Mapping the spatial distribution of plant diversity indices in a tropical forest using multi-spectral satellite image classification and field measurements

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Abstract. The relationships among alpha and beta diversity indices, computed from 141 randomly sampled quadrats, and the vegetation classes obtained by multi-spectral satellite image classification, were used as a strategy for mapping plant diversity in a tropical landscape mosaic. A relatively high accuracy of the land cover map was revealed by the overall accuracy assessment and the Cohen’s Kappa statistic. Species accumulation models were used to evaluate how representative the sample size was of the different vegetation types. A standard one-way, between-subjects ANOVA confirmed a significant reduction of the within-class variance of plant diversity with respect to their total variance across the landscape. Computed uniformity indices, to assess the internal uniformity of vegetation classes on the diversity indices, confirmed the goodness of the mapped classes in stratifying variability of plant diversity. This allowed for the use of the mapped classes as spatial interpolators of plant diversity values for estimation and up-scaling purposes. Finally, it was revealed that the plant diversity of the landscape depends, to a large extent, on the diversity contained in the most mature forest class, which is also the most diverse community in the studied area. High and moderate beta diversity values between mature forests and both the secondary associations and the first stages of succession, respectively, indicated that there is a significant contribution to the diversity of the landscape by those vegetation classes.

Introduction

Tropical forests of the Yucatan peninsula in Mexico consist not only of mature forests but also of other habitats (Cabrera et al. 1982). In the context of the landscape, they form a mosaic of forests in different stages of succession, which together with other non-forested land cover habitats, such as flooded or deforested areas, croplands and grasslands, produce a relatively broad range of ecological conditions. These habitats vary in size, shape, and composition. These variations are attributed to a combination of interacting physical, biological and anthropogenic elements (Forman 1995). In some cases the disturbance regime is dominated by natural causes, for example fire and hurricanes (Whigham et al. 1991). In others, disturbances are of anthropogenic origin, such as slash-and-burn shifting cultivation and land use changes. The characteristics, spatial distribution and configuration of these habitats may also influence the presence and abundance of species (Mazerolle and Villard 1999), causing them to be unevenly distributed over space.
During the past decade the forests of the Yucatan peninsula have endured high rates of deforestation (SEMARNAP 1998). The resulting effects of this process are the loss of biological diversity and damage to wilderness habitats, increase in soil erosion, disturbance to the hydrological cycle and nutrient losses, among others (Isik et al. 1997). To stop these processes and preserve the biological diversity of these forests, accurate information on their biodiversity is required. Developing and using this type of information is therefore an essential part of conservation programs. For example, the spatial distribution of species over a landscape aids in the identification of high priority areas (Carroll 1998; Myers et al. 2000), which may be used for locating reserves, refuges or other protected areas.

One approach to describing the spatial patterns of plant diversity in landscape mosaics consists of accounting for the diversity within and between particular habitats that could be considered homogeneous communities. On the one hand, plant diversity is estimated inside each of these habitats. On the other, the dissimilarity (or complementarity) between such habitats is also estimated (Colwell and Coddington 1995). Whittaker (1972) defined these two components of species diversity as z- and β-diversity (i.e., within and between communities). This approach to measuring plant diversity is useful in assessing not only the relative importance in terms of diversity of different areas, but also in estimating dissimilarities in species composition among habitats or ecosystems in a landscape. The ‘intrinsic’ diversity of a community is given by its z-diversity. Thus, an area with higher z-diversity may be considered more important than one with lower z-diversity values, for conservation purposes. The contribution of any given area or habitat to the overall diversity in the landscape can be determined through the estimation of β-diversity. In consequence, areas with lower z-diversity can still be of importance for conservation because of their contribution to the total diversity at the landscape scale (Groombrige 1992). That is to say, there are some species that are only present in these particular areas.

The most commonly employed measures for estimating the diversity of species in a community are those related to species richness (i.e., the number of species present in an area) and measures based on species frequencies or abundance, including Shannon and Simpson indices (Magurran 1988; Krebs 1989). Several measures of species diversity among communities have been recommended to assess biodiversity through environmental gradients (Whittaker 1972; Magurran 1988). These measures, however, can also be applied to assess the replacement of species among habitats in a heterogeneous landscape mosaic (Moreno and Halffter 2001).

One of the main problems in comparing the number of species among communities is that species richness is not independent of the sample size. The number of species increases with the size of the area sampled. Therefore, to make comparable the number of species among different habitat types, it is necessary to employ the same sampling effort in every one of them (Soberon and Llorente 1993; Moreno and Halffter 2000). Another problem in measuring biological diversity is presented by the difficulties and effort required for sampling large areas of densely forested landscapes, particularly when access to some particular sites is difficult,