CHAPTER 38

OUTLOOK ON FOREST BIODIVERSITY RESEARCH, MONITORING AND MODELING FRAMEWORK

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INTRODUCTION

In the words of Norman Myers (1997), 'While biodiversity, and indeed life itself, is the key characteristic of our planet, we know more about the total numbers of atoms in the universe than the Earth's complement of species'. The loss of biodiversity worldwide has spawned a race against time to learn more about the functioning of the world's ecosystems. It is hoped that this knowledge will help to predict future changes, determine which areas of biological interest to protect, and restore areas degraded through the action of natural or anthropogenic factors.

Under Agenda 21 of the 1992 United Nations Conference on Environment and Development, all signatory nations must inventory, monitor, and assess their biological resources. The use of monitoring plots has been paramount in achieving this goal. One of the primary purposes of the International Symposium, 'Measuring and Monitoring Forest Biological Diversity', was to assess the status of global, plot-based research. With more than 200 oral and poster presentations, the symposium succeeded in attracting researchers from a variety of international plot-based projects. This volume, describing the monitoring framework and presenting old-world case studies, unveils a wealth of information derived from plot-based research.

In this concluding chapter, we provide an overview of some of the important research directions that are highlighted in the book. Note that this is the first of two volumes of proceedings from the international symposium, the content of which was separated by geographical regions rather than by aims of the individual studies. Therefore, some of the ideas and concepts put forward span the two volumes.

THE FOREST MONITORING FRAMEWORK

In the first section of this book, Dallmeier and Comiskey review the conceptual framework behind SI/MAB's international network of biodiversity monitoring plots. The permanent plots, which are initially established to monitor vegetation, provide a framework upon which other taxonomic groups may be monitored.

This allows for a community- versus taxa-based approach, permitting changes in one taxonomic group to be measured against changes in other taxa. In these times of diminished funding, reduced numbers of trained specialists, and rapidly declining biodiversity, such a unified approach leads to better use of resources by maximizing shared human, financial, and institutional resources (Reaka-Kudla *et al.*, 1997). Initial vegetation inventories provide a picture of the forest's floristic composition. Over time, continued monitoring contributes to understanding of the population dynamics in the study sites. By adding other taxonomic layers for monitoring, a clearer picture of the causes and effects of change will emerge. The implementation of multi-taxa monitoring should be encouraged wherever there is a long-term vegetation plot. Dallmeier and Comiskey also stress the need to incorporate evaluation and decision-making into the monitoring cycle in order to make the resulting information more accessible to protected-area managers.

Through long-term studies in plots, several basic theories of community structure and organization are being reevaluated. At the 50-ha plot in Barro Colorado Island (BCI), Hubbell (Chapter 2) and colleagues have been monitoring changes in the forest since 1980 (Hubbell and Foster, 1983, 1990). In his paper, Hubbell reviews the data collected at BCI and speculates on the evidence supporting the niche-assembly and dispersal–assembly theories of community organization within the forest. Smaller plots in Manu are also finding that the nonequilibrium model does not account for high similarity levels between disjunct floodplain forests (Terborgh *et al.*, 1996). The intermediate disturbance model developed by Connell (1978) is also showing evidence of weakness at the very site where it was developed, the Budongo Forest, Uganda. Sheil (Chapter 23) suggests that community organization models should take into account the influences that affect regeneration within the forest. To evaluate changes over time, it is essential to achieve a greater understanding of basic ecological processes that determine community structure. Long-term monitoring will continue to provide needed data.

A question of scale

Plot-based research occurs within a range of plot sizes, from 0.1-ha plots (Stergios *et al.* and Aymard *et al.* other volume; Gentry, 1988) to 1-ha (e.g. Pipoly and Madulid; Kong *et al.*; Yide *et al.*; Oatham and Beehler, Chapters 34, 31, 32 and 36) through 50-ha plots (Ashton; Condit *et al*; Sukumar *et al.*, Chapters 3, 14 and 28). The 0.1-ha plots are rarely permanent and usually provide only an initial assessment of diversity in an area. The cost and time to establish these plots are low, but they provide no information about forest dynamics unless they are made permanent, requiring more time and money. Stern compares the results of two 0.1-ha methods with those from a 1-ha plot, finding that replicability of the transects within that given habitat was low. At an intermediate

provide a characterization of floristic composition and forest dynamics over time. At the 50-ha scale, the cost and effort are large, but so is the wealth of information arising from the plot. At this scale, it is possible to assess the dynamics of individual species in the forest.

Among the many important applications of 50-ha plots is the development of techniques to increase the utility of data arising from smaller plots (Condit *et al.* Chapter 14). By analyzing individual 1-ha units within the 50-ha plot, Condit and colleagues demonstrate that it is possible to calibrate the measures for assessing diversity in the smaller plots. Some of the diversity indices commonly used are more sensitive than others when dealing with smaller sample sizes. Hall *et al.* (Chapter 4), based on the 50-ha plots in BCI and Pasoh Forest Reserve, Malaysia, describe a method for determining the minimum number of plots and their respective sizes to detect variability between populations. For cross-site comparisons, they show that the number of individuals is more important than the size of the plot and suggest enumerating a minimum of 1,500 individuals. The high cost of large plots both in the establishment and maintenance will restrict their use. We strongly encourage that the results continue to be used to fine tune the interpretations made from the smaller sample plots.

Measurement of mortality within a forest is an important factor for assessing change. Phillips and Gentry (1994) found that there has been an increase in tree mortality globally in the second half of this century. Phillips (Chapter 13) iterates that this is a real phenomenon suggesting that forests have been affected by large-scale anthropogenic activities or natural changes. This provides a strong case for long-term monitoring and the compilation of mortality data worldwide. But mortality and recruitment need to be measured accurately, and this is dealt with by Hall *et al.*, who suggest that at least 1,000 individuals need to be monitored. Assessment of variability in mortality and recruitment at different sites leads to the suggestion that 10 to 20 enumerations are required to determine accurate dynamic rates for a particular site.

STANDARDIZED PROTOCOLS AND SITE NETWORKS

Standardized methodologies for the establishment and monitoring of permanent plots are available (Dallmeier, 1992; Dallmeier and Comiskey, 1996; Dallmeier *et al.*, in press). Kohl *et al.* (Chapter 20) report on a European project that will provide standardized methodologies for diversity assessment and tools for creating management planning strategies based on measures of habitat diversity. The aim is to develop a common currency, or denominator, among different sites to allow cross-site comparisons. Nonetheless, there is an urgent need to develop more protocols that can be applied within the framework of biodiversity plots.

A series of sites linked by common protocols forms a network. Several such networks are currently operating at a variety of scales. These may be within a structure and composition of a forest subject to typhoons and heavy human population pressures. All these studies and similar ones in the Caribbean (Dallmeier *et al.*; Reilly *et al.*; Rogers *et al.*; Weaver , other volume) illustrate the natural resilience of forests exposed to disturbance. These studies will add to our understanding of how natural ecosystems deal with external stress, and will help us in restoring areas degraded by deforestation in these regions.

SATELLITE IMAGERY

Changes in forest diversity can be measured through the use of long-term biodiversity monitoring plots, as already demonstrated. But how can such information be extrapolated to larger forested areas? Measuring all the trees in a region is obviously an impossible task. The answer may lie in remote sensing. Lund *et al.* (Chapter 5) discuss how biodiversity plots may be used to develop a classification system from ground-truthing of remote sensing data. Gerard *et al.* (Chapter 9) show how structural parameters measured in biodiversity plots in the Beni Biosphere Reserve (Comiskey *et al.* other volume) are being used to map tropical forests using satellite imagery. This allows extrapolation of data to areas that have not been visited on the ground and also enable assessments at regional and national scales.

Studies of the changes of forest, shrubland, and savanna communities in the Venezuelan Llanos using Landsat data show that the forests of the region could disappear by the year 2020 (Berroteran, Chapter 8). This information is important in determining appropriate land-management practices for the region. Lobo and Gullison (Chapter 10) provide a new approach for discriminating between different tropical forest types using Landsat imagery, which has been found by ground verification to be highly accurate. Many such projects, including NASA's Mission to Planet Earth (1996), are currently underway to improve the interpretation of ground-based changes.

FINAL NOTE

Forest plots provide an ideal setting for measuring, monitoring, and modelling forest biodiversity at various spatial and temporal scales. The standardisation of protocols and the development of networks has greatly enhanced the value of plot based research. This should continue to be encouraged.

Important steps are also being made to provide ways of assessing the value of data arising from different size plots. Sampling intensity increases with plot size, but the number of possible replicates decreases due to higher cost and effort. It is therefore clear that there is a need to use plots of different sizes. We find it greatly encouraging to see the effort being made to address the comparison of data arising from the different methodologies. We will all benefit from these comparative studies.

There is an on-going need to improve the information derived from satellite

based on the results of small study plots – whether they be 1 or 50 ha in a forested area of several thousand ha. How can this information be extrapolated to the larger area?

The present volume has helped to illustrate the wealth of information derived from long-term vegetation monitoring plots. Many of the studies are being carried out in areas with high levels of biological diversity (Makana, Pascal, and Pipoly *et al.*). It is imperative to continue monitoring at these areas to gain a deeper understanding of ecosystem processes and predict future changes.

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Chapter 22), or protected area (Comiskey *et al.* other volume). On a national scale, Brown (Chapter 26) reports on a network of forest sites in Australia, illustrating his example with activities in Tasmania. Cool temperate forest biodiversity monitoring protocols are linking sites internationally in Australia, Chile, and the Pacific Northwest (Brown *et al.*, Chapter 27) to detect the impact of global climatic change. Another, initiated by the Smithsonian Institution's Center for Tropical Forest Science, was begun in Asia on 50-ha plots. The goals are to represent the major habitat conditions and forest types to inform policy-makers and to build predictive models for optimal forest management (Ashton, Chapter 3). In all cases, the link among the different sites is the common monitoring protocol.

Even though Europe has a long history of forestry research, including a network of more than 100 monitoring plots in use for the last century, there is still a need for quantifying trends in biodiversity to assess management techniques. Several networks have been established with standardized data management protocols to assist in the creation of management planning strategies that are based on measures of habitat diversity (Kohl *et al.*, Chapter 20). Belchansky *et al.* (Chapter 6) also illustrates a data management system, Interactive Information System, that was developed to monitor changes in biodiversity and micro-climate of boreal forests in the Russian Urals.

Under the auspices of UNESCO's Man and the Biosphere Programme, EuroMAB (which encompasses Europe and North America) has developed the Biosphere Reserve Integrated Monitoring Project (BRIM; Nauber, Chapter 21). Through this initiative, a data base has been developed for all biosphere reserves in Europe. It includes information on flora, fauna, hydrology, anthropogenic impacts, meteorology, soil, and topography. A directory has been published and is also available on the World Wide Web, allowing researchers to see what data is available for different biosphere reserves. Under this initiative, the US MAB program initiated the development of MabFauna and MabFlora through the University of California. These software packages allow storage of inventory data and provide metadata standards for additional information. At SI/MAB, the Biodiversity Monitoring Database (BioMon) was developed to process site-specific data arising from biodiversity plots (Comiskey *et al.*, 1994; Dallmeier and Comiskey, 1996). BioMon, now being used throughout the international biodiversity monitoring network at nearly 200 sites, forms part of the BRIM initiative. With the implementation of new monitoring protocols there is a need to develop associated standard data management protocols to allow for the transfer of information between different sites.

DIVERSITY ASSESSMENT

Analysis and quantitative assessments of community structure are essential for a meaningful evaluation of biodiversity. Estimating diversity for extrapolation

research. Several papers focussed on how to improve the accuracy of diversity indexes. Condit *et al.* (Chapter 14) reviewed which indices are most accurate for different sample sizes. Chazdon *et al.* (Chapter 16) assess various statistical approaches for estimating speies richness, and provide broad guidelines for the use of non-parametric estimators.

Hayek and Buzas (Chapter 17) report on a new decomposition formula that allows the researcher to obtain estimates of species richness and evenness from accumulated samples. This new SHE analysis will also enable evaluation of which distributions fit the observed species abundance data and comparison of data sets from different sites at levels that were previously unavailable.

FLORISTIC DATA AND BEYOND

Most of the papers in this volume have at least one issue in common: characterization of a forest type using a permanent plot. But the information derived from biodiversity plots goes beyond forest inventory and monitoring, as already noted. Several papers illustrate other applications for the data.

Mistry (Chapter 12) shows that a forest may be categorized by different seed-dispersal modalities of the existing species. In his paper, Mistry relates these modalities across disturbance, latitude, and moisture gradients. Further application of plot data to the study of biogeographical patterns of seed dispersal will most likely yield important results. Two questions that arise are how these modalities change over time at a particular site and how to use the information for conservation purposes.

Changes over time and how to differentiate between a true 'signal' and the 'noise' that is inherent in the data have been addressed by Hall *et al.* (Chapter 4). It is necessary to detect whether changes are part of the natural process of the forest or caused by other, external pressures. Several papers address the need for baseline data to determine the effects of global climatic change. In his paper, Innes *et al.* (Chapter 22) shows how long-term plots have been used to measure not only habitat characteristics but also ecosystem processes and the effects of air pollution and climatic change on forests in Switzerland. The Dinghushan Biosphere Reserve (Kong *et al.* Chapter 31), because of its location in the monsoon forests, will prove to be a good indicator of climatic change in Southeast Asia.

Several papers in this volume also address the effects of natural frequent disturbance such as that caused by wind. I-Fang *et al.* (Chapter 33) show how the impact of wind has affected the forest in Taiwan, while Abdulhadi *et al.* (Chapter 35) attributes mortality in forests of West Java to wind disturbance. Southeast Asia is renowned for the effect of typhoons, and several studies address the impact of these storms on the vegetation. One of the longest running studies of this kind is described by Burslem *et al.* (Chapter 37); the authors address the effects that cyclones have had on the Solomon Islands since 1964. On Hainan