

Report

Assessing Biodiversity from Space: an Example from the Western Ghats, India

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ABSTRACT. We demonstrate for the first time the potential use of satellite imagery to characterize areas of high and low species richness of trees in tropical forests. Our studies, conducted in the Biligiri Rangaswamy hills in the Western Ghats, India, show a high positive correlation between species richness and the Normalized Difference Vegetation Index (NDVI), which is an index of green biomass. We discuss the application of NDVI values for biodiversity assessment and monitoring, as well as for conservation planning. The NDVI is a rough measure of green biomass.

INTRODUCTION

Biodiversity losses around the world continue to mount despite considerable efforts to protect species and wildlands. According to the latest FAO report (FAO 2000), the annual rate of deforestation in the world during 1990–2000 was 9.4 million ha, and a recent report issued by the IUCN (Walter and Gillett 1998) indicates that one out of every eight plant species is endangered or threatened with extinction. Rapid assessment and monitoring of biodiversity, particularly in the tropics, is critical for conservation planning, but we lack methods to delineate areas with high levels of biodiversity at large spatial scales without intensive, time-consuming ground surveys. Although remote sensing imagery has greatly enhanced our ability to monitor biodiversity losses at the landscape level, such imagery has not yet been used to differentiate areas with varying levels of species richness or biodiversity within a landscape in the tropics. Here we demonstrate for the first time the potential use of satellite imagery to characterize areas of high and low species richness of trees in tropical forests where biodiversity losses are high. We also discuss the application of our technique for biodiversity assessment and monitoring, as well as for conservation planning.

METHODS

We divided the Biligiri Rangaswamy Temple Wildlife Sanctuary, in Karnataka, India (Lat. 11° 43' to 12° 08' N and Long. 77° to 77° 16' E), approximately 540 km²

in size, into 147 2 x 2-km grid cells. The size of the cells was determined by the number of plots that could be sampled within a reasonable time.

The Normalized Difference Vegetation Index (NDVI), an index of green biomass, was calculated by using cloud-free IRS 1C LISS III images, with a spatial resolution of 23.5 m, from three different seasons: February 2, 1998; November 16, 1998; and April 15, 1999. The images were processed using ERDAS Imagine software. February marks the start of the dry season, April marks its peak, and November is the earliest month following the monsoons that a cloud-free image can be obtained. Thus, imagery captured during these 3 months shows the annual variation in NDVI. The April image was geo-coded using five 1:25,000 and one 1:50,000 Survey of India(SOI) toposheets. The projection was polyconic and the RMS error was 6.81 m or 0.2961 pixels. The other two images were registered to this reference image. The RMS errors were 0.097 and 0.0833 pixels, respectively.

The NDVI of each image was calculated using the formula: $NDVI = (NIR - R) / (NIR + R)$; Where NIR = Near Infrared Band, and R = Red Band. The mean NDVI of three seasons for each pixel was calculated and then the mean NDVI of all pixels falling in each cell (2 x 2 km) was determined. This value was correlated with the tree species richness of each cell (N=134 cells). There are four types of forests found on the study site: scrub, dry deciduous, moist deciduous, and evergreen. Many cells have more than one

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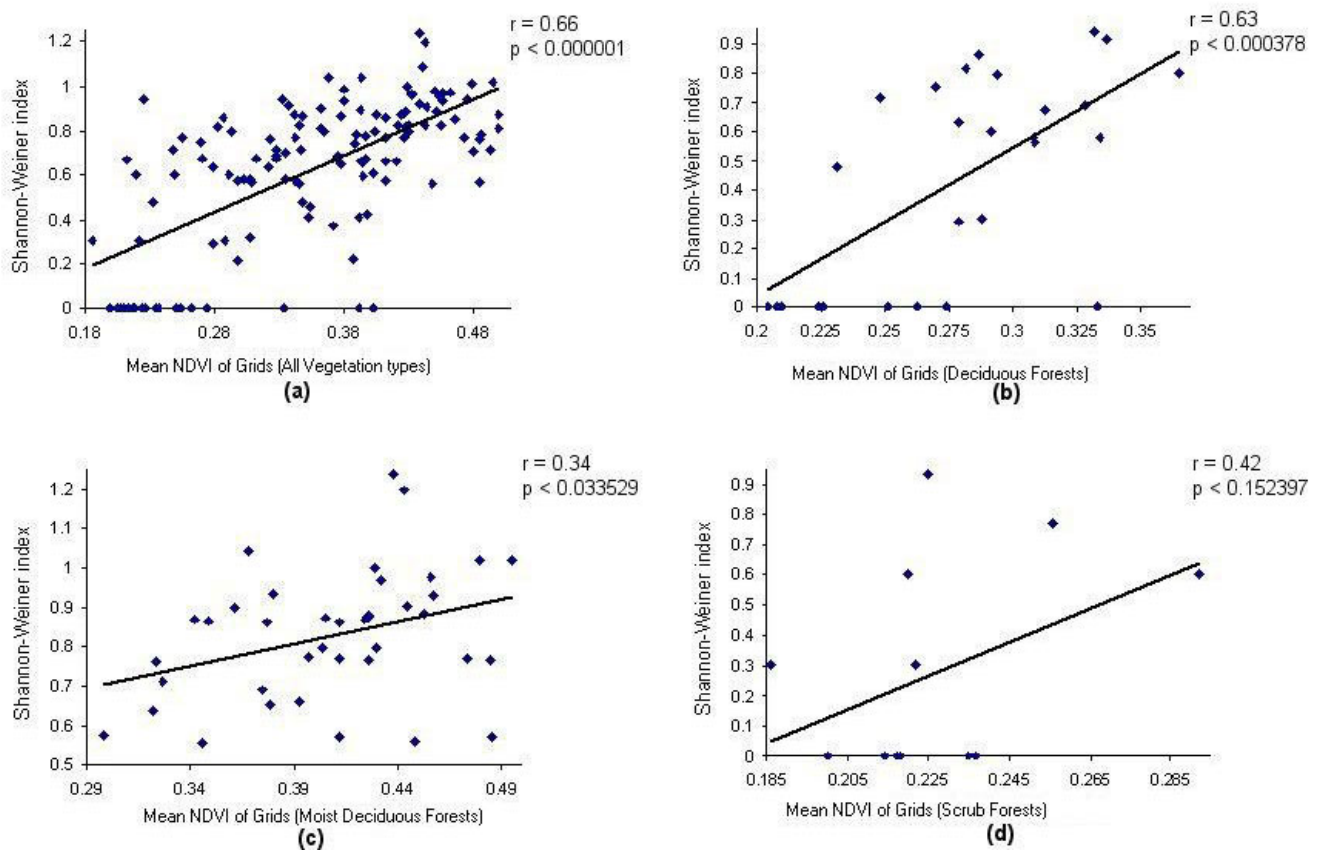
vegetation type. Thus, they were categorized according to whichever vegetation type occupied more than 60% area of the cell. In 45 cells, no one particular

vegetation type occupied more than 60% of the cell area. These cells were removed from the analysis.

Table 1. Basic parameters of plots on the ground (values in parentheses are the ranges for the corresponding parameters)

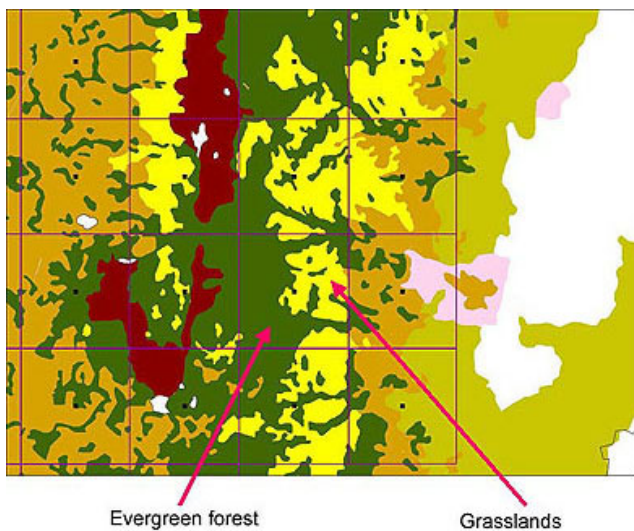
Vegetation type	Number of plots	Average basal area (m ²) /plot	Average number of individuals >10 cm dbh/plot	Total number of tree species
Scrub	13	0.0571	4.23 (0–22)	14 (0–11)
Dry Deciduous	27	0.1211	9.85 (0–33)	26 (0–11)
Moist Deciduous	41	0.7181	19.15 (4–33)	74 (1–19)
Evergreen	8	0.6656	31.37 (20–45)	25 (8–14)

Fig. 1. Relationships between NDVI and species diversity in different vegetation types.



Species diversity (Shannon and Weiner 1963) was determined for 134 cells in 80 x 5-m plots laid in the center of each cell. Plot size was determined by time available for sampling all plots (one year) and the size needed to adequately capture tree species richness of various vegetation types. All trees greater than 10 cm diameter at breast height (dbh) were enumerated and totaled for each cell. Index was calculated by using the formula: $-\sum (n_i/N) \log_{10}(n_i/N)$, where n_i is the importance value of each species and N is the total importance value (i.e., 300).

Fig. 2. Scattered distribution of evergreen forests and grasslands in various cells.



RESULTS AND DISCUSSION

The basic parameters of each forest type found on the study site, such as basal area, average number of individuals, and average number of tree species, are shown in Table 1. The greatest species richness was found in the evergreen forests.

There was a positive correlation between mean NDVI and tree species diversity for all cells, without considering the vegetation types (Fig. 1a). Analysis for each of the four vegetation types revealed a positive correlation for deciduous (Fig. 1b) and moist deciduous forest (Fig. 1c). For the scrub forest, the relationship was positive (Fig. 1d), but not significant. The non significance could be due to the small sample size for the scrub forest. A separate analysis was not done for the evergreen forest because it is found in patches of various sizes interspersed in high-altitude

grasslands that have relatively low NDVI values (Fig. 2). Thus, the mean NDVI of the grid is not representative of the evergreen forests. Furthermore, in evergreen forests, NDVI values quickly get saturated after a certain number of species accumulates (Arturo Sanchez, *personal communication*).

Previous workers have found that an annual sum of NDVI derived from satellite imagery, and weighted with parameters for radiation absorption and light-use efficiency, may be used to estimate primary productivity at global and regional scales (Runyon et al. 1994, Tucker and Sellers 1986). As there is a well-known relationship between species richness and productivity (Adams and Woodward 1989, Currie 1991), we expected a positive relationship between plant species richness and NDVI values.

Indeed our results demonstrate that NDVI from remotely sensed images could identify areas of high species richness (Fig. 3). The two images in Fig. 3 are visually similar.

These results are not surprising because the NDVI should reflect the productivity of the ecosystem or the availability of free energy. Indeed both productivity and availability of energy are assumed to be the major determinants of species richness (Adams and Woodward 1989, Currie 1991, Rosenzweig and Abramsky 1993, Currie and Paquin 1987). However, despite the well-established relationship between productivity and species richness, remotely sensed imagery that can detect differences in measures of productivity has not previously been used to assess biodiversity. We should caution here that, as NDVI is a reflection of productivity or biomass, plantations or other human-managed ecosystems on the landscape can complicate the patterns described here.

The NDVI may be used not only to detect spatial patterns of biodiversity but also the distribution of biophysical parameters. The differences in vegetation type are primarily due to variation in soils, moisture, and temperature. Further analysis of the exact relationship between vegetation types and NDVI may lead to the detection of variation in biophysical parameters from satellite imagery.

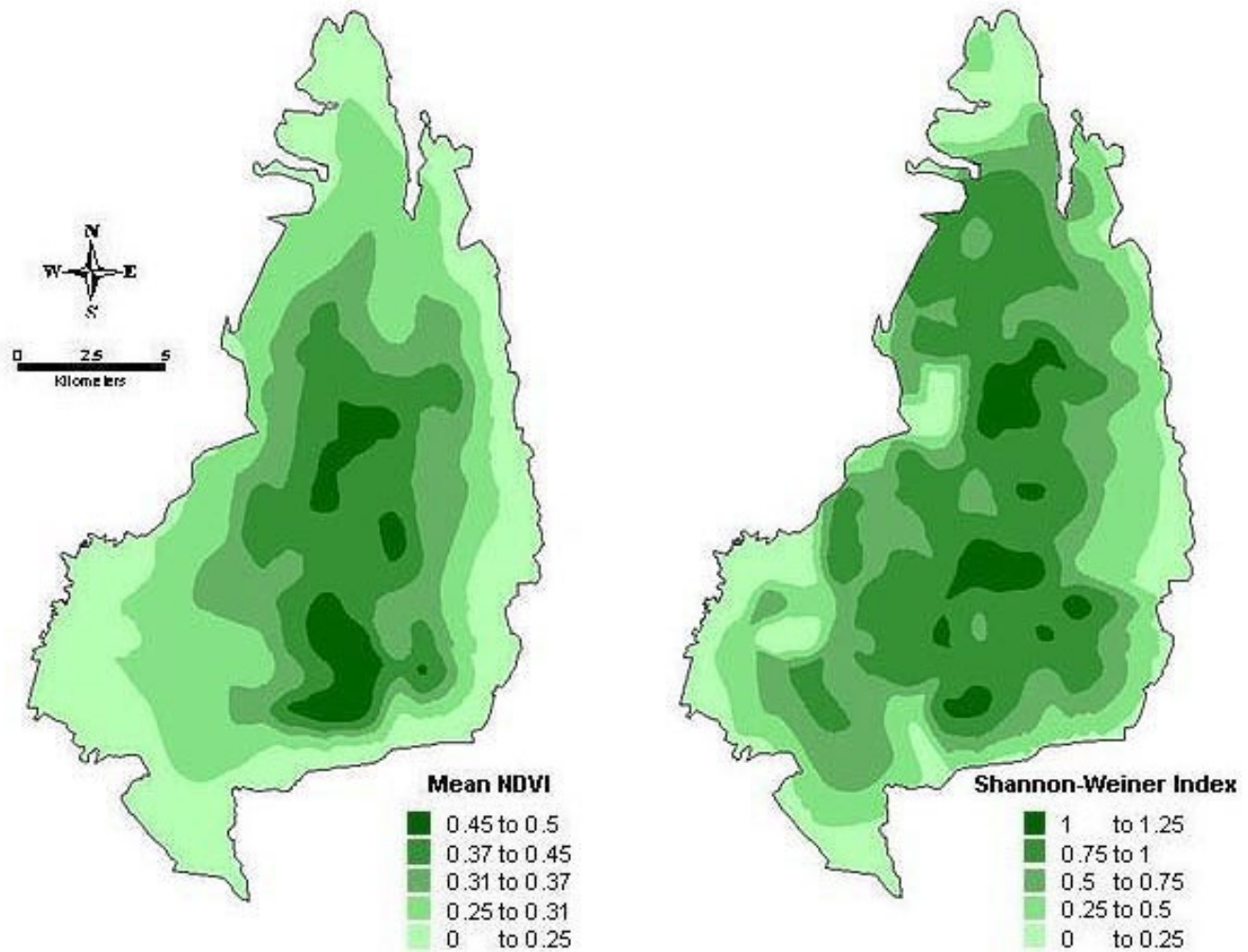
The urgent need for knowledge about biodiversity distribution over large areas of the globe, as emphasized by Wilson (2000), requires the use of remotely sensed imagery to identify areas of high species richness over large landscapes. We have

demonstrated that satellite imagery can identify broad patterns of tree species diversity in tropical forests. We recognize that the identification of such patterns must be followed by detailed work on the ground to confirm the trends and to document precisely the distribution

of the biodiversity.

Responses to this article can be read online at:
<http://www.consecol.org/vol6/iss2/art7/responses/index.html>.

Fig. 3. NDVI and tree-species diversity in the Biligiri Rangaswamy Temple Wildlife Sanctuary.



Acknowledgments:

We thank Arturo Sanchez and Jagdish Krishnaswamy for their advice and help with various analyses. Financial support was provided by grants from the Ford Foundation and the MacArthur Foundation.

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