Br.	Convolvulaceae	C	F	NA/CL
138	Vet vel/ Naval vel	Grape-leaf Wood Rose	*Merremia gangetica* L.	*Convolvulaceae*	C	F, CP	LC
139	Vishnukrant	Dwarf Morning Glory	*Evolvulus alsinoides* L.	*Convolvulaceae*	H	F	NA/CL
140	Samudra Maryada Vel	Railroad vine	*Ipomoea pes-caprae* (L.) R. Br.	*Convolvulaceae*	C	F, CP	NA/CL
141	Ganesh vel	Star Glory	*Ipomoea quamoclit* L.	Convolvulaceae	C	HG	NA/CL
142	Kosta	Costus	*Costus speciosus* (J. Koning.) Sm.	Costaceae	H	F, HG	NA/CL
143	Chirti	Pea pumpkin	*Mukia maderaspatana*	Cucurbitaceae	C	F	NA/NCL
144	Ran padval	Wild snake Gourd	*Trichosanthes nervifolia*	Cucurbitaceae	C	F	NA/NCL
145	Kadu Karate	Kadu Karate	*Cucumis setosus*	Cucurbitaceae	C	F, CP	NA/NCL
146	Raan Dodka	Ribbed Sponge Gourd	*Luffa acutangula* (L.) Roxb.	Cucurbitaceae	C	F, HG	NA/CL
147	Ran tondla	Creeping Cucumber	*Solena amplexicaulis*	Cucurbitaceae	C	F, HG	NA/NCL
148	Kalingad	Watermelon	*Citrullus lanatus*	Cucurbitaceae	C	HG	NA/CL
149	Tondli	Ivy Gourd	*Coccinia grandis* (L.) Voigt.	Cucurbitaceae	C	HG	NA/CL
150	Chibud	Wild Melon	*Cucumis melo* (L.)	Cucurbitaceae	C	HG	NA/CL
151	Kakdi	Cucumber	*Cucumis sativus* L.	Cucurbitaceae	C	HG	NA/CL
152	Kashi Bhopla	Pumpkin	*Cucurbita pepo* L.	Cucurbitaceae	C	HG	NA/CL

Sr.	Vernacular Name	Common Name	Scientific Name	Family	Type	Habitat	IUCN status
153	Bhopla	Bottle Gourd	*Lagenaria siceraria* Molina.	Cucurbitaceae	C	HG	NA/CL
154	Dodka	Ribbed Sponge Gourd	*Luffa acutangula* (L.) Roxb.	Cucurbitaceae	C	HG	NA/CL
155	Ghosale	Sponge Gourd	*Luffa aegyptiaca* P. Mill.	Cucurbitaceae	C	HG	NA/CL
156	Karle	Bitter gourd	*Momordica charantia* L.	Cucurbitaceae	C	HG	NA/CL
157	Padval	Snake Gourd	*Trichosanthes cucumerina* L.	Cucurbitaceae	C	HG	NA/CL
158	Mayur Pankhi	Morpankhi	*Platycladus orientalis* L.	Cupressaceae	T	HG	LR/NT
159	Barik motha lavala	Common Nut Sedge	*Cyperus rotundus* L.	Cyperaceae	H	F	LC
160	Fimbristylis	Fimbristylis	*Fimbristylis littoralis*	Cyperaceae	H	F	LC
161	Karmal	Dog Treeeak/ Dillenia	*Dillenia pentagyna*	Dilleniaceae	T	F	NA/NCL
162	Shendvel	Five leaf Yam	*Dioscorea pentaphylla* L.	Dioscoreaceae	C	F	NA/CL
163	Karanda/ Dangkand	Aerial yam	*Dioscorea bulbifera* L.	*Dioscoreaceae*	C	F, CP, HG	NA/CL
164	Chin/ Kondfal	Aerial Yam	*Dioscoria alata* L.	Dioscoreaceae	C	HG	NA/CL
165	Gavti davbindu	Flycatcher/ Indian Sundew	*Drosera indica* Willd.	Droseraceae	H	F	LC
166	Kolsa	Eriocaulon	*Eriocaulon heterolepis*	Eriocaulaceae	H	F	NA/CL
167	Khajkhujli	Indian acalypha	*Acalypha lanceolata* Willd.	Euphorbiaceae	H	F	NA/CL
168	Dudhi	Asthma plant	*Chamaesyce hirta* (L.) Mills. P.	Euphorbiaceae	H	F	NA/CL
169	Kokan Dhudi	Konkan Dudhi	*Euphorbia concanensis*	Euphorbiaceae	H	F	NA/CL
170	Vanerand	Cotton-leaf physic nut	*Jatropha gossypiifolia* L.	Euphorbiaceae	S	F	NA/CL
171	Awla	Indian Gooseberry	*Emblica officinalis* Gaertn.	Euphorbiaceae	T	F	NA/CL
172	Kunkuphal	Kamala Tree	*Mallotus philippensis* Lam.	Euphorbiaceae	T	F	NA/CL

Sr.	Vernacular Name	Common Name	Scientific Name	Family	Type	Habitat	IUCN status
173	Hura/ Kirkind	Treeiger's Milk Spruce	*Sapium insigne* (Royle) Trimon.	Euphorbiaceae	T	F	NA/CL
174	Ratanjyaot	Phisic nut	*Jatropha curcas* L.	Euphorbiaceae	S	F, CP, HG	NA/CL
175	Narashya	Cactus	*Euphorbia antiquorum* L.	Euphorbiaceae	S	F, HG	NA/CL
176	Chandvad	Chandada	*Macaranga peltata* Roxb.	Euphorbiaceae	T	F, HG	NA/CL
177	Acalypha	Cat's tail	*Acalypha hispida* Brum. f.	Euphorbiaceae	S	HG	NA/CL
178	Copperleaf	Copperleaf	*Acalypha wilkesiana* Mull. Arg.	Euphorbiaceae	S	HG	NA/CL
179	Erand	Castor Bean	*Ricinus communis* L.	Euphorbiaceae	S	HG	LC
180	Sher	Pencil tree	*Euphorbia tirucalli*	Euphorbiaceae	T	HG	LC
181	Phungali	Bild your eyes mangrove	*Excoecaria agallocha* (L.)	Euphorbiaceae	T	MF	NA/CL
182	Asana	Spinous Kino Tree	*Bridelia retusa* L.	Euphorbiaceae	T	F, HG	NA/CL
183	Gunj	Coral bead vine	*Abrus precatorius* L.	Fabaceae	C	F	NA/CL
184	Sagar Abai	Beach Bean	*Canavalia lineata* (Thunb.) DC.	Fabaceae	C	F	NA/CL
185	Pendkul vel	Prickly Dalbergia	*Dalbergia horrid*	Fabaceae	C	F	NA/NCL
186	Vagheti	Poison Vine	*Derris elliptica* (Wall.) Benth.	Fabaceae	C	F	NA/CL
187	Raan chawli	Wild Chawli	*Vigna capensis* L.	Fabaceae	C	F	NA/CL
188	Raan udid	Wild Udid	*Vigna pilosa* (Willd.) Baker.	Fabaceae	C	F	NA/CL
189	Kanphuti	Luck plant	*Flemingia strobilifera* L.	Fabaceae	H	F	NA/CL
190	Barki	Barki	*Geissapis cristata*	Fabaceae	H	F	NA/NCL
191	Raan shevri	Wild Sesbenia	*Sesbenia aegyptica*	Fabaceae	H	F	NA/NCL
192	Lajalu Kavla	Sensitive Smithia	*Smithia sensitive*	Fabaceae	H	F	NA/NCL

Sr.	Vernacular Name	Common Name	Scientific Name	Family	Type	Habitat	IUCN status
193	Kak Ganja	Trefle Gros	*Tadehagi triquetrum* L.	Fabaceae	H	F	NA/CL
194	Unhali	Wild Indigo	*Tephrosia purpurea* L.	Fabaceae	H	F	NA/CL
195	Keshri Unhali	Orange Tephrosia	*Tephrosia tinctoria* Pers.	Fabaceae	H	F	NA/CL
196	Bivla	Malabar kino	*Pterocarpus marsupium* L.	Fabaceae	T	F	V
197	Salmul	Sal Leaved Desmodium	*Desmodium gangeticum* (L.) DC.	Fabaceae	S	F, CP	NA/CL
198	KhajKhujlli/ Kevach	Velvet bean	*Mucuna pruriens* (L.) DC.	Fabaceae	C	F, CP, HG, MF	NA/CL
199	Ran Ghevda	Wild Ghevada	*Paracalyx scariosus* Roxb. Ali.	Fabaceae	C	F, HG	NA/CL
200	Pangara	Indian Coral Treeee	*Erythrina variegata* L.	Fabaceae	T	F, HG	NA/CL
201	Subabul	Leucaena	*Leucaena leucocephala* Lam.	Fabaceae	T	F, HG	NA/CL
202	Parjyanyavriksha	Rain Tree	*Samanea saman* (Jacq.) Merr.	Fabaceae	T	F, HG	NA/CL
203	Derris	Jewel Vine	*Derris scandens* (Roxb.) Benth.	Fabaceae	C	F, MF	NA/CL
204	Ghagri	Blue flower rattlepod	*Crotolaria verrucosa* L.	Fabaceae	H	F, MF, CP	NA/NCL
205	Bhuimung	Ground nut	*Arachis hypogaea* L.	Fabaceae	H	HG	NA/CL
206	Harbhara	Chickpea	*Cicer arietinum* L.	Fabaceae	H	HG	NA/CL
207	Bhut shevra	Loose Flowered Desmodium	*Desmodium laxiflorum* DC.	Fabaceae	H	HG	NA/CL
208	Tur	Pigeon Pea	*Cajanus cajan* L.	Fabaceae	S	HG	NA/CL
209	Giripushpa	Glirisidia	*Gliricidia sepium* (Jacq.) Walp.	Fabaceae	S	HG	NA/CL
210	Raan Shevri	Sesban	*Sesbania bispinosa*	Fabaceae	S	HG	LC
211	Hatga	Agati	*Sesbania grandiflora* L. Pers.	Fabaceae	T	HG	NA/CL
212	Sagar Lata	Crested fever nut	*Caesalpinia crista* (L.)	Fabaceae	C	MF	NA/CL

Sr.	Vernacular Name	Common Name	Scientific Name	Family	Type	Habitat	IUCN status
213	Karanj	Karanj/ Pongam	*Pongamia pinnata* (L.) Pierre.	Fabaceae (Papilionaceae)	T	F	NA/CL
214	Kirmira	Casearia	*Casearia ovata*	Flacourtiaceae	T	F	NA/NCL
215	Kumbhal	mountain sweet thorn	*Flacourtia Montana*	Flacourtiaceae	T	F	NA/CL
216	Fried Egg Tree	Fried Egg Tree	*Oncoba spinosa*	Flacourtiaceae	T	F	NA/CL
217	Chimni pakhare	Hanging heliconia	*Heliconia rostrata* Ruiz & Pav.	Heliconiaceae	S	HG	NA/CL
218	Kali musali	Orchid palm grass	*Curculigo orchioides* Gaertn.	Hypoxidaceae	H	F	NA/CL
219	Dudhani	*Leucas*	*Leucas longifolia*	Lamiaceae	H	F	NA/NCL
220	Madanghanti	poaia	*Spermacoce articularis* L. f.	Lamiaceae	H	F	NA/CL
221	Spermococca	Spermococca sp.	*Spermococca stricta*	Lamiaceae	H	F	NA/NCL
222	Ran Tulas	Wild basil	*Hyptis suaveolens* (L.) Poit.	Lamiaceae	S	F	NA/CL
223	Deepmal	Christmas candlestick	*Leonotis nepetifolia* L.	Lamiaceae	H	HG	NA/CL
224	Tulas/ Tulasi	Holy basil	*Ocimum tenuiflorum* L.	Lamiaceae	H	HG	NA/CL
225	Tamalpatra	Indian Bay Leaf	*Cinnamomum tamala* (Buch-Ham.)	Lauraceae	T	HG	NA/CL
226	Dalchini	Cinnamon	*Cinnamomum verum* J. Presl.	Lauraceae	T	HG	NA/CL
227	Kumbha	Wild Guava	*Careya arborea* Roxb.	Lecythidaceae	T	F, HG	NA/CL
228	Dhinda	Bandicoot Berry	*Leea indica*	Leeaceae	S	F, HG	NA/NCL
229	Sitechi asve	Grass Leaved Bladderwort	*Utricularia graminifolia*	Lentibularaceae	H	F, CP	LC
230	Safed musali	Musali	*Chlorophytum laxum* R. Br.	Liliaceae	H	F	NA/CL
231	Kokan Deepkadi	Konkan Deepkadi	*Dipkadi concanensis*	Liliaceae	H	F	NA/NCL
232	Motha Dhinda	Hathikana	*Leea macrophylla*	Liliaceae	H	F	NA/NCL

Sr.	Vernacular Name	Common Name	Scientific Name	Family	Type	Habitat	IUCN status
233	Raan Kanda	Wild Onion	*Drimia indica* (Roxb.) Jessop.	Liliaceae	H	F, CP	NA/CL
234	Ghot Vel	Kumarika	*Smilax ovalifolia* Roxb.	*Liliaceae*	C	F, CP,HG	NA/CL
235	Kalalavi/ Kalihari	Glory Lily	*Gloriosa superb* L.	Liliaceae	C	F, HG	NA/CL
236	May flower	Purple Mayflower	*Maianthemum purpureum* Wall.	Liliaceae	H	HG	NA/CL
237	Kajra	Poison Nut	*Strychnos nux-vomica* (L.)	Loganiaceae	T	F, HG	NA/CL
238	Fern/Neche	Fern	*Nephrolepis spp.*	Lomariopsidaceae	H	F	NA/NCL
239	Mehandi	Henna	*Lawsonia inermis* L.	Lytharaceae	S	HG	NA/CL
240	Ammannia	Many flowered Ammannia	*Ammannia muliflora*	Lythraceae	H	F	NA/NCL
241	Machim	Rotala spp.	*Rotala floribunda* L.	Lythraceae	H	F	V
242	Dhayti	Fire Flame Bush	*Woodfordia fruticosa* L.	Lythraceae	S	F	LR/LC
243	Nana Bondara	Ben teak	*Lagerstromia microcarpa*	Lythraceae	T	F	NA/NCL
244	Kavti chafa	Champak	*Magnolia champaca* L.	Magnoliaceae	T	HG	NA/CL
245	Sonchafa	Champak	*Michelia champaca* L.	Magnoliaceae	T	HG	NA/CL
246	Bokad vel	Bokad vel	*Aspidopterys cordata*	*Malpighiaceae*	C	F	NA/NCL
247	Jungli bhendi	Wild Ladies fingure	*Abelmoschus esculentus* L.	Malvaceae	H	F	NA/CL
248	Shreemudre	Indian Mallow	*Abutilon indicum* (L.) Sweet	Malvaceae	H	F	NA/CL
249	Devki	Country mallow	*Sida rhombifolia* L.	Malvaceae	H	F	NA/CL
250	Jungli Bhendi	Van bhendi	*Abelmoschus tetraphyllus*	Malvaceae	S	F	NA/NCL
251	Ran Bhendi	Yellow Hibiscus	*Hibiscus tetraphyllus*	Malvaceae	H	F, CP	NA/NCL
252	Tupkada	Bala	*Sida cordifolia* L.	Malvaceae	H	F, CP	NA/CL

Sr.	Vernacular Name	Common Name	Scientific Name	Family	Type	Habitat	IUCN status
253	Vanbhendi	Burr Mallow	*Urena sinuata* L.	Malvaceae	H	F, CP	NA/CL
254	Bala/ Chikna	Bala	*Sida acuta* Burm. f.	Malvaceae	H	F, HG	NA/CL
255	Paras Bhendi	Indian tulip Tree	*Thespesia populnea* L.	Malvaceae	T	F, MF, HG	NA/CL
256	Bhendi	Ladies Finger	*Abelmoschus esculentus* L.	Malvaceae	H	HG	NA/CL
257	Kapus/ Kapas	Cotton	*Gossypium arboretum*	Malvaceae	S	HG	NA/CL
258	Jaswand	China rose	*Hibiscus rosa-sinensis* L.	Malvaceae	S	HG	NA/CL
259	Samudra Jasvand	Sea Hibiscus	*Hibiscus tiliaceus* L.	Malvaceae	T	MF	NA/CL
260	Wichvi	Devil's Claws	*Martynia annua* L.	Martyniaceae	H	F, HG	NA/CL
261	Anjan	Ironwood	*Memecylon umbellatum* Burm.f.	Melastromataceae	T	F	NA/CL
262	Limb	Neem	*Azadirachta indica* Adr. Juss.	Meliaceae	T	F, HG	NA/CL
263	Rindha	Indian Rhododendron	*Melastoma malabathricum* L.	Melostomaceae	H	F	NA/CL
264	Pandrukh vel	Cyclea	*Cyclea peltata*	Menispermaceae	C	F	NA/NCL
265	Gulvel/ Amritvel	Indian Tinospora	*Tinospora cordifolia*	*Menispermaceae*	C	F	NA/NCL
266	Vasan vel	Broom Creeper	*Cocculus hirsutus*	*Menispermaceae*	C	F, CP	NA/NCL
267	Shikekai	Soap-pod	*Acacia concinna* Willd. DC.	*Mimosaceae*	C	F	NA/CL
268	Dev Babul	Ironwood	*Acacia farnesiana* (L.) Willd.	Mimosaceae	T	F	NA/CL
269	Babul	Babul	*Acacia nilotica* (L.) Delile.	Mimosaceae	T	F	NA/CL
270	Kalam	Kaim	*Mitragyna pervifolia*	Mimosaceae	T	F	NA/NCL
271	Lajwanti	Touch me not plant	*Mimosa pudica* L.	Mimosaceae	H	F, HG	NA/CL
272	Khair	Cutch Tree	*Acacia catechu* L. Willd.	Mimosaceae	T	F, HG	NA/CL

Sr.	Vernacular Name	Common Name	Scientific Name	Family	Type	Habitat	IUCN status
273	Australian Babul	Norther Black Wattle	*Acacia auriculiformis* Benth.	Mimosaceae	T	F, HG, MF	NA/CL
274	Vilayati chinch	Sweet tamarind	*Pithecellobium dulce* Roxb. Benth.	Mimosaceae	T	HG	NA/CL
275	Umber	Cluster Fig	*Ficus glomerata* Roxb.	Moraceae	T	F	NA/CL
276	Pimpal	Scared fig	*Ficus religiosa* L.	Moraceae	T	F	NA/CL
277	Phanas	Jackfruit	*Artocarpus heterophyllus* Lam.	Moraceae	T	F, HG	NA/CL
278	Payar	India Rock Fig	*Ficus arnottiana*	Moraceae	T	F, HG	NA/NCL
279	Vad	Banyan tree	*Ficus bengalensis* L.	Moraceae	T	F, HG	NA/CL
280	Bokhada	Devil Fig	*Ficus hispida*	Moraceae	T	F, HG	NA/NCL
281	Vilayti Phanas	Breadfruit	*Artocarpus altilis* P.	Moraceae	T	HG	NA/CL
282	Rabracho-vad	Rubber Tree	*Ficus elastic*	Moraceae	T	HG	NA/NCL
283	Umbar	Cluster fig	*Ficus racemosa* L.	Moraceae	T	HG	NA/CL
284	Kharvat	Toothbrush tree	*Streblus asper*	Moraceae	T	HG	NA/NCL
285	Shevga	Drumstick tree	*Moringa oleifera* Lam.	Moringaceae	T	HG	NA/CL
286	Rann keli	Wild Banana	*Ensete superbum* Roxb.	Musaceae	S	F, HG	NA/CL
287	Keli	Banana	*Musa paradisiacal* L.	Musaceae	S	HG	NA/CL
288	Nutmeg	Jaiphal	*Myristica fragrans* Houtt.	Myristicaceae	T	HG	DD
289	Kajala	River Mangrove	*Aegiceras corniculatum*	Myrsinaceae	T	MF	LC
290	Rantil	Wild Sesame	*Sesamum orientale* L.	Myrtaceae	H	F	NA/CL
291	Nilgiri	Eucalyptus	*Eucalyptus globulus* Labill.	Myrtaceae	T	F	NA/CL
292	Jambhul	Jamun	*Syzygium cumini* (L.) Skeel.	Myrtaceae	T	F, HG	NA/CL

Sr.	Vernacular Name	Common Name	Scientific Name	Family	Type	Habitat	IUCN status
293	Allspice	Jamaica pepper	*Pimenta dioica* L. Mer.	Myrtaceae	T	HG	NA/CL
294	Peru	Guava,	*Psidium guajava* L.	Myrtaceae	T	HG	NA/CL
295	Lavang	Clove	*Syzygium aromaticum* (L.) Merr.	Myrtaceae	T	HG	NA/CL
296	Jam	Malabar plum	*Syzygium jambos* (L.) Alston.	Myrtaceae	T	HG	NA/CL
297	Booganvel	Bougainvillea	*Bougainvillea glabra* Choisy	Nyctaginaceae	C	HG	NA/CL
298	Chini Gulab	Beauty-of-the-night	*Mirabilis jalapa* L.	Nyctaginaceae	H	HG	NA/CL
299	Kamal/ Kumud	Water lily	*Nymphaea pubescens*	Nymphaeaceae	H	HG	NA/CL
300	Kusari/ Pusar	Malabar Jasmine	*Jasminum malabaricum*	Oleaceae	C	F, CP	NA/NCL
301	Kunda/ Mukunda	Star jasmine	*Jasminum multiflorum* (Burm.f.)	Oleaceae	S	HG	NA/CL
302	Chameli	Jasmine	*Jasminum officinale* (L.) Ait.	Oleaceae	S	HG	NA/CL
303	Mogra	Arabian Jasmine	*Jasminum sambac*	Oleaceae	S	HG	NA/CL
304	Prajakta	Tree of Sorrow	*Nyctanthes arbortristis*	Oleaceae	T	HG	NA/NCL
305	Jussuea	Jussuea safrutica	*Jussuea safrutica*	Onagraceae	H	F	NA/NCL
306	Chikarkanda	Single Leaved Habenaria	*Habenaria grandifloriformis*	Orchidaceae	H	F	NA/CL
307	Lajalu/ Lajari	Tree Plant	*Biophytum sensitivium*	Oxalidaceae	H	F, CP, HG	NA/NCL
308	Kevda	Beach Pandanus	*Pandanus tectorius*	Pandanaceae	T	F	NA/CL
309	Dhakta	Oval-leafed Alysicarpus	*Alysicarpus ovalifolius* (Schum.)	Papilionaceae	H	F	NA/CL
310	Khulkhuli	Crotalaria spp.	*Crotalaria triquetra* (Dalzell.)	Papilionaceae	H	F	NA/CL
311	Krisna Kamal	Passion flower	*Passiflora edulis* Sims.	Passifloraceae	C	HG	NA/CL
312	Bhui Awala	Gulf Leaf-Flower	*Phyllanthus fraternus* G.L.	Phyllanthaceae	H	F	NA/CL

Sr.	Vernacular Name	Common Name	Scientific Name	Family	Type	Habitat	IUCN status
313	Kangli/ Lalya	Cup Saucer Plan	*Breynia retusa* Dennst.	Phyllanthaceae	S	F	NA/CL
314	Pandharphali	Bushweed	*Flueggea leucopyrus* Willd.	Phyllanthaceae	S	F	NA/CL
315	Shaiche Zaad	Ink tree	*Phyllanthus reticulatus* Poir.	Phyllanthaceae	S	F, HG	NA/CL
316	Bhui awala	Madras Leaf-Flower	*Phyllanthus maderaspatensis* L.	Phyllanthaceae	H	HG	NA/CL
317	Rai awala	Star Gooseberry	*Phyllanthus acidus* L.	Phyllanthaceae	T	HG	NA/CL
318	Awala	Indian gooseberry	*Phyllanthus emblica* L.	Phyllanthaceae	T	HG	NA/CL
319	Christmas Tree	Christmas Tree	*Picea abies* L.	Pinaceae	T	HG	LR/LC
320	Pimpli	Indian long pepper	*Piper longum* L.	Piperaceae	C	HG	NA/CL
321	Kalimiri	Black Pepper	*Piper nigrum* L.	Piperaceae	C	HG	NA/CL
322	Chitrak	Plumbago	*Plumbago zeylanica* L.	Plumbaginaceae	S	HG	NA/CL
323	Durva	Haryali	*Cynodon dactylon* (L.) Pers.	Poaceae	H	F, CP	NA/CL
324	Chikta Gavat	Bristly Foxtail grass	*Setaria verticillata* L.	Poaceae	H	F, CP	NA/CL
325	Shiteche pohe	Love grass	*Eragrostis unioloides*	Poaceae	H	F, CP, HG	LC
326	Bas	Bamboo	*Dendrocalamus strictus* (Roxb.) Ness.	Poaceae	T	F, HG	NA/CL
327	Gavti chaha	Lemon Grass	*Cymbopogon citrates* (DC.) Stapf.	Poaceae	H	HG	NA/CL
328	Rice	Bhat	*Oryza sativa* L.	Poaceae	H	HG	NA/CL
329	Khas/ Vala	Khus grass	*Vetiveria zizanioides* (L.) Nash.	Poaceae	H	HG	NA/CL
330	Maka	Maize	*Zea mays* L.	Poaceae	H	HG	NA/CL
331	Bajri	Pearl millet	*Pennisetum glaucum* (L.) R.Br.	Poaceae	S	HG	NA/CL
332	Hatti Gavat	Elephant Grass	*Pennisetum purpureum* L.	Poaceae	S	HG	NA/CL

Sr.	Vernacular Name	Common Name	Scientific Name	Family	Type	Habitat	IUCN status
333	Uoos/Sherdi	Sugar cane	*Saccharum officinarum*	Poaceae	S	HG	NA/CL
334	Lygodium	Lygodium	*Lygodium flexuosum*	Polipodiaceae	C	F	NA/NCL
335	Bor	Ber	*Ziziphus mauritiana* Lam.	Rhaminaceae	T	F, MF, HG	NA/CL
336	Toran/ Churan	Wild Jujube	*Ziziphus rugosa*	Rhamnaceae	S	F	NA/NCL
337	Ran bor	Wild Ber	*Ziziphus spp.*	Rhamnaceae	S	F	NA/NCL
338	Zumbar	Black Mangrove	*Bruguiera gymnorrhiza* (L.) Lam.	Rhizophoraceae	T	MF	NA/CL
339	Tagal	Yellow Mangrove	*Ceriops tagal*	Rhizophoraceae	T	MF	LC
340	Kandal	Kandal	*Kandelia candel*	Rhizophoraceae	T	MF	LC
341	Mangrove	Tall- stilt/ True Mangrove	*Rhizophora apiculata*	Rhizophoraceae	T	MF	LC
342	Red Mangrove	Red Mangrove	*Rhizophora mangle*	Rhizophoraceae	T	MF	LC
343	Kamo/ Bogo	Asiatic Mangrove	*Rhizophora mucronata*	Rhizophoraceae	T	MF	LC
344	Gulab	Rose	*Rosa*	Rosaceae	H	HG	NA/CL
345	Poripath/ Pittapapda	Diamond Flower	*Oldenlandia corymbosa*	Rubiaceae	H	F	NA/CL
346	Ghela/ Khajkanda	Spiny Randia	*Catunaregam spinosa* Thunb.	Rubiaceae	S	F	NA/CL
347	Bakara/ Devari	Jungle geranium	*Ixora coccinea* L.	Rubiaceae	S	F	NA/CL
348	Sarvad/ Bhutkes	Mussaenda	*Mussaenda glabrata* Hook.f.	Rubiaceae	S	F	NA/CL
349	Pendro	Indian Boxwood	*Gardinia latifolia*	Rubiaceae	T	F	NA/NCL
350	Malwa/ Lokhandi	Malwa	*Ixora brachiata* Roxb.	Rubiaceae	T	F	NA/CL
351	Alu	Muyna	*Meyna laxiflora* Pobyns.	Rubiaceae	T	F	NA/CL
352	Bartondi/ Noni	Indian Mulberry	*Morinda citrifolia* L.	Rubiaceae	T	F	NA/CL

Sr.	Vernacular Name	Common Name	Scientific Name	Family	Type	Habitat	IUCN status
353	Kadam	Kadam	*Neolamarckia cadamba* (Roxb.) Bosser	Rubiaceae	T	F	NA/CL
354	Hed/ Hedu	Haldu	*Haldina cordifolia* (Roxb.) Ridsdsle	Rubiaceae	T	HG	NA/CL
355	Kalam/kadam	Kaim	*Mitragyna parvifolia* (Roxb.) Korth.	Rubiaceae	T	HG	NA/CL
356	Treeisal/ Treeirphal	Indian Prickly Ash	*Zanthoxylum rhetsa*	Rutaceae	T	F, HG	NA/NCL
357	Bel	Bel	*Aegle marmelos* (L.) Corr. Serr.	Rutaceae	T	HG	NA/CL
358	Limbu	Lemon	*Citrus aurantifolia* Christm.	Rutaceae	T	HG	NA/CL
359	Torinjan	Pomelo	*Citrus maxima* (Burm.f) Merr.	Rutaceae	T	HG	NA/CL
360	Mosambi	Orange	*Citrus spp.*	Rutaceae	T	HG	NA/CL
361	Kadipatta	Sweet neem	*Murraya koenigii*	Rutaceae	T	HG	NA/CL
362	Khakan	Mustard tree	*Salvadora persica*	Salvadoraceae	S	MF	NA/NCL
363	Chimat	Wild Tea	*Osyris quadripartite*	Santalaceae	S	F	NA/NCL
364	Tipani	Indian Allophylus	*Allophylus cobbe*	Sapindaceae	S	F	NA/NCL
365	Kapalphodi	Balloon Vine	*Cardiospermum halicacabum* L.	*Sapindaceae*	C	F, CP	NA/CL
366	Ritha/ Ringi	Soapnut	*Sapindus mukorossi* Gaertner.	Sapindaceae	T	HG	NA/CL
367	Katekumbal	Hairy Xantolis	*Xantolis tomentosa* (Roxb.) Raf.	Sapotaceae	T	F	NA/CL
368	Chiku	Chikoo	*Manilkara zapota* (L.) P. Royea.	Sapotaceae	T	HG	NA/CL
369	Undir kani	Mouse hairs	*Centranthera indica*	Scrophulariaceae	H	F	LC
370	Tutari	Tutari	*Rhamphicarpa longifolia*	Scrophulariaceae	H	F	NA/NCL
371	Dudhali	Common Sopubia	*Sopubia delphinifolia*	Scrophulariaceae	H	F	NA/NCL
372	Dudhani	Split Leaf Sopubia	*Sopubia trifida*	Scrophulariaceae	H	F	NA/NCL

Sr.	Vernacular Name	Common Name	Scientific Name	Family	Type	Habitat	IUCN status
373	Bambaku	Cowpea Witchweed	*Striga gesnerioides* (Willd.) Vatke.	Scrophulariaceae	H	F	NA/CL
374	Mahaneem	Indian Tree of Heaven	*Ailanthus excelsa*	Simaroubaceae	T	F	NA/NCL
375	Mothi Popti	Ground Cherry	*Physalis minima* L.	Solanaceae	H	F	NA/CL
376	Ranwangi	Wild Brinjal	*Solanum angui*	Solanaceae	S	F	NA/NCL
377	Mirchi	Chilli	*Capsicum frutescens*	Solanaceae	H	HG	NA/NCL
378	Dhotra	Devil's Trumpet/ Datura	*Datura metel* auct. non.L.	Solanaceae	H	HG	NA/CL
379	Wangi	Brinjal	*Solanum melongena* L.	Solanaceae	H	HG	LC
380	Kandal/ Chipi	Crabapple Mangrove	*Sonneratia caseolaris*	Sonneratiaceae	T	MF	LC
381	Gooseweed	Chickenspike	*Sphenoclea zeylanica*	Sphenocleaceae	S	F	NA/NCL
382	Bharkoi,supli	Scarlet Sterculia	*Firmiana CLorata*	Sterculiaceae	T	F	NA/NCL
383	Murudsheng	Indian screw tree	*Helicteres isora*	Sterculiaceae	S	F, HG	NA/NCL
384	Pandhruk	Naked Lady Tree	*Sterculia urens* Roxb.	Sterculiaceae	T	F, HG	NA/CL
385	Ziprya/ Devkand	Indian arrowroot	*Tacca leontoletaloides*	Taccaceae	H	F, CP, HG	NA/NCL
386	Chikat gunda	Thinjhira	*Triumfetta rhobidea*	Tiliaceae	H	F	NA/NCL
387	Khatkhati	Donkey Berry	*Grewia flavescens*	Tiliaceae	T	F	NA/NCL
388	Dhaman	Dhaman	*Grewia tiliifolia*	Tiliaceae	T	F	NA/NCL
389	Hasoli/ Shiral	Microcos	*Microcos paniculata*	Tiliaceae	S	F, HG	NA/NCL
390	Sangam/ Vanjai	Wild Jasmine	*Clerodendrum inerme* (L.) Gaertn.	verbanaceae	S	MF	NA/CL
391	Lingad	Chasteberry	*Vitex trifolia* L.	Verbenaceae	T	F	NA/CL
392	Ghaneri	Lantana	*Lantana camara* L.	Verbenaceae	S	F, CP, HG	NA/CL

Sr.	Vernacular Name	Common Name	Scientific Name	Family	Type	Habitat	IUCN status
393	Bharangi	Blue Fountain Bush	*Clerodendrum serratum*	Verbenaceae	S	F, HG	NA/NCL
394	Shivan	Gamhar	*Gmelina arborea* Roxb.	Verbenaceae	T	F, HG	NA/CL
395	Sag/ Sagwan	Treeeak	*Tectona grandis* L.f.	Verbenaceae	T	F, HG	NA/CL
396	Nirgudi	Chaste tree	*Vitex negundo* L.	Verbenaceae	S	F, MF, HG	NA/CL
397	Bhat Mogra	Glory tree	*Clerodendrum chinense* (Osb.) Mabb.	Verbenaceae	S	HG	NA/CL
398	Tushar	Pagpda flower	*Clerodendrum paniculatum*	Verbenaceae	S	HG	NA/NCL
399	Narvel	Agnimantha	*Premna mucronata*	Verbenaceae	S	HG	NA/NCL
400	Raan Drakshe	Wild Grape	*Ampelocissus erioclada*	Vitaceae	C	F	NA/NCL
401	Raan drakshe	Wild Grape	*Ampelocissus latifolia*	Vitaceae	C	F	NA/NCL
402	Ambat vel	Three-leaved wild vine	*Cayratia trifolia* (L.) Domin.	Vitaceae	C	F	NA/CL
403	Cissus	Cissus	*Cissus repens* Lam.	Vitaceae	C	F, CP	NA/CL
404	Nilgiri Haldai	Nilgiri Turmeric	*Curcuma neilgherrensis* Wight.	Zingiberaceae	H	F	NA/CL
405	Raan halad	Wild Turmeric	*Curcuma pseudomontana* J. Graham.	Zingiberaceae	H	F	NA/CL
406	Halad	Turmeric	*Curcuma longa* L.	Zingiberaceae	H	HG	NA/CL
407	Sontakke	Butterfly Ginger Lily	*Hedychium coronarium* J. Koning.	Zingiberaceae	H	HG	NA/CL

8.2 Appendix II: Mode of regeneration and use of the plant species recorded in Homegardens.

Sr.	Local Name	Common Name	Type	Mode of regeneration	Utilization
1	Aboli	Crossandra	H	Cultivated	Ornamental
2	Ghonas pan	Snake Plant	H	Cultivated	Ornamental, medicinal
3	Lili	Spider Lily	H	Cultivated	Ornamental
4	Hirva Chafa	Green chapha	T	Cultivated	Medicinal
5	Ashok	Ashok	T	Cultivated	Ornamental
6	Tagar	Crape jasmine	S	Cultivated	Ornamental
7	Anant	Carnation of India	S	Cultivated	Ornamental
8	Karnchafa	Lucky Nut	T	Cultivated	Ornamental, medicinal
9	Supari	Areca nut	T	Cultivated	Fruit, ornamental
10	Naral	Coconut	T	Cultivated	Fruit, ornamental
11	Zendu	Marigold	H	Cultivated	Ornamental
12	Suryaphul	Sunflower	S	Cultivated	Vegetable
13	Ananas	Pineapple	H	Cultivated	Fruit
14	Ratrani	Hedge Cactus	S	Cultivated	Ornamental
15	Gulmohar	Flame Tree	T	Cultivated	Ornamental
16	Sagar Gota	bonduc nut	C	Cultivated	Medicinal, fencing
17	Pandhara mandar	Dwarf white bauhinia	T	Cultivated	Medicinal, ornamental
18	Suru	*Casuarina*	T	Cultivated	Ornamental, timber
19	Nag champa	Indian rose chestnut	T	Cultivated	Medicinal, ornamental

Sr.	Local Name	Common Name	Type	Mode of regeneration	Utilization
20	Badam	Indian Almond	T	Cultivated	Ornamental
21	Kalingad	Watermelon	C	Cultivated	Fruit
22	Tondli	Ivy Gourd	C	Cultivated	Vegetable
23	Kakdi	Cucumber	C	Cultivated	Vegetable
24	Kashi Bhopla	Pumpkin	C	Cultivated	Vegetable
25	Bhopla	Bottle Gourd	C	Cultivated	Vegetable
26	Dodka	Ribbed Sponge Gourd	C	Cultivated	Vegetable
27	Ghosale	Sponge Gourd	C	Cultivated	Vegetable
28	Karle	Bitter gourd	C	Cultivated	Vegetable, medicinal
29	Mayur Pankhi	Morpankhi	T	Cultivated	Ornamental
30	Chin/ Kondfal	Aerial Yam	C	Cultivated	Medicinal
31	Acalypha	Cat's tail	S	Cultivated	Ornamental
32	Copperleaf	Copperleaf	S	Cultivated	Ornamental
33	Sher	Pencil tree	T	Cultivated	Medicinal
34	Parjyanyavriksha	Rain Tree	T	Cultivated	Ornamental
35	Bhuimung	Ground nut	H	Cultivated	Vegetable
36	Harbhara	Chickpea	H	Cultivated	Vegetable
37	Tur	Pigeon Pea	S	Cultivated	Vegetable
38	Hatga	Agati	T	Cultivated	Vegetable, ornamental
39	Chimni pakhare	Hanging heliconia	S	Cultivated	Ornamental, medicinal

Sr.	Local Name	Common Name	Type	Mode of regeneration	Utilization
40	Tamalpatra	Indian Bay Leaf	T	Cultivated	Spice crop, medicinal, ornamental
41	Dalchini	Cinnamon	T	Cultivated	Spice crop, medicinal, ornamental
42	May flower	Purple Mayflower	H	Cultivated	Ornamental
43	Kavti chafa	Champak	T	Cultivated	Medicinal, ornamental
44	Sonchafa	Champak	T	Cultivated	Medicinal, ornamental
45	Bhendi	Ladies Finger	H	Cultivated	Vegetable
46	Kapus/ Kapas	Cotton	S	Cultivated	Ornamental
47	Limb	Neem	T	Cultivated	Medicinal, ornamental
48	Australian Babul	Norther Black Wattle	T	Cultivated	Ornamental
49	Vilayti Phanas	Breadfruit	T	Cultivated	Medicinal
50	Rabracho-vad	Rubber Tree	T	Cultivated	Ornamental
51	Shevga	Drumstick tree	T	Cultivated	Vegetable, medicinal
52	Nutmeg	Jaiphal	T	Cultivated	Spice crop, medicinal, ornamental
53	Allspice	Jamaica pepper	T	Cultivated	Spice crop, medicinal, ornamental
54	Peru	Guava,	T	Cultivated	Fruit
55	Lavang	Clove	T	Cultivated	Spice crop
56	Jam	Malabar plum	T	Cultivated	Fruit, medicinal
57	Booganvel	Bougainvillea	C	Cultivated	Ornamental
58	Kunda/ Mukunda	Star jasmine	S	Cultivated	Medicinal, ornamental
59	Chameli	Jasmine	S	Cultivated	Medicinal, ornamental

Sr.	Local Name	Common Name	Type	Mode of regeneration	Utilization
60	Mogra	Arabian Jasmine	S	Cultivated	Ornamental
61	Awala	Indian gooseberry	T	Cultivated	Medicinal, fruit
62	Christmas Tree	Christmas Tree	T	Cultivated	Ornamental
63	Pimpli	Indian long pepper	C	Cultivated	Spice crop
64	Kalimiri	Black Pepper	C	Cultivated	Spice crop
65	Gavti chaha	Lemon Grass	H	Cultivated	Medicinal, ornamental
66	Rice	Bhat	H	Cultivated	Food
67	Khas/ Vala	Khus grass	H	Cultivated	Medicinal, ornamental
68	Maka	Maize	H	Cultivated	Fodder, food
69	Bajri	Pearl millet	S	Cultivated	Ornamental
70	Hatti Gavat	Elephant Grass	S	Cultivated	Fodder, ornamental
71	Uoos/Sherdi	Sugar cane	S	Cultivated	Ornamental
72	Gulab	Rose	H	Cultivated	Ornamental
73	Limbu	Lemon	T	Cultivated	Fruit
74	Torinjan	Pomelo	T	Cultivated	Fruit, medicinal
75	Mosambi	Orange	T	Cultivated	Fruit, ornamental
76	Chiku	Chikoo	T	Cultivated	Fruit
77	Mirchi	Chilli	H	Cultivated	Vegetable
78	Wangi	Brinjal	H	Cultivated	Vegetable
79	Bhat Mogra	Glory tree	S	Cultivated	Ornamental, medicinal

Sr.	Local Name	Common Name	Type	Mode of regeneration	Utilization
80	Tushar	Pagpda flower	S	Cultivated	Ornamental
81	Narvel	Agnimantha	S	Cultivated	Medicinal
82	Dhotra	Devil's Trumpet/ Datura	H	Natural regeneration	Medicinal
83	Dashmuli	Blue eranthemum	H	Natural regeneration	Medicinal
84	Jambhali Koranti	Mayurpankh	S	Natural regeneration	Medicinal
85	Kate Koranti	Spiny Barleria	S	Natural regeneration	Medicinal
86	Math	Green Amaranth	H	Natural regeneration	Vegetable
87	Moya/ Shimti	Indian Ash Tree	T	Natural regeneration	Medicinal
88	Bibba/ Bhilava	Marking Nut	T	Natural regeneration	Medicinal
89	Ambada	Wild Mango	T	Natural regeneration	Medicinal
90	Karvanda	Karonda	S	Natural regeneration	Fruit
91	Nagal Kuda	Nag Kuda	T	Natural regeneration	Medicinal
92	Alu	Green Taro	H	Natural regeneration	Vegetable
93	Ran Suran	Wild Yam	S	Natural regeneration	Vegetable, medicinal
94	Anantmul	Indian Sarsaparilla	C	Natural regeneration	Medicinal
95	Madar/ Rui	Rubber bush	S	Natural regeneration	Medicinal
96	Rui	Rubber bush	S	Natural regeneration	Medicinal
97	Kavali	Indian sarsaparilla	C	Natural regeneration	Medicinal
98	Sontar	Sonki	H	Natural regeneration	Ornamental
99	Terda	Balsum plant	H	Natural regeneration	Medicinal, ornamental

Sr.	Local Name	Common Name	Type	Mode of regeneration	Utilization
100	Lal terda	Rosemary Leaved Balsam	H	Natural regeneration	Medicinal, ornamental
101	Kate Savar	Silk Cotton Tree	T	Natural regeneration	Medicinal
102	Trichodesma	Clasping-Leaf Borage	H	Natural regeneration	Medicinal
103	Takla	Takala	H	Natural regeneration	Medicinal
104	Lahan pivla gulmohar	Candle bush	S	Natural regeneration	Medicinal, ornamental
105	Surangi	Surangi	T	Natural regeneration	Medicinal, ornamental
106	Ganesh vel	Star Glory	C	Natural regeneration	Ornamental
107	Kosta	Costus	H	Natural regeneration	Medicinal
108	Raan Dodka	Ribbed Sponge Gourd	C	Natural regeneration	Medicinal, vegetable
109	Ran tondla	Creeping Cucumber	C	Natural regeneration	Medicinal, vegetable
110	Karanda/ Dangkand	Aerial yam	C	Natural regeneration	Medicinal
111	KhajKhujlli/ Kevach	Velvet bean	C	Natural regeneration	Medicinal
112	Ran Ghevda	Wild Ghevada	C	Natural regeneration	Medicinal, vegetable
113	Bhut shevra	Loose Flowered Desmodium	H	Natural regeneration	Medicinal
114	Deepmal	Christmas candlestick	H	Natural regeneration	Medicinal
115	Dhinda	Bandicoot Berry	S	Natural regeneration	Medicinal
116	Ghot Vel	Kumarika	C	Natural regeneration	Medicinal
117	Kalalavi/ Kalihari	Glory Lily	C	Natural regeneration	Medicinal
118	Kajra	Poison Nut	T	Natural regeneration	Medicinal
119	Bala/ Chikna	Bala	H	Natural regeneration	Medicinal

Sr.	Local Name	Common Name	Type	Mode of regeneration	Utilization
120	Wichvi	Devil's Claws	H	Natural regeneration	Medicinal
121	Lajwanti	Touch me not plant	H	Natural regeneration	Medicinal
122	Bokhada	Devil Fig	T	Natural regeneration	Medicinal, fencing
123	Kharvat	Toothbrush tree	T	Natural regeneration	Medicinal
124	Lajalu/ Lajari	Tree Plant	H	Natural regeneration	Medicinal
125	Shaiche Zaad	Ink tree	S	Natural regeneration	Medicinal
126	Bhui awala	Madras Leaf-Flower	H	Natural regeneration	Medicinal
127	Shiteche pohe	Love grass	H	Natural regeneration	Grass, fodder
128	Bor	Ber	T	Natural regeneration	Medicinal, fencing, fruit
129	Treeisal/ Treeirphal	Indian Prickly Ash	T	Natural regeneration	Medicinal, timber
130	Murudsheng	Indian screw tree	S	Natural regeneration	Medicinal
131	Pandhruk	Naked Lady Tree	T	Natural regeneration	Medicinal, timber
132	Hasoli/ Shiral	Microcos	S	Natural regeneration	Medicinal, fencing
133	Ghaneri	Lantana	S	Natural regeneration	Medicinal, ornamental
134	Bharangi	Blue Fountain Bush	S	Natural regeneration	Medicinal, ornamental
135	Adulsa	Malabar nut	S	Natural regeneration/ cultivated	Medicinal, fencing
136	Rajgira	Love-lies-bleeding	H	Natural regeneration/ cultivated	Vegetable
137	Kaju	Cashew	T	Natural regeneration/ cultivated	Fruit
138	Amba	Mango	T	Natural regeneration/ cultivated	Fruit
139	Ram phal	Netted Custard Apple	T	Natural regeneration/ cultivated	Fruit

Sr.	Local Name	Common Name	Type	Mode of regeneration	Utilization
140	Shitaphal	Sugar Apple	T	Natural regeneration/ cultivated	Fruit
141	Sarpagandha	Indian Snakeroot	H	Natural regeneration/ cultivated	Medicinal
142	Sadaphuli	Periwinkle	H	Natural regeneration/ cultivated	Ornamental, medicinal
143	Pandra Kuda	Indrajao	S	Natural regeneration/ cultivated	Medicinal
144	Kanher	Nerium	T	Natural regeneration/ cultivated	Ornamental, medicinal
145	Pandra Chafa	White Plumeria	T	Natural regeneration/ cultivated	Ornamental
146	Chapha	Plumeria	T	Natural regeneration/ cultivated	Ornamental
147	Bherli mad	Fish Treeail Palm	T	Natural regeneration/ cultivated	Ornamental
148	Korphad	Aloe	S	Natural regeneration/ cultivated	Medicinal, ornamental
149	Tilgundi	Cosmos	H	Natural regeneration/ cultivated	Ornamental
150	Nivdung	Prickly Pear	S	Natural regeneration/ cultivated	Fencing, medicinal, ornamental
151	Apta	Bidi leaf Tree	T	Natural regeneration/ cultivated	Medicinal, ornamental
152	Kanchan	Orchid Tree	T	Natural regeneration/ cultivated	Medicinal, ornamental
153	Bhava	Amaltash	T	Natural regeneration/ cultivated	Medicinal, ornamental
154	Chinch	Treeamarind	T	Natural regeneration/ cultivated	Medicinal, fruit, timber
155	Shankasur	Peacock Flower	S	Natural regeneration/ cultivated	Medicinal, fencing, ornamental
156	Pivla Gulmohar	Copper pod	T	Natural regeneration/ cultivated	Medicinal, ornamental
157	Kardal	Indian Shot	S	Natural regeneration/ cultivated	Ornamental, medicinal, fencing
158	Papai	Papaya	T	Natural regeneration/ cultivated	Fruit
159	Ratamba	Kokum	T	Natural regeneration/ cultivated	Medicinal, fruit, ornamental

Sr.	Local Name	Common Name	Type	Mode of regeneration	Utilization
160	Arjun	Arjun	T	Natural regeneration/ cultivated	Timber, medicinal
161	Behra	Belliric Myrobalan	T	Natural regeneration/ cultivated	Medicinal
162	Aine	Indian Laurel	T	Natural regeneration/ cultivated	Medicinal, timber
163	Kinjal	Flowering Murdah	T	Natural regeneration/ cultivated	Medicinal, timber
164	Chibud	Wild Melon	C	Natural regeneration/ cultivated	Fruit
165	Padval	Snake Gourd	C	Natural regeneration/ cultivated	Vegetable
166	Ratanjyaot	Phisic nut	S	Natural regeneration/ cultivated	Fencing, medicinal, ornamental
167	Narashya	Cactus	S	Natural regeneration/ cultivated	Fencing, medicinal, ornamental
168	Chandvad	Chandada	T	Natural regeneration/ cultivated	Timber
169	Erand	Castor Bean	S	Natural regeneration/ cultivated	Medicinal, fodder
170	Asana	Spinous Kino Tree	T	Natural regeneration/ cultivated	Timber, medicinal
171	Pangara	Indian Coral Tree	T	Natural regeneration/ cultivated	Medicinal, timber
172	Subabul	Leucaena	T	Natural regeneration/ cultivated	Fodder, fuel
173	Giripushpa	Glirisidia	S	Natural regeneration/ cultivated	Medicinal, fencing, green manure
174	Raan Shevri	Sesban	S	Natural regeneration/ cultivated	Medicinal, green manure
175	Tulas/ Tulasi	Holy basil	H	Natural regeneration/ cultivated	Medicinal, ornamental
176	Kumbha	Wild Guava	T	Natural regeneration/ cultivated	Medicinal, timber, fuel
177	Mehandi	Henna	S	Natural regeneration/ cultivated	Medicinal, ornamental
178	Paras Bhendi	Indian tulip Tree	T	Natural regeneration/ cultivated	Ornamental
179	Jaswand	China rose	S	Natural regeneration/ cultivated	Ornamental

Sr.	Local Name	Common Name	Type	Mode of regeneration	Utilization
180	Khair	Cutch Tree	T	Natural regeneration/ cultivated	Medicinal
181	Vilayati chinch	Sweet tamarind	T	Natural regeneration/ cultivated	Medicinal, fruit
182	Phanas	Jackfruit	T	Natural regeneration/ cultivated	Fruit, timber
183	Payar	India Rock Fig	T	Natural regeneration/ cultivated	Ornamental, religious tree
184	Vad	Banyan tree	T	Natural regeneration/ cultivated	Ornamental, religious tree
185	Umbar	Cluster fig	T	Natural regeneration/ cultivated	Medicinal, religious tree
186	Rann keli	Wild Banana	S	Natural regeneration/ cultivated	Fruit
187	Keli	Banana	S	Natural regeneration/ cultivated	Fruit
188	Jambhul	Jamun	T	Natural regeneration/ cultivated	Fruit, medicinal, timber
189	Kamal/ Kumud	Water lily	H	Natural regeneration/ cultivated	Medicinal, ornamental
190	Prajakta	Tree of Sorrow	T	Natural regeneration/ cultivated	Medicinal, ornamental
191	Krisna Kamal	Passion flower	C	Natural regeneration/ cultivated	Medicinal, ornamental
192	Rai awala	Star Gooseberry	T	Natural regeneration/ cultivated	Medicinal
193	Chitrak	Plumbago	S	Natural regeneration/ cultivated	Medicinal
194	Bas	Bamboo	T	Natural regeneration/ cultivated	Ornamental
195	Hed/ Hedu	Haldu	T	Natural regeneration/ cultivated	Medicinal
196	Kalam/kadam	Kaim	T	Natural regeneration/ cultivated	Medicinal
197	Bel	Bel	T	Natural regeneration/ cultivated	Medicinal, religious tree, ornamental
198	Kadipatta	Sweet neem	T	Natural regeneration/ cultivated	Spice crop, ornamental
199	Ritha/ Ringi	Soapnut	T	Natural regeneration/ cultivated	Medicinal

Sr.	Local Name	Common Name	Type	Mode of regeneration	Utilization
200	Shivan	Gamhar	T	Natural regeneration/ cultivated	Medicinal, timber
201	Sag/ Sagwan	Treeeak	T	Natural regeneration/ cultivated	Timber
202	Nirgudi	Chaste tree	S	Natural regeneration/ cultivated	Medicinal, fencing
203	Halad	Turmeric	H	Natural regeneration/ cultivated	Medicinal, spice crop
204	Sontakke	Butterfly Ginger Lily	H	Natural regeneration/ cultivated	Ornamental, medicinal
205	Suran	Elephant foot Yam	S	Natural regeneration/ cultivated	Vegetable, medicinal
206	Chini Gulab	Beauty-of-the-night	H	Natural regeneration/ cultivated	Ornamental, medicinal

8.3 Appendix III: Vegetation component wise list of the species with highest and lowest IVI values the forest land-use type

	Tree		Shrub		Herb		Climber	
Sr.	**Species**	**IVI**	**Species**	**IVI**	**Species**	**IVI**	**Species**	**IVI**
1	*Terminalia paniculata*	31.82	*Abelmoschus lampus*	30.89	*Cassia tora*	21.74	*Hemidesmus indicus*	34.46
2	*Bridelia retusa*	25.02	*Holarrhena pubescens*	30.56	*Daedalcanthus roseum*	14.91	*Smilax ovalifolia*	34.18
3	*Memecylon umbellatum*	19.74	*Leea macrophylla*	28.09	*Senecio bombayensis*	14.63	*Dioscorea bulbifera*	29.38
4	*Terminalia elliptica*	17.60	*Carissa congesta*	21.92	*Impatiens tomentosa*	13.98	*Calycopteris floribunda*	27.31
5	*Ficus benghalensis*	17.57	*Ixora coccinea*	17.66	*Euphorbia concanensis*	12.36	*Jasminum malabaricum*	24.97
6	*Morinda citrifolia*	13.72	*Helicteres isora*	17.58	*Urena sinuata*	7.90	*Tylophora dalzellii*	23.86
7	*Mangifera indica*	11.14	*Microcos paniculata*	13.75	*Tacca leontoletaloides*	7.69	*Mucuna pruriens*	17.62
8	*Acacia catechu*	10.73	*Lantana camara*	12.54	*Nephrolepis spp.*	7.04	*Solena amplexicaulis*	16.47
9	*Strychnos nux-vomica (L.)*	10.71	*Desmodium gangeticum*	11.22	*Sida rhombifolia*	6.25	*Abrus precatorius*	13.68
10	*Careya arborea*	10.34	*Ziziphus rugosa*	10.72	*Cyperus rotundus L.*	0.90	*Gloriosa superb*	13.16
11	*Zanthoxylum rhetsa*	10.33	*Barleria prionitis*	2.51	*Evolvulus alsinoides*	0.90	*Merremia vitifolia*	11.72
12	*Buchanania lanzan*	10.03	*Calotropis gigantean*	2.36	*Acalypha lanceolata Willd.*	0.90	*Asparagus racemosus*	11.61
13	*Eucalyptus globulus*	0.35	*Chromolaena odorata*	2.25	*Rauvolfia serpentine*	0.90	*Ipomoea pes-tigridis*	2.34
14	*Casuarina equisetifolia*	0.35	*Solanum angui*	2.25	*Barleria cuspidate*	0.90	*Operculina turpethum*	2.34
15	*Delonix regia*	0.35	*Phyllanthus reticulatus*	1.65	*Ammannia muliflora*	0.64	*Thunbergia fragrans*	2.34
16	*Trema orientalis*	0.31	*Cassia alata*	1.65	*Martynia annua*	0.64	*Canavalia lineata*	1.79
17	*Acacia nilotica*	0.29	*Sphenoclea zeylanica*	1.36	*Oldenlandia corymbosa*	0.64	*Ipomoea nil*	1.79
18	*Casearia ovate*	0.29	*Cassia occidentalis*	1.36	*Fimbristylis littoralis*	0.64	*Cissus repens*	1.79

	Tree		Shrub		Herb		Climber	
Sr.	**Species**	**IVI**	**Species**	**IVI**	**Species**	**IVI**	**Species**	**IVI**
19	*Acacia farnesiana*	0.27	*Woodfordia fruticosa*	1.36	*Physalis minima*	0.64	*Convolvulus arvensis*	1.79
20	*Azadirachta indica*	0.27	*Justicia adhatoda*	1.36	*Abutilon indicum (L.) Sweet*	0.64	*Dioscorea pentaphylla*	1.79
21	*Gardinia latifolia*	0.27	*Barleria involucrate*	1.36	*Tephrosia tinctoria*	0.64	*Holostemma annulare*	1.79
22	*Xantolis tomentosa*	0.26	*Mussaenda glabrata*	1.36	*Impatiens oppositifolia*	0.64	*Argyreia elliptica*	1.79
23	*Ficus hispida*	0.26	*Opuntia elatior*	1.36	*Sopubia trifida*	0.64	*Derris elliptica*	1.79
24	*Erythrina variegate*	0.26	*Ensete superbum*	1.36	*Mimosa pudica*	0.64	*Luffa acutangula*	1.79
25	*Annona reticulate*	0.26	*Osyris quadripartite*	1.36	*Tephrosia purpurea*	0.64	*Trichosanthes nervifolia*	1.79

8.4 Appendix IV: Vegetation componenet wise list of the the species with highest and lowest IVI values the homegardens

	Tree		Shrub		Herb		Climber	
Sr.	**Species**	**IVI**	**Species**	**IVI**	**Species**	**IVI**	**Species**	**IVI**
1	*Cocos nucifera*	22.34	*Jatropha curcas*	23.20	*Colocasia esculenta*	21.36	*Hemidesmus indicus*	30.24
2	*Mangifera indica*	15.03	*Musa paradisiaca*	22.21	*Tagetes erecta*	14.94	*Trichosanthes cucumerina*	21.76
3	*Dendrocalamus strictus*	13.52	*Hibiscus rosa-sinensis*	17.07	*Oryza sativa*	14.26	*Piper longum*	19.48
4	*Psidium guajava*	10.06	*Gliricidia sepium*	16.03	*Impatiens oppositifolia*	11.30	*Piper nigrum*	19.27
5	*Areca catechu*	8.89	*Justicia adhatoda*	14.76	*Arachis hypogaea*	11.29	*Cucumis sativus*	18.60
6	*Anacardium occidentale*	8.01	*Cajanus cajan*	12.48	*Ananas comosus*	10.20	*Smilax ovalifolia*	16.96
7	*Artocarpus heterophyllus*	7.90	*Euphorbia antiquorum*	9.75	*Senecio bombayensis*	7.07	*Momordica charantia*	13.63
8	*Garcinia indica*	6.98	*Leea indica*	9.71	*Solanum melongena*	5.82	*Cucumis melo ssp. agrestis*	11.77

	Tree		Shrub		Herb		Climber	
Sr.	**Species**	**IVI**	**Species**	**IVI**	**Species**	**IVI**	**Species**	**IVI**
9	*Murraya koenigii*	6.93	*Canna indica*	8.97	*Pennisetum glaucum*	5.41	*Luffa acutangula*	11.58
10	*Tectona grandis*	5.96	*Tabernaemontana divaricata*	8.78	*Cosmos spp.*	4.89	*Paracalyx scariosus*	10.71
11	*Moringa oleifera*	5.65	*Helianthus annuus*	8.48	*Nymphaea pubescens*	4.77	*Bougainvillea glabra*	10.55
12	*Manilkara zapota*	5.54	*Amorphophallus paeonifolius*	7.24	*Hedychium coronarium*	4.60	*Phyllanthus reticulatus*	9.51
13	*Spondias pinnata*	1.34	*Tabernaemontana spp.*	7.13	*Sansevieria trifasciata*	4.29	*Cucurbita pepo*	9.47
14	*Artabotrys hexapetalus*	1.34	*Amorphophallus*	3.31	*Amaranthus caudatus*	3.82	*Gloriosa superba*	8.90
15	*Bauhinia acuminata*	1.34	*Barleria cuspidata*	3.30	*Costus speciosus*	3.74	*Ipomoea quamoclit*	8.73
16	*Careya arborea*	1.34	*Caesalpinia pulcherrima*	3.30	*Desmodium laxiflorum*	3.68	*Lagenaria siceraria*	8.73
17	*Magnolia champaca*	1.34	*Helicteres isora*	3.30	*Trichodesma inaequale*	3.60	*Mucuna pruriens*	8.50
18	*Ficus elastic*	1.34	*Cassia alata*	2.92	*Datura metel*	2.75	*Citrullus lanatus*	8.31
19	*Ficus bengalensis*	1.34	*Acalypha wilkesiana*	2.85	*Martynia annua*	2.65	*Luffa aegyptiaca*	8.13
20	*Haldina cordifolia*	1.34	*Lantana camara*	2.85	*Leonotis nepetifolia*	2.47	*Dioscorea bulbifera*	8.13
21	*Mitragyna parvifolia*	1.34	*Opuntia elatior*	2.16	*Rauvolfia serpentina*	2.42	*Caesalpinia bonduc*	8.13
22	*Casuarina equisetifolia*	1.08	*Sesbania bispinosa*	2.16	*Hymenocallis littoralis*	2.21	*Coccinia grandis*	7.14
23	*Terminalia arjuna*	1.08	*Microcos paniculata*	1.73	*Cymbopogon citratus*	1.81	*Passiflora edulis*	6.44
24	*Terminalia paniculata*	1.08	*Clerodendrum chinense*	1.73	*Maianthemum purpureum*	1.53	*Solena amplexicaulis*	5.81
25	*Artocarpus altilis*	1.08	*Premna mucronata*	1.31	*Vetiveria zizanioides*	1.50	*Dioscoria alata*	5.24

8.5 Appendix V: Vegetation component wise list of the species with highest and lowest IVI values in thethe mangrove

	Tree				Shrub		Climber	
Sr.	**Species**	**IVI**	**Species**	**IVI**	**Species**	**IVI**	**Species**	**IVI**
1	*Sonneratia caseolaris*	40.60	*Rhizophora apiculata*	19.22	*Acanthus ilicifolius*	158.18	*Caesalpinia crista (L.)*	106.83
2	*Avicennia officinalis*	37.88	*Ceriops tagal*	10.63	*Crotalaria verrucosa*	47.59	*Cryptolepis buchananii*	73.40
3	*Excoecaria agallocha (L.)*	31.67	*Kandelia candel*	6.91	*Clerodendrum inerme*	40.52	*Derris scandens*	65.07
4	*Aegiceras corniculatum*	27.74	*Thespesia populnea*	6.50	*Salvadora persica*	31.14	*Mucuna pruriens*	54.73
5	*Rhizophora mucronata*	26.81	*Hibiscus tiliaceus*	5.89	*Vitex negundo*	22.57		
6	*Bruguiera gymnorrhiza*	23.71	*Ziziphus mauritiana*	5.69				
7	*Avicennia marina*	21.54	*Calophyllum inophyllum*	5.49				
8	*Rhizophora mangle*	20.94	*Cordia dichotoma*	3.25				

8.6 Appendix VI: Vegatation component wise list of the S species with highest and lowest IVI values the casuarina plantation

	Shrub		Herb				Climber	
Sr.	Species	IVI	Species	IVI	Species	IVI	Species	IVI
1	*Calotropis procera*	79.54	*Sonchus oleraceus*	57.52	*Impatiens balsamina*	12.70	*Ipomoea pes-caprae*	64.81
2	*Chromolaena odorata*	53.38	*Sonchus asper*	37.39	*Sida cordifolia*	12.70	*Hemidesmus indicus*	33.05
3	*Desmodium gangeticum*	52.72	*Achyranthes aspera*	25.78	*Commelina forsskalaei*	12.04	*Tylophora dalzellii*	25.74
4	*Calotropis gigantean*	45.34	*Cynodon dactylon*	18.48	*Urena sinuata*	12.04	*Cucumis setosus*	23.72
5	*Lantana camara*	28.98	*Arisaema tortuosum*	14.76	*Biophytum sensitivium*	12.04	*Dioscorea bulbifera*	20.72
6	*Barleria prionitis*	20.02	*Cassia tora*	14.76	*Setaria verticillata*	12.04	*Smilax ovalifolia*	20.72
7	*Jatropha curcas*	20.02	*Utricularia graminifolia*	14.76	*Crotolaria verrucosa L.*	9.48	*Mucuna pruriens*	14.94
8			*Eragrostis unioloides*	14.76	*Drimia indiaca*	6.25	*Cocculus hirsutus*	11.68

8.7 Appendix VII: Bird survey data sheet (Point transect survey)

Season……………………	Land-use/ habitat……..…	Transect number……………
Village……………………	Waypoint………………..	Date……/……/……………..
Start time…..End time……	Number of species………	Total number of birds……….
GPS location 16^0……………………..N and 73^0………………………E		

Point	Sr.	Name of species	Number/ occurrence	Radial distance
1	1			
	2			
	3			
	4			
	5			
	6			
	7			
	8			
2	1			
	2			
	3			
	4			
	5			
	6			
	7			
	8			
3	1			
	2			
	3			
	4			
	5			
	6			
	7			
	8			
4	1			
	2			
	3			
	4			
	5			
	6			
	7			
	8			
	9			
5	1			
	2			
	3			
	4			
	5			
	6			
	7			

8.8 Appendix VIII: List of species with their local name, scientific name, family, IWPA (1972) schedule status and abundance status of birds recorded in the study area

Sr.	Common Name	Vernacular Name	Scientific Name	Family	IWPA status	Abundance	IUCN status
1	Asian Koel	Kokil/ Kokila	*Eudynamys scolopaceus* (Linnaeus, 1758)	Cuculidae	IV^{th}	A	LC
2	Asian Paradise-flycatcher	Banpakhroo	*Terpsiphone paradisi* (Linnaeus, 1758)	Monarchidae	IV^{th}	UC	LC
3	Bank Myna	Bank Myna	*Acridotheres ginginianus* (Latham, 1790)	Sturnidae	IV^{th}	R	LC
4	Baya Weaver	Sugran	*Ploceus philippinus* (Linnaeus, 1766)	Ploceidae	IV^{th}	A	LC
5	Black Bulbul	Kala Bulbul	*Hypsipetes leucocephalus* (Gmelin, 1789)	Pycnonotidae	IV^{th}	C	LC
6	Black Drongo	Kotwal	*Dicrurus macrocercus* (Vieillot, 1817)	Dicruridae	IV^{th}	A	LC
7	Black-Hooded Oriole	Kala-Dokya Haldya	*Oriolus xanthornus* (Linnaeus, 1758)	Oriolidae	IV^{th}	O	LC
8	Black Kite	Ghar	*Milvus migrans* (Boddoert, 1783)	Accipitridae	IV^{th}	A	LC
9	Black shouldered	Kapsi	*Elanus caeruleus* (Desfontaines, 1789)	Accipitridae	IV^{th}	A	LC
10	Blue-Capped Redstart	Blue-Capped Redstart	*Phoenicurus coeruleocephala* (Vigors, 1831)	Muscicapidae	IV^{th}	UC	LC
11	Blue-Rock Pigeon	Parwa	*Columba livia* (Gmelin, 1789)	Columbidae	IV^{th}	O	LC
12	Ruddy Shelduck	Brahmani Badak	*Tadorna ferruginea* (Pallas, 1764)	Anatidae	IV^{th}	CO	LC
13	Brahminy Kite	Brahminy Ghar	*Haliastur indus* (Boddoert, 1783)	Accipitridae	IV^{th}	A	LC
14	Brahminy Starling	Bamani Myna	Sturnus pagodarum (Gmelin, 1789)	Sturnidae	IV^{th}	C	LC
15	Brainfever Bird	Pawasha	*Cuculus varius* (Vahl, 1797)	Cuculidae	IV^{th}	UC	LC
16	Brown Fish-Owl	Hooman	*Ketupa zeylonensis* (Gmelin, 1788)	Strigidae	IV^{th}	UC	LC
17	Brown-Headed Barbet	Kartuk	*Megalaima zeylanica* (Gmelin, 1788)	Capitonidae	IV^{th}	A	LC
18	Cattle egret	Gai Gagla	*Bubulcus ibis* (Linnaeus, 1758)	Ardeidae	IV^{th}	C	LC

Sr.	Common Name	Vernacular Name	Scientific Name	Family	IWPA status	Abundance	IUCN status
19	Cliff Swallows	Pakoli	*Hirundo fluvicola* (Blyth, 1855)	Hirundinidae	IVth	C	LC
20	Common Barn Swallow	Pakoli	*Hirundo rustica* (Linnaeus, 1758)	Hirundinidae	IVth	C	LC
21	Common Iora	Subhaga	*Aegithina tiphia* (Linnaeus, 1758)	Aegithinidae	IVth	C	LC
22	Common Kestrel	Kharuchi	*Falco tinnunculus* (Linnaeus, 1758)	Falconidae	IVth	V	LC
23	Indian Myana	Salunkhi	*Acridotheres tristis* (Linnaeus, 1766)	Sturnidae	IVth	A	LC
24	Common Redshank	Raktasurama	*Tringa tetanus* (Linnaeus, 1758)	Scolopacidae	IVth	C	LC
25	Common Rosefinch	Gulabi chimni	*Carpodacus erythrinus* (Pallas, 1770)	Fringillidae	IVth	UC	LC
26	Common Sandpiper	Tutwar	*Actitis hypoleucos* (Linnaeus, 1758)	Scolopacidae	IVth	C	LC
27	Common Stone Chat	Rangeet Vatvatya	*Saxicola torquatus* (Linnaeus, 1766)	Muscicapidae	IVth	O	LC
28	Common wood Shrike	Raan Khatik	*Tephrodornis pondicerianus* (Gmelin, 1789)	Campephagidae	IVth	C	LC
29	Coppersmith Barbet	Tambat	*Megalaima haemacephala* (Muller, 1776)	Ramphastidae	IVth	C	LC
30	Crested Hawk Eagle	Mor Ghaar	*Nisaetus cirrhatus* (Gmelin, 1788)	Accipitridae	Ist	C	LC
31	Crested Honey Buzzard	Madhadya Garud	*Pernis ptilorhyncus* (Temminck, 1821)	Accipitridae	IVth	UC	LC
32	Crested Serpent-Eagle	Panghada	*Spilornis cheela* (Latham, 1790)	Accipitridae	IVth	R	LC
33	Crested T Swift	Turebaaz Pangali	*Hemiprocne coronata* (Tickell, 1833)	Hermiprocnidae	IVth	UC	LC
34	Dusky Crag-martin	Duskey Swallows	*Hirundo concolor* (Skyes, 1832)	Hirundinidae	IVth	C	LC
35	Common Chiffchaff	Panphukti	*Phylloscopus collybita* (Vieillot, 1817)	Sylvidae	IVth	UC	LC
36	Emerald Dove	Bhil Kavda	*Chalcophaps indica* (Linnaeus, 1758)	Columbidae	IVth	C	LC
37	Eurasian Black Bird	Kaloo	*Turdus merula* (Linnaeus, 1758)	Turdiae	IVth	R	LC
38	Eurasian Curlew	Kuree/Kural	*Numenius arquata* (Linnaeus, 1758)	Scolopacidae	IVth	C	NT/D

Sr.	Common Name	Vernacular Name	Scientific Name	Family	IWPA status	Abundance	IUCN status
39	Eurasian Golden Oriole	Amrapakshi	*Oriolus oriolus* (Liannaeus, 1758)	Oriolidae	IV^{th}	UC	LC
40	Golden fronted Leafbird	Hirva Bulbul	*Chloropsis aurifrons* (Temminck, 1829)	Chloropseidae	IV^{th}	O	LC
41	Greater Coucal	Bhardwaj	*Centropus sinensis* (Stephens, 1815)	Cuculidae	IV^{th}	O	LC
42	Greenish Leaf Warbler	Hirvi Panphutki	*Phylloscopus trochiloides* (Sundevall, 1837)	Sylvidae	IV^{th}	C	LC
43	Gray Francolin	Chitur	*Francolinus pondicerianus* (Gmelin, 1789)	Phasianidae	IV^{th}	C	LC
44	Grey Headed Fish-Eagle	Matsy Garud	*Ichthyophaga ichthyaetus* (Horsfield, 1821)	Accipitridae	Ist	O	NT/D
45	Grey Hooded Warbler	Grey Hooded Warbler	*Phylloscopus xanthoschistos* (Gray 1746)	Sylvidae	IV^{th}	NT	LC
46	Grey Hypocolius	Khari Jar	*Hypocolius ampelinus* (Bonaparte, 1850)	Bombycillidae	IV^{th}	UC	LC
47	Heart Spotted Woodpecker	Dilwala Sutar	*Hemicircus canente* (Lesson, 1830)	Picidae	IV^{th}	C	LC
48	Hoopoe	Hoopoe	*Upupa epops* (Linnaeus, 1758)	Upupidae	IV^{th}	R	LC
49	House Sparrow	Ghar Chimni	*Passer domesticus* (Linnaeus, 1758)	Passeridae	IV^{th}	C	LC
50	Indian Grey Hornbill	Dhanesh	*Ocyceros birostris* (Scopoli, 1786)	Bucerotidae	IV^{th}	C	LC
51	Indian House Crow	Kavla	*Corvus splendens* (Vieillot, 1817)	Corvidae	V^{th}	C	LC
52	Indian Peafowl	Mor, Mayur	*Pavo cristatus* (Linnaeus, 1758)	Phasianidae	I^{th}	C	LC
53	Indian Pitta	Navrang	*Pitta brachyura* (Linnaeus, 1766)	Pittidae	IV^{th}	C	LC
54	Indian Pond-Heron	Vanchak	*Ardeola grayii* (Sykes, 1832)	Ardeidae	IV^{th}	O	LC
55	Indian Robin	Chirak/ Lalbudya	*Saxicoloides fulicatus* (Linnaeus, 1766)	Muscicapidae	IV^{th}	C	LC
56	Indian Roller	Neelkhanth	*Coracias benghalensis* (Linnaeus, 1758)	Coraciidae	IV^{th}	C	LC
57	Indian/Rufous Tpie	Takachor, Bhera	*Dendrocitta vagabunda* (Latham, 1790)	Corvidae	IV^{th}	C	LC
58	Indian Shag/ Cormorant	Pankavla	*Phalacrocorax fuscicollis* (Stephens, 1826)	Phalacrocoracidae	IV^{th}	UC	LC

Sr.	Common Name	Vernacular Name	Scientific Name	Family	IWPA status	Abundance	IUCN status
59	Indian Small Sky Lark	Gawai Chandol	*Alauda gulgula* (Franklin, 1831)	Alaudidae	IV^{th}	UC	LC
60	Jungle Bush-Quail	Jungli Durlav	*Perdicula asiatica* (Latham, 1790)	Phasianidae	IV^{th}	R	LC
61	Jungle Crow	Domkavla	*Corvus macrorhynchos* (Wagler, 1827)	Corvidae	IV^{th}	A	LC
62	Jungle Starling	Jungle Myna	*Acridotheres fuscus* (Wagler, 1827)	Sturnidae	IV^{th}	C	LC
63	Lagger Falcon	Sasana, Laggad	*Falco jugger* (Gray, 1834)	Falconidae	IV^{th}	C	NT
64	Large Cuckoo Shrike	Motha Kahua	*Coracina macei* (Lesson, 1831)	Compephagidae	IV^{th}	UC	LC
65	Large Grey Babbler	Gosawi	*Turdoides malcolmi* (Sykes, 1832)	Timaliidae	IV^{th}	UC	LC
66	White-browed Wagtail	Thorla Dhobi	*Motacilla madaraspatensis* (Gmelin, 1789)	Motacillidae	IV^{th}	C	LC
67	L-Golden Backed Woodpecker	Sonpathi Sutar	*Dinopium benghalense* (Linnaeus, 1758)	Picidae	IV^{th}	C	LC
68	Laughing Dove	Hola	*stigmatopelia senegalensis* (Linnaeus, 1766)	Columbidae	IV^{th}	C	LC
69	Little Coromorant	Pankavla	*Phalacrocorax niger* (Vieillot, 1837)	Phalacrocoracidae	IV^{th}	C	LC
70	Little Egret	Lahan Bagla,	*Egretta garzetta* (Linnaeus, 1766)	Ardeidae	IV^{th}	C	LC
71	Malabar-Crested Lark	Dongri, Malabari Chandol	*Galerida malabarica* (Scopoli, 1786)	Alaudidae	IV^{th}	R	LC
72	Malabar / Indian Pied Hornbill	Kakan/Garud	*Anthracocerous coronatus* (Boddaert, 1783)	Bucerotidae	I^{st}	C	NT/D
73	Malabar / Indian Trogon	Karna	*Harpactes fasciatus* (Pennant, 1769)	Trogonidae	IV^{th}	NT	LC
74	Night Heron	Raat Bagla	*nycticorax nycticorax* (Linnaeus, 1758)	Ardeidae	IV^{th}	C	LC
75	Orange-Headed Thrush	Kadookhaoo	*Zoothera citrina* (Latham, 1790)	Turdidae	IV^{th}	C	LC
76	Oriental Magpie-Robin	Dayal, Dominga	*Copsychus saularis* (Linnaeus, 1758)	Muscicapidae	IV^{th}	C	LC
77	Painted Spurfowl	Chakotri, Sakotri	*Galloperdix lunulata* (Valenciennes, 1825)	Phasianidae	IV^{th}	C	LC
78	Pied Crested Cuckoo	Chatak	*Clamator jacobinus* (Boddaert, 1783)	Cuculidae	IV^{th}	UC patchilly	LC

Sr.	Common Name	Vernacular Name	Scientific Name	Family	IWPA status	Abundance	IUCN status
79	Bar-Winged Flycatcher-Shrike	Kabra Khatik	*Hemipus picatus* (Sykes, 1832)	Campephagidae	IV^{th}	R	LC
80	Pied Harrier	Kavdya Hareen	*Circus melanoleucos* (Pennant, 1769)	Accipitridae	IV^{th}	C	LC
81	Rock Pigeon	Kabutar	*Columba livia* (Gmelin, 1789)	Columbidae	IV^{th}	O	LC
82	Purple Sun Bird	Suryapakshi	*Nectarinia asiatica* (Latham, 1790)	Nectariniidae	IV^{th}	C	LC
83	Red Munia	Lal Munia	*Amandava amandava* (Linnaeus, 1758)	Estrildidae	IV^{th}	C	LC
84	Red-Rumped Swallow	Lalbudi Bhingri	*Hirundo daurica* (Linnaeus, 1771)	Hirundinidae	IV^{th}	UC	LC
85	Red-Vented Bulbul	Lalbudya Bulbul	*Pycnonotus cafer* (Linnaeus, 1766)	Pycnonotidae	IV^{th}	A	LC
86	Red-Wattled Lapwing	Titwi	*Vanellus indicus* (Boddaert, 1783)	Charadriidae	IV^{th}	A	LC
87	Red-Whiskered Bulbul	Shipai/ Narad Bulbul	*Pynonotus jocosus* (Linnaeus, 1758)	Pycnonotidae	IV^{th}	A	LC
88	River Tern	Nadi Suray	*Sterna aurantia* (Gray, 1831)	Laridae	IV^{th}	C	LC
89	Rose-Ringed Parakeet	Popat, Raghu, Keer	*Psittacula krameri* (Scopoli, 1769)	Psittacidae	IV^{th}	C	LC
90	Rosy Starling	Bhordi, Gulabi Myna	*Sturnus roseus* (Linnaeus, 1758)	Sturnidae	IV^{th}	C	LC
91	Long-Tailed Shrike	Naklya Khatik	*Lanius schach* (Linnaeus, 1758)	Laniidae	IV^{th}	C	LC
92	Rufous-Tailed Lark	Murari	*Ammomanes phoneicura* (Franklin, 1831)	Alaudidae	IV^{th}	C	LC
93	Singing Bush Lark	Singing Bush Lark	*Mirafa cantillans* (Blyth, 1844)	Alaudidae	IV^{th}	C	LC
94	Sirkeer Malkoha	Mungshya	*Phoenicophaeus leschenaultia* (Lesson, 1830)	Cuculidae	IV^{th}	C	LC
95	Green Bee-Eater	Bahira Popat	*Merops orientalis* (Latham, 1802)	Meropidae	IV^{th}	O	LC
96	Common Blue Kingfisher	Dhiwar, Khandya	*Alcedo atthis* (Linnaeus, 1758)	Alcedinidae	IV^{th}	A	LC
97	Small Minivet	Chota Nikhar	*Pericrocotus cinnamomeus* (Linnaeus, 1766)	Campephagidae	IV^{th}	C	LC
98	Small Pratincole	Panbhingari	*Glareola lacteal* (Temminck, 1820)	Glareolidae	IV^{th}	C	LC

Sr.	Common Name	Vernacular Name	Scientific Name	Family	IWPA status	Abundance	IUCN status
99	Spotted Dove	Tipkya Kavda	*stigmatopelia chinensis* (Scopoli, 1786)	Columbidae	IVth	A	LC
100	Spotted Owlet	Pingala	*Athene brama* (Temminck, 1821)	Strigidae	Ist	C	LC
101	Stork-Billed Kingfisher	Jalmadgu	*pelargopsis capensis* (Linnaeus, 1766)	Alcedinidae	IVth	C	LC
102	Tickells Blue-Flycatcher	Neelang	*Cyornis tickelliae* (Blyth, 1843)	Muscicapidae	IVth	R	LC
103	Whimbrel	Nakshidar Kudlya	*Numenius phaeopus* (Linnaeus, 1758)	Scolopacidae	IVth	C	LC
104	White-Bellied Blue-Flycatcher	Pandharpotya Nartak	*Cyornis pallipes* (Gerdon, 1840)	Muscicapidae	IVth	C	LC
105	White-Bellied Sea-Eagle	Samudra Garud	*Haliaeetus leucogaster* (Gmelin, 1788)	Accipitridae	Ist	UC	LC
106	White-Breasted Waterhen	Lajri Pankombadi	*Amaurornis phoenicurus* (Pennant, 1769)	Rallidae	IVth	C	LC
107	White-Cheeked Barbet	Kartuk, Kuturga	*Megalaima viridis* (Boddaert, 1783)	Ramphastidae	IVth	UC	LC
108	White-Rumped Vulture	Gidhad	*Gyps bengalensis* (Gmelin, 1788)	Accipitridae	Ist	R	CE/D
109	White-Throated Fantail-Flycatcher	Nachra, Navhi	*Rhipidura albicollis* (Vieillot, 1818)	Rhipiduridae	IVth	C	LC
110	White-Throated Kingfisher	Khandya/Kilkilya	*Halycon smyrnensis* (Linnaeus, 1758)	Alcedinidae	IVth	C	LC
111	Yellow-Browed Bulbul	Kajal	*Iole indica* (Gerdon, 1839)	Pycnonotidae	IVth	C	LC
112	Yellow-Fronted Barbet	Yellow-Fronted Barbet	*Megalaima flavifrons* (Cuvier, 1816)	Capitonidae	IVth	C	LC
113	Yellow-Fronted Pied-Woodpecker	Maratha Sutar	*Dendrocopos mahrattensis* (Latham, 1801)	Picidae	IVth	C	LC
114	Yellow-Wattled Lapwing	Maaltitwi	*Vanellus malabaricus* (Boddaert, 1783)	Charadridae	IVth	C	LC

Where, C = Common, UC = Uncommon, R = Rare, NT = Near Threatened, O = Occasinal, OR = Occasinal to rare, A = Abundant, IWPA = The Indain Wildlife (Protection) Act, 1972. CE= Critically Endangered, D = Decreasing

8.9 Appendix XV: Tree species observed in the forest during the investigation

Strychnos nux-vomica

Memecylon umbellatum

Terminalia paniculata

Terminalia elliptica

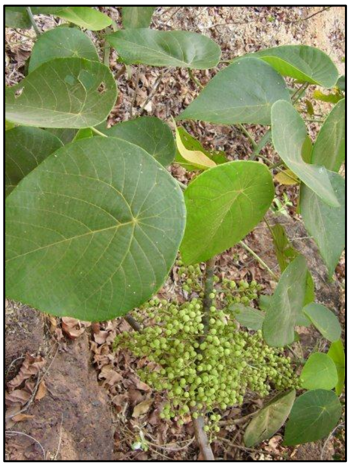
Calophyllum inophyllum

Morinda citrifolia

Acacia catechu

Bombax ceiba

Continued.....



Macaranga peltata

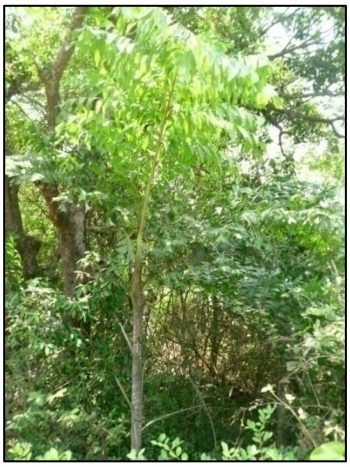
Stereospermum colais

Bridelia retusa

Sterculia urens

Trema orientalis

Careya arborea



Zanthoxylum rhetsa

Caryota urens

Buchanania lanzan

Shrub species observed in the forest during the investigation

Helicteres isora

Carissa congesta

Leea indica

Holarrhena pubescens

Calotropis gigantean

Abelmoschus lampus

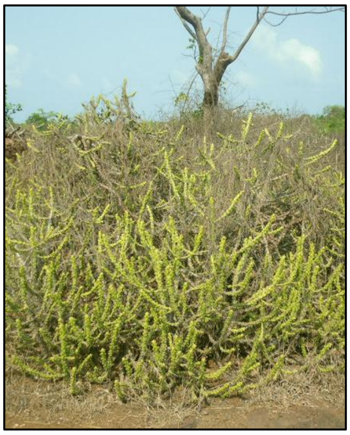
Mussaenda glabrata

Continued….

Microcos paniculata

Clerodendrum serratum

Clerodendrum inerme



Euphorbia antiquorum

Breynia retusa

Lantana camara

Tabernaemontana alternifolia

Cassia alata

Ixora coccinea

Herb species observed in the forest during the investigation

Cassia tora

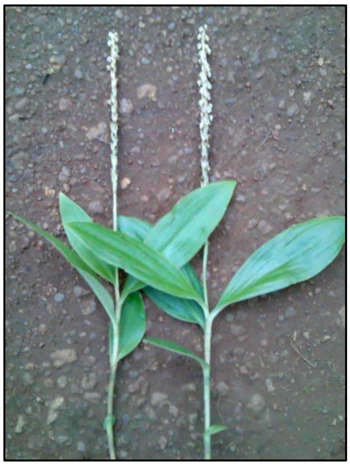
Sonchus oleraceus

Martynia annua

Eriocaulon heterolepis

Rauvolfia serpentine

Striga gesnerioides



Fimbristylis littoralis

Biophytum sensitivum

Daedalcanthus roseum

Continued…..

Dipkadi concanensis *Achyranthes aspera* *Barleria cuspidate*

Barleria involucrate *Neuracanthus sphaerostachyus* *Trichodesma inaequale*

Senecio bombayensis *Sonchus asper*

Continued……

Cleome chelidonii

Rhamphicarpa longifolia

Evolvulus alsinoides

Begonia crenata

Murdannia wightii

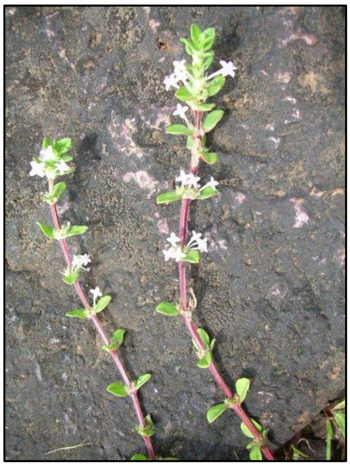
Celosia argentea

Adianatum lunulatum

Utricularia graminifolia

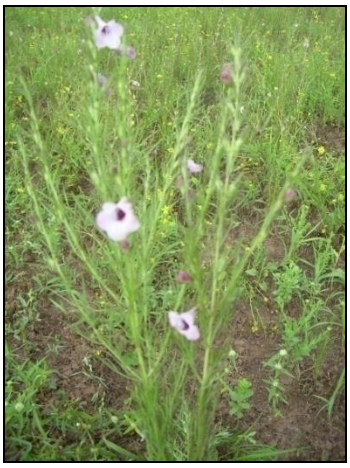
Continued….

Centranthera indica



Spermacoce articularis

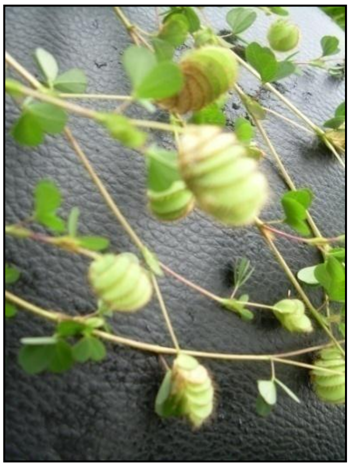
Sopubia delphinifolia



Sopubia trifida

Sida cordifolia

Costus speciosus



Geissapis cristata

Drosera indica

Urena sinuata

Climber species observed in the forest during the investigation

Gloriosa superba

Smilax ovalifolia

Tylophora dalzellii

Dioscorea bulbifera

Jasminum malabaricum

Ampelocissus latifolia

Canavalia lineate

Holostemma annulare

Ipomoea pes-tigridis

Continued…….

Celastrus paniculatus

Mucuna pruriens

Hemidesmus indicus

Calycopteris floribunda

Ipomoea pes-caprae

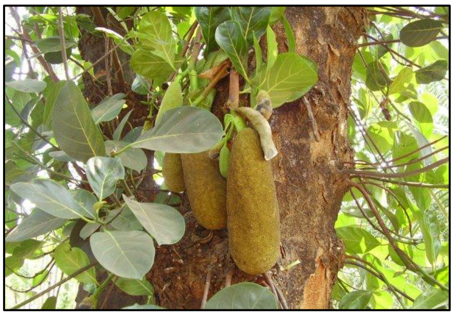
Ipomoea campanulata

Thunbergia fragrans

Unknown

Plant species observed in the homegardens during the investigation

Anacardium occidentale



Artocarpus heterophyllus

Passiflora edulis

Colocasia esculenta

Dioscoria alata

Heliconia rostrata

Typhonium roxburghii

Curcuma longa

Continued…….

Michelia champaca *Gmelina arborea* *Acalypha hispida*

Phyllanthus acidus *Mimosa pudica* *Hedychium coronarium*

Piper nigrum *Artabotrys hexapetalus*

Plant species observed in the mangrove vegetation during the investigation



Bruguiera gymnorrhiza *Ceriops tagal* *Rhizophora mucronata*

Sonneratia caseolaris

Avicennia marina

Acanthus ilicifolius

Caesalpinia crista

Aegiceras corniculatum

Thespesia populnea

Continued…….

Plant species observed in the study during the investigation

Salvadora persica

Ixora brachiata

Ensete superbum

Trichosanthes nervifolia

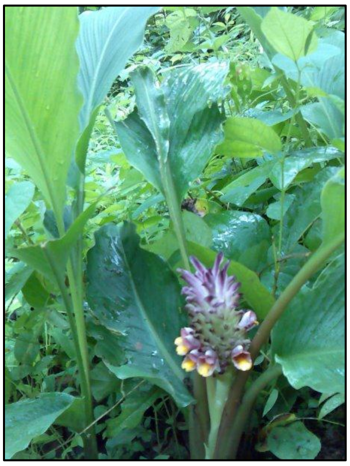
Wattakaka volubilis

Justicia adhatoda

Unknown

Ziziphus rugosa

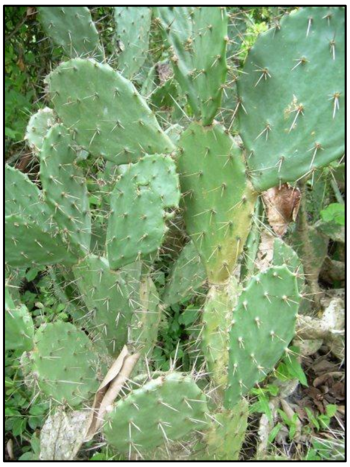
Continued……


Leea macrophylla *Curcuma neilgherrensis* *Leonotis nepetifolia*



Desmodium gangeticum *Sphenoclea zeylanica* *Thespesia populnea*


Streblus asper *Opuntia elatior* *Nymphaea pubescens*

8.10 Appendix XVI: Bird species found in the study area


Indian-Pied Hornbill


Indian-Pond Heron


Cattle Egret


Lagger Falcon


Red-Whiskered Bulbu


Rock Pigeon


Jungle Crow


Indian House Crow


Crested Malabar Lark


White-Throated Kingfisher


Yellow-Wattled Lapwing


Indian Myna

Continued……..

Red-wattled Lapwing

Brahminy Kite

Little Cormorant

Dusky Swallow

Baya Weaver

Black-Hooded Oriole