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Structure, Diversity, Threats and Conservation of Tropical Forests

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1. Introduction

In this elegant book, we have defined 'Tropical Forests' broadly, into five different themes: (1) tropical forest structure, synergy, synthesis, (2) tropical forest fragmentation, (3) impact of anthropogenic pressure, (4) Geographic Information System and remote sensing, and (5) tropical forest protection and process. The cutting-edge synthesis, detailed current reviews, several original data-rich case studies, recent experiments/experiences from leading scientists across the world (Fig.1) are presented as unique chapters. Though, the chapters differ noticeably in the geographic focus, diverse ecosystems, time and approach, they share these five important themes and help in understanding, educating, and creating awareness on the role of 'Tropical Forests' on the diversity of biota, impact of disturbances, climate change and the very survival of mankind.

2. Tropical forests - Structure, synergy, synthesis

Tropical forests are located in the 'tropics' which lie between the Tropic of Cancer and Capricorn, approximately between 23° N and 23° S latitudes (Thomas and Baltzer, 2002). They support vast biodiversity and are a source of wonderment, scientific curiosity, enormous complexity as well as a basic foundation for human welfare (Tilman, 2000). While occupying only one-tenth of the world's land area, tropical forests are economically, ecologically, environmentally (Fig. 2), culturally and aesthetically vital as they play crucial role in ensuring global food security, climate change, poverty eradication and improvement of human health (Rajora and Mosseler, 2001; Thomas and Baltzer, 2002; Nageswara Rao and Soneji, 2010a, 2011). They are important in terms of global biogeochemical cycles and are home to more than half of the world's species (Thomas and Baltzer, 2002).

It is estimated that more than 10 million species of plants, animals and insects live in the tropical rainforests (http://www.rain-tree.com). One-fifth of the world's fresh water is in

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the Amazon Basin and more tree species are found in 0.5 km² of some tropical forests than in all of North America or Europe (Burslem et al., 2001). These forests sustain the livelihoods of hundreds of millions of people globally (Nageswara Rao et al., 2008a; Uma Shaanker et al., 2001a) and studies estimate that at least 80% of the developed world's diet originated in the tropical rainforests. About 70% plants that are active against cancer cell lines found by the US National Cancer Institute (NCI) are found only in the tropical forests (http://www.rain-tree.com).

The dense leafy canopies of tropical forests make them highly productive plant communities storing almost 30% of the global soil carbon (Sayer et al., 2007). This makes tropical forests, with relatively high litterfall, a critical component of the global carbon cycle. To assess the tropical forest productivity, phenology, and turnover of biomass, litterfall collection is a standard non-destructive technique (Newbould, 1967; Lowman, 1988). The amount of leaf material falling reflects a forest's productivity and represents a major flux of carbon from vegetation to soil in the forest. Hence, changes in litter inputs are likely to have far-reaching consequences on the soil carbon dynamics (Proctor et al., 1983; Lowman, 1988; Sayer et al., 2007). In the chapter "*Comparing litterfall and standing vegetation: Assessing the footprint of litterfall traps*", the authors have analyzed the correspondence between litterfall samples and standing vegetation at three different spatial scales. They examined the factors affecting the relative abundance of species in litterfall samples. To gain an insight for the scaling of litterfall data from the level of sampling plots up to the level of the forest stand, they compared the composition and relative abundance of species collected in litter traps. The authors' findings will prove instrumental for the improvement of methods in terrestrial and forest ecology, especially in the tropics where the high species diversity and structural complexity of forests impose tough challenges to the study of forest structure and their dynamics.

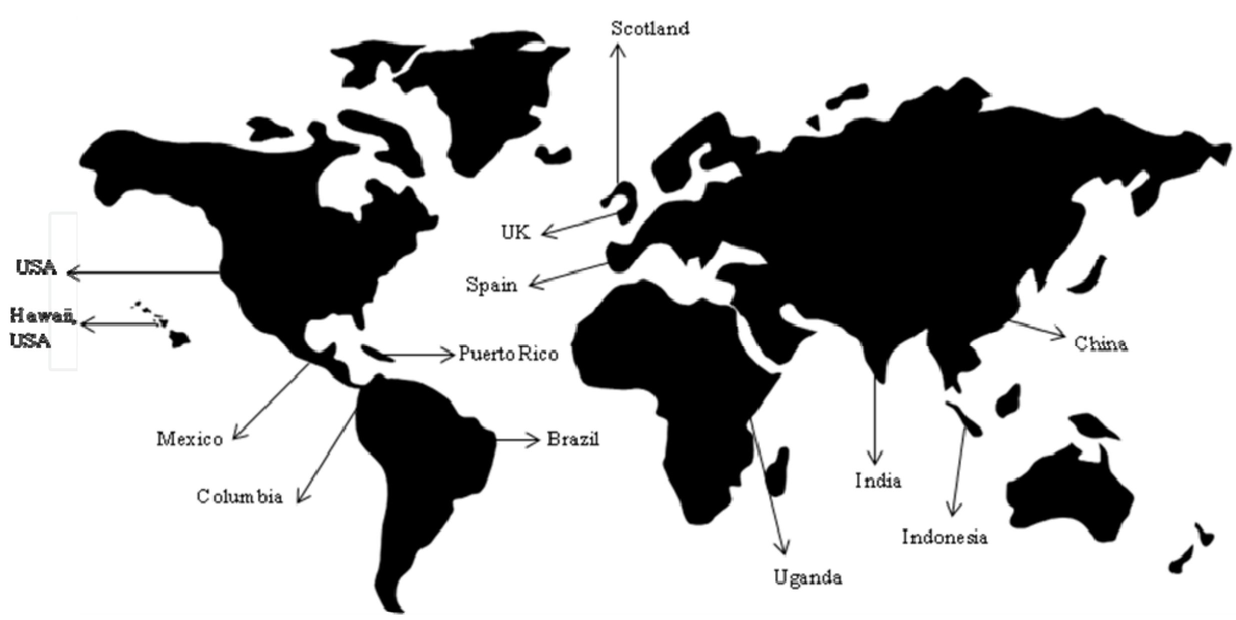

Fig. 1. Author geographic locations of studies in this book.

By regulating the microclimate, the litter layer helps to maintain favorable conditions for decomposition (Vasconcelos and Lawrence, 2005; Sayer et al., 2006) while the soil faunal activities can indirectly affect decomposition rates and the nutrient cycles (Moore and Walter, 1988). The interactions between the soil fauna and microbes can influence the microbial species composition (Visser, 1985), thus playing an important role in soil ecosystems (Lussenhop, 1992; Sayer et al., 2006) and creating habitats for arthropods (Arpin et al., 1995). Millipedes and other macroarthropods, as detritivores, affect the nutrient cycling by releasing chemical elements such as nitrogen and redistributing the organic material in the soil (Dangerfield and Milner, 1996). In the chapter "*Direct and indirect effects of millipedes on the decay of litter of varying lignin content*", the authors have used a microcosm approach to answer what are the direct (leaf fragmentation) and indirect effects (microbial biomass) of millipedes on the decomposition of leaf litter and how these outcomes are influenced by the substrate (litter) quality and the density of millipedes. In the chapter "*Quantifying variation of soil arthropods using different sampling protocols: is diversity affected?*", the authors have assessed how the diversity of extracted arthropods was affected by variations in the collection and extraction methodologies, and by variations in the duration of the extraction. This data will provide researchers with data to simplify the logistics of arthropod sampling and extraction, and to better choose a specific procedure for a given focal organism in a given habitat.

Fig. 2. A typical view of diverse tropical forest (see Chapter 20, by Canuto et al. in this book).

In the chapter "*Patterns of plant species richness within families and genera in lowland Neotropical forests: Are similarities related to ecological factors or to chance*?", the authors have made a quantitative floristic comparison based on the patterns of species richness in families and genera for more than twenty five tropical areas, and correlated the floristic similarities with the ecological and stochastic factors (i.e. geographical distance). They also attempted to test the significance and relative roles of ecological and stochastic factors. Such studies can provide information on the present-day communities that have resulted from speciation, extinction, and migration (Leigh et al., 2004).

Compared to the wealth of botanical and ecological studies carried out in the tropical ecosystems, little is known about the status of mycorrhizae or the influence of mycorrhizal mutualisms on the tropical forest diversity and tree assemblages (Alexander and Lee, 2005; McGuire et al., 2008). In the chapter "*Dispersion, an important radiation mechanism for ectomycorrhiyzal fungi in Neotropical low land forest*", the author has evaluated different hypothesis about the possible origin of ectomycorrhiyzal (EcM) fungi associated with *Pakaraimaea dipterocarpacea*. The EcM fungi diversity and community structure, and also the phylogenetic analysis have been carried out. This study is the first evidence of host sharing between both sympatric and allopatric tree species belonging to Dipterocarpaceae and EcM Fabaceae in the Neotropics.

3. Tropical forest fragmentation

Fragmentation, due to rapid economic growth and agricultural expansion, of the tropical forests and the natural habitats into smaller and non-contiguous patches is the most serious threat to the long-term survival of the biological diversity on earth (Myers, 1994; Chapin et al., 2000; Pimm and Raven, 2000; Cruse-Sanders and Hamrick, 2004; Nageswara Rao et al., 2008b).

Fig. 3. Shola forest fragments in the Western Ghats (one of the mega diversity 'hot-spot' in the world), India (see Rajanikanth et al., 2010).

As a consequence of fragmentation, natural or man-made, plant populations are isolated from their conspecific populations (Fig. 3), have reduced population size (Lamont et al., 1993; Hall et al., 1996; Risser, 1996; Rajanikanth et al., 2010) and have decreased fruit set or poor seed germination relative to large population (Menges, 1991; Byers and Meagher, 1992;

Hendrix, 1994; Heschel and Paige, 1995; Agren, 1996). These fragmented patches of forest are often embedded in a matrix of anthropogenically manipulated landscapes (such as pastures, agricultural fields or habitations; Fig. 4), behave as "islands" in a "sea" of pasture or agricultural ecosystem and may lead to distinct ecological, demographic and genetic consequences which result in the extinction of the native species (Tilman et al., 1994; Gilpin, 1988; Laurance, 2000; Nageswara Rao et al., 2001, 2007; Uma Shaanker et al., 2001b; Honnay et al., 2005). Fragmentation or conversion of forest into grassland or savanna due to forest harvesting, fertilization, atmospheric deposition, and climate change also affects the nitrogen mineralization of the tropical forests (Wang et al., 2004).

Anuran amphibians inhabit regions that have high moisture levels and moderate to warm temperatures owing to their skin permeability and dependence on aquatic and terrestrial habitats during their life cycles (Duellman and Trueb, 1994; Wells, 2007). Fragmentation and/or deforestation makes the environment drier and more seasonal, reduces the population size of anuran species, adversely affects the anuran richness in local assemblages that depend on breeding ponds for reproduction and sometimes eliminating those that depend on humid forest microhabitats (Haddad and Prado, 2005; Becker et al., 2007). In the chapter "*The role of environmental heterogeneity in maintenance of anuran amphibian diversity of the Brazilian mesophytic semideciduous forest*", the authors employed tests of null hypotheses to assess whether patterns of spatial distribution of anuran assemblages differ from a random distribution among aquatic breeding sites monitored at Morro do Diabo State Park. They also verified the existence of indicator anuran species of environmental heterogeneity on a local scale.

The formation of treefall gaps and their influence on forest regeneration and dynamics have ecological consequences (Schnitzer et al., 2008). These canopy gaps, formed by death or injury to one or a few canopy trees, create sufficient resource heterogeneity to allow for resource partitioning and niche differentiation (Grinnell, 1917). They also release sufficient resources (e.g., light and nutrients) to permit the establishment or reproduction of plant species that would otherwise be excluded from the forest in the absence of gaps (Schnitzer et al., 2008). Such transitory events occur frequently in the tropical forests (Brokaw, 1985), where plant species of early successional stages (pioneers and secondary ones) take advantage of the gaps formed as they can tolerate higher micro-climate and ecological variations (Mulkey et al., 1996). In the chapter "*Gap area and tree community regeneration in a tropical semideciduous forest*", the authors have identified ecological patterns related to richness and the potential of natural regeneration of tree species in natural gaps and have investigated whether the tree community responds to different levels of canopy openings represented by gaps of different sizes found in the tropical semideciduous forests.

4. Impact of anthropogenic pressure

In the tropical forests, where both species diversity and anthropogenic pressures on the natural environments are high, biodiversity is threatened by human-driven, land-use changes (Dirzo and Raven, 2003; Gibson et al., 2011). Rapid deforestation of tropical forests for agriculture (Fig. 4), timber production, pasture, firewood, construction of roads and dams, and other uses, have dire consequences on the tropical biodiversity along with the water sources and non-timber forest products (Sudarshana et al., 2001; Uma Shaanker et al., 2003, 2004; Foley et al., 2005; Lamb et al., 2005; Ravikanth et al., 2009; Gibson et al., 2011). The increasing rate of human population in the developing countries, where most of these forests are located, has triggered a greater demand for timber and other forest products, making sustainable management of these remnant forests a major challenge (Wright and Muller-Landau, 2006). Human disturbances often lead to altered environmental conditions, which influence the process that can both augment and erode species diversity in the tropical forest community (Kennard et al., 2002; Sapkota et al., 2010).

Fig. 4. Conversion of pristine tropical forests into agricultural lands, Western Ghats (one of the mega diversity 'hot-spot' in the world), India.

Changes in vertebrate assemblages in the tropical rain forests caused by anthropogenic disturbances affect the seed dispersal patterns and subsequent tree spatial recruitment patterns in the secondary tropical rain forests. Even though a variety of seed dispersal mechanisms are found within tropical forests, most plants produce fleshy fruits that are dispersed primarily by vertebrate frugivores (Jordano, 1992). Behavioral disparities among vertebrate seed dispersers could influence patterns of seed distribution and thus forest structure (Howe, 1990; Clark et al., 2001). In the chapter "*Seed dispersal and tree spatial recruitment patterns in secondary tropical rain forests*", the author examined the seed dispersal and tree spatial recruitment patterns in three tropical forests whose vertebrate populations have been altered differently over the past few decades. The changes in vertebrate seed disperser community on tree recruitment in the secondary forest landscapes in the wider context of the effectiveness of remnant vertebrate populations in seed dispersal and the possible consequences for tree demography are presented.

Forest fragmentation not only affects the plants but also the large predators that play an important role in regulating herbivore prey populations (Duffy, 2003). The ecological consequences of such fragmentation on the mesoherbivores remain largely undocumented.

In an effort to understand the magnitude of the effects of human-perturbed, mesoherbivore populations on the tropical forest plant communities, in the chapter "*Human altered mesoherbivore densities and cascading effects on plant and animal communities in fragmented tropical forests*", the authors have reviewed substantial tropical literature on human overhunting of mesoherbivores and the consequences for the tropical forest plant communities. For the first time, the authors have synthesized the sparse and scattered literature involving tropical examples of mesoherbivore release, making a case that the cascading consequences of increased mesoherbivore abundance can be as widespread and ecologically destructive as those resulting from mesoherbivore decline. The authors have also addressed the most pressing conservation and management implications of the research on perturbed mesoherbivore populations and have identified topics in need of further investigation, in terms of both ecology and conservation.

Knowledge of forest structure and floristics are necessary for the study of forest dynamics, plant-animal interactions and nutrient cycling (Reddy and Pattanaik, 2009). In the chapter "*Floristic composition, diversity and status of threatened medicinal plants in tropical forests of Malyagiri hill ranges, Eastern Ghats, India*", the authors have analyzed the diversity, distribution and population structure of tree species in a tropical deciduous forest stand, with special emphasis on the documentation of threatened medicinal plants. Medicinal plant species belonging to different threat categories were recorded from the forest and suggestive conservation measures for sustainable use of medicinal plant resources are presented.

Aboveground coarse necromass, a major component of the carbon cycle in the tropical forests, accounts for up to 20% of carbon stored above ground and for 14–19% of the annual aboveground carbon flux in the tropical forests (Palace et al., 2008). The dynamics of necromass production and loss through disturbance and decay are poorly understood and quantified in the tropical forests (Eaton and Lawrence, 2006). In the chapter "*A review of above ground necromass in tropical forests*", the authors have examined literature pertaining to stocks or pools of above ground necromass, the disturbance and the episodic production of coarse necromass, and the slower process of decomposition in the tropical forests. They have described and defined important terms and components in necromass research and have various methodologies designed to measure these components and current literature involved with field based estimates of necromass.

5. Geographic information system and remote sensing

Combating deforestation requires factual information about the tropical forests which is not readily available (Ochego, 2003). Geographic Information System (GIS) and remote sensing provides a unique opportunity to assess (Fig. 5) and monitor deforestation, degradation, and fragmentation (Lyngdoh et al., 2005; Tejaswi, 2007). GIS integrates hardware, software and data for capturing, managing, analyzing and displaying all forms of geographically referenced information (http://www.gis.com/content/what-gis) and can be utilized for deciphering location, condition, trends, patterns and modeling of forests. Remote sensing utilizes the acquisition of information about an object, area or phenomenon through the analysis of data acquired by a device that is not in contact with the object, phenomenon or area under investigation (Lillesand and Kiefer, 1987). It has become a very powerful tool associated with the estimation of the interactions between earth's surface materials and electromagnetic energy reflected from them which are recorded by sensors aboard satellites in space (Ochego, 2003).

Remote sensing can work at multiple scales ranging from few meters to several kilometers, even in places where accessibility is an issue, and the data can be acquired periodically (e.g. daily, monthly) with measurements made in near real time basis (Tejaswi, 2007).

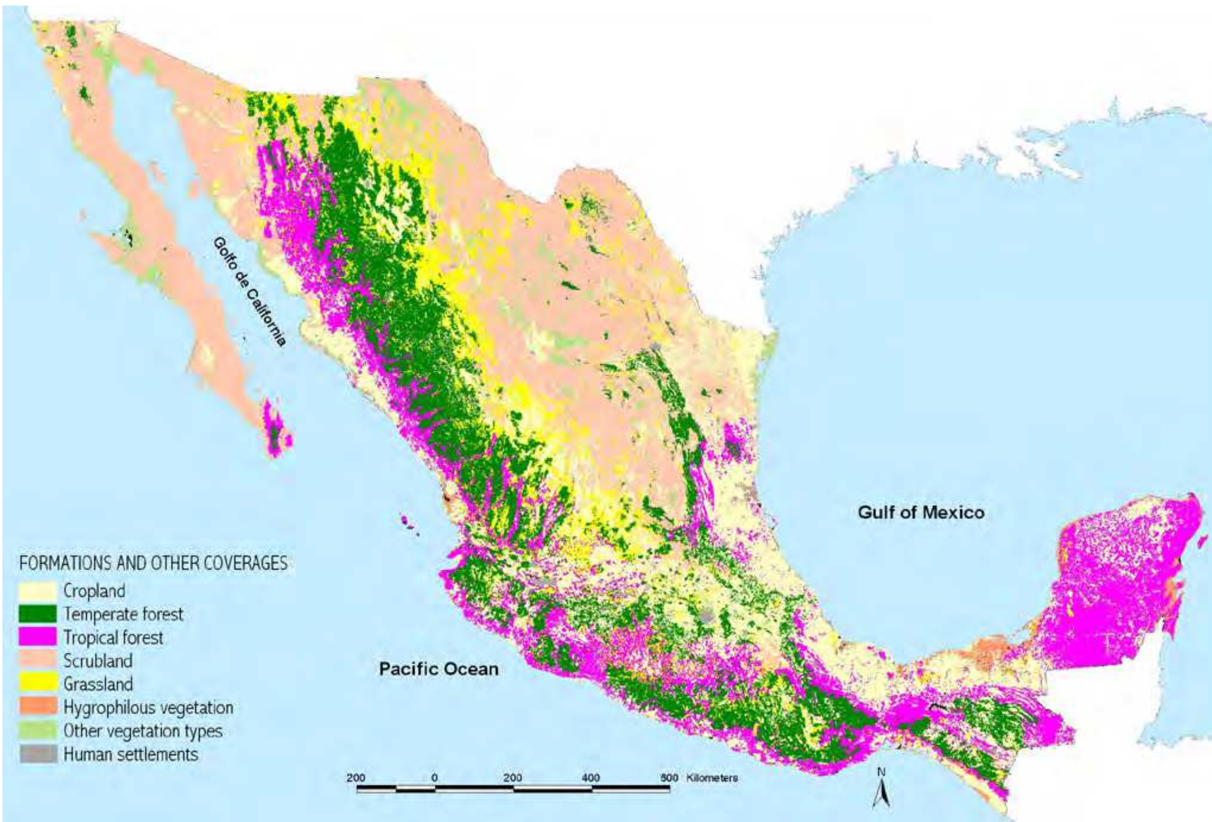

Fig. 5. National Forest Inventory map of Mexico (see Chapter 15, by Couturier et al. in this book).

Estimating the rate of change in tropical forest cover has become a crucial component of global change monitoring. In the chapter "*Seasonal pattern of vegetative cover from NDVI time-series*", the authors have employed seasonal adjustment of time-series statistical method to understand the phenology and detect disturbance on some woody vegetation utilizing the Normalized Difference Vegetation Index (NDVI) time-series of SPOT VEGETATION. In the chapter "*Measuring tropical deforestation with error margins: A method for REDD monitoring in South-eastern Mexico*", the authors present a methodological framework for the measurement of tropical deforestation in Southeast Mexico, based on the experience of accuracy assessment of regional land cover maps and on-site measurements of tropical forest cover in Mexico. In the chapter "*Natural forest change in Hainan, China, 1991-2008 and conservation suggestions*", the authors have analyzed the changes in natural forest and plantations on Hainan Island between 1991-2008 by using GIS and remote sensing, have tried to explore the driving factors of changes based on local policies, and have given suggestions for the future conservation plan. In the chapter "*Exchange of carbon between the atmosphere and the tropical Amazon rainforest*", the authors have examined the subcanopy flow dynamics and local micro-circulation features, how they relate to spatial and temporal distribution of CO_2 on the Manaus LBA Project site and have discussed the contribution of exchange of carbon between the atmosphere and the tropical Amazon Rainforest.

6. Tropical forest protection and process

During the last decade, a need to address conservation questions with a wider social, political and cultural framework was recognized (Hodgkin and Rao, 2002). With rapid vanishing of tropical forests and increasing extinction numbers, it is imperative to evolve holistic strategies to conserve the surviving populations. But launching of any such conservation program is contingent upon the knowledge of what, where and how to conserve (Ganeshaiah and Uma Shaanker, 1998). There is a general consensus among scientists and practitioners that no single conservation method is adequate and different methods should be applied in a complementary manner. In the recent past, approaches such as the *ex situ* conservation, *in situ* conservation, creating biosphere reserves, protected areas, etc. have been extended to address the conservation and restoration of tropical forest resources (Shands, 1991; Uma Shannker et al., 2001b,c; Nageswara Rao et al., 2007, 2011). In the chapter "*Direct sowing: an alternative to the restoration of ecosystems of tropical forests*", the authors have analyzed ecological, technical, socio-economic and forestry aspects involved in the use of direct sowing to restore degraded ecosystems in the tropical forest regions (Fig. 6). The authors have also highlighted several experiments conducted in the tropical regions, which may contribute to broaden the perspective and enhance methodologies for ecological restoration and bring to light some experiences that may contribute to the decision making over the choice of direct sowing for restoration of degraded ecosystems.

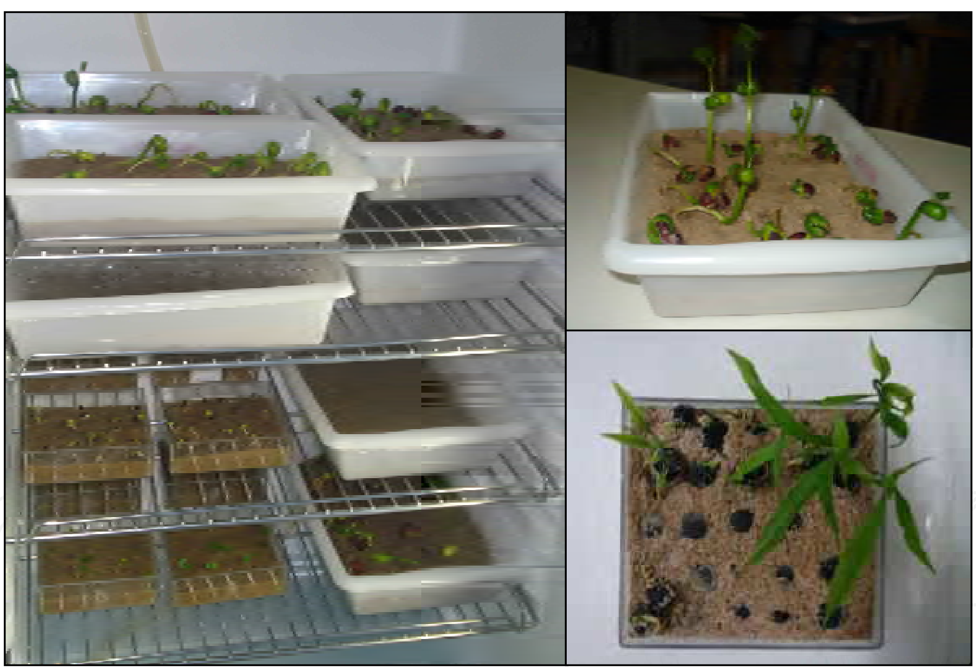

Fig. 6. Seed variability and restoration efforts in tropical forests, Brazil (see Chapter 18, by Ferreira et al. in this book).

In the chapter "*Patterns of tree mortality in monodominant tropical forests*", the author has used information from a long term study in permanent vegetation plots within 200 ha of monodominant Hakalau Forest National Wildlife Refuge, (Hawaiian, wet forest) to address basic ecological questions such as, how does tree mortality vary with respect to species, size, position in the canopy (crown class), and geographic location? What is the age of trees in this forest? To what extent can patterns of mortality provide evidence for succession in this forest?

Their results provide evidence that gap-phase dynamics may play a role in the succession, stand structure, and community composition in a large structured forest in Hawaii. Dead standing trees also provide important habitat for diverse wildlife, micro flora and fauna.

Protected areas are believed to be the corner stones for biodiversity conservation and the safest strongholds of wilderness around the globe (Pimm and Lawton, 1998; Bruner et al., 2001). With ever increasing threats to the tropical forests, protected areas and their networks offer the best possible approach to conserve the biological diversity (Hogbin et al., 2000; Bruner et al., 2001; Theilade et al., 2001). They harbor a greater level of biodiversity than the adjoining non-protected areas and may serve as *in situ* sites for the conservation of forest resources. In the chapter "*Conservation, management and expansion of protected and non-protected tropical forest remnants through population density estimation, ecology and natural history of top predators; case studies of birds of prey (Spizaetus taxon)*", the authors have described results of six studies conducted in Brazil by analyzing the incidence of specimens of the genus *Spizaetus* in areas with different fragmentation histories and considering the different population and reproductive ecological aspects of these taxons collected at each locality. The authors promote a reflection on the perspectives of local and punctual conservation of these species, according to their ecological requirements and have used these species as "flags" to point out the problems involving conservation of top predators, which present small density (Fig. 7) but demand a large area, in the fragmented and continuous areas. Protected areas could in fact be the last refugia for several tropical species (Ramesha et al., 2007; Nageswara Rao M et al., 2010). However, most protected areas may be too small to host viable populations. They may not allow for gene pool mixing across the population, due to their insular and isolated habitat. Efforts need to also be complemented by actions outside protected areas such as sustainable management and conservation of forests for multiple uses (FAO, 1993).

Fig. 7. Canopy survey, population estimation, conservation and management of Black Hawk, Black-and-White Hawk eagle in protected and non-protected tropical forests, Brazil (see Chapter 20, by Canuto et al. in this book).

The tropical forests, undoubtedly, are heritage for our future generations. They deal with the totality of gene, species, population and ecosystem on the basis of cellular, molecular, taxonomic and geographic criteria (Sharma, 1996) and face multiple threats. Although, monitoring and conserving the loss of forest biodiversity is crucial, there appears to be no single measure that can assess all the aspects of biodiversity. Consolidated efforts on the information on parameters such as the levels of threats, the spatial patterns of population/species richness, distribution, their interactions, genetic diversity, etc., are utmost needed for planning any effective conservation and sustainable utilization. First and foremost, ecosystems and landscapes with high concentration of endemic and useful species at risk need to be identified. Potential threats that these resources are facing should be highlighted. Species that are rare, endangered, highly threatened and economically important need to be selected and given highest priority (Uma Shaanker et al., 2001c), to study their effective population size, spatial structure, variability, and community interactions. Detailed data on all these parameters affected by native habitat loss, invasiveness, expansion of agriculture, and extraction patterns needs to be generated (Bawa et al., 2001). Mitigation strategies to counter the threats, restoration strategies, and understanding the local adaptive nature information should be an integral component of programs designed to conserve and manage the tropical forest resources (Nageswara Rao and Soneji, 2010b). Well organized national, as well as, international programs should be conducted to bridge the gap between local community, forest managers, policy-makers and the scientific community. They should be brought together through networking, training and public awareness programs. Thus, there is urgent need to consider, consolidate and complement research, policy making and on-field efforts to effectively conserve, efficiently utilize and sustainably manage the tropical forest resources before they are irrevocably lost (Nageswara Rao and Soneji, 2009).

7. References

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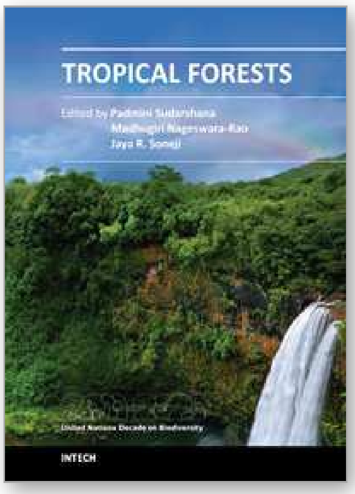

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The astounding richness and biodiversity of tropical forests is rapidly dwindling. This has severely altered the vital biogeochemical cycles of carbon, phosphorus, nitrogen etc. and has led to the change in global climate and pristine natural ecosystems. In this elegant book, we have defined "Tropical Forests" broadly, into five different themes: (1) tropical forest structure, synergy, synthesis, (2) tropical forest fragmentation, (3) impact of anthropogenic pressure, (4) Geographic Information System and remote sensing, and (5) tropical forest protection and process. The cutting-edge synthesis, detailed current reviews, several original data-rich case studies, recent experiments/experiences from leading scientists across the world are presented as unique chapters. Though, the chapters differ noticeably in the geographic focus, diverse ecosystems, time and approach, they share these five important themes and help in understanding, educating, and creating awareness on the role of "Tropical Forests" for the very survival of mankind, climate change, and the diversity of biota across the globe. This book will be of great use to the students, scientists, ecologists, population and conservation biologists, and forest managers across the globe.