H. M. Dogan, M. Dogan & F. Celep

Recent innovations brought by geographic information systems and remote sensing in vegetation and flora studies in Turkey

Abstract

Dogan, H. M., Dogan, M. & Celep, F.: Recent innovations brought by geographic information systems and remote sensing in vegetation and flora studies in Turkey. — Bocconea 24: 61-67. 2012. — ISSN 1120-4060.

In the last two decades, the use of geographic information systems (GIS) and Remote Sensing (RS) increased rapidly due to the great interest of many institutions in Turkey. Parallel to this increase, hardware, software and trained people structures started to develop. This progress enabled the preparation of some countrywide digital databases to be used in spatial analysis and modeling processes. Flora and vegetation studies took the benefit of these improvements, and some applications showed the emerging utility of these tools. In this presentation, we summarized two latest innovations of us that can be used for plant bio-diversity and community composition mapping. In the former, we explained how plant bio-diversity of Nallihan forest ecosystem was modeled and mapped in GIS by utilizing diversity (Shannon Wiener, Simpson, Number of Species) indices, environmental (soil, topography, geology and climate) variables, and remotely sensed data (LANDSAT-ETM+). In the latter, we summarized the ways of Normalized Difference Vegetation Index (NDVI) usage to develop plant community composition maps of Tersakan Valley in Amasya by using both GIS and RS.

Introduction

Depending on its importance, there is a strong concern to preserve biological diversity, and this issue has been depicted in many international conferences such as; Rio Declaration in Brazil (Anon. 1992), and Antalya Declaration in Turkey (Anon. 1997). Furthermore, the issue has been repeatedly emphasized in many of the reports, decisions and recommendations of Food and Agriculture Organization of the United Nations (FAO), United Nations Environment Program (UNEP), The World Conservation Union (IUCN) and other international or national organizations.

A broad capacity-building effort is urgently needed so that countries can monitor their plant resources (an essential requirement of Rio Declaration). Governments and institutions should establish and/or strengthen national assessment and observation systems for plant resources. This will require new data systems and statistical modeling, ground surveys and other technological innovations such as geographical information systems (GIS) and remote sensing (RS). Consequently, the demand for maps of specific themes of the earth`s surface, such as natural resources, has accelerated recently. Remotely sensed imagery has given the researchers enormous advantages for reconnaissance and semi-detailed mapping. The resulting thematic maps have been a source of useful information for resource exploitation and management (Burrough 1986). Development of these thematic maps and models has been limited in the past by the large amount of input data required and the difficulty of hardware. These two limitations have begun to reduce with the increasing availability of remote sensing data and geographic information systems (GIS) to manipulate it, and the development of hardware systems that allow computation of large complex spatial arrays (Constanza & Maxwell 1991).

In the last two decades, the utilization of geographic information systems (GIS) and Remote Sensing (RS) increased rapidly due to the great interest of many institutions in Turkey. Consequently, hardware, software and trained people structures started to increase that enabled the preparation of some countrywide digital databases to be used in spatial analysis and modeling processes. Flora and vegetation studies took the advantages of these improvements, and some applications showed the emerging utility of these tools. In this presentation, we first summarized the development of GIS and RS applications in plant studies in Turkey, and then two latest innovations of us that can be used for plant bio-diversity and community composition mapping.

The development of GIS and RS applications in plant studies in Turkey

Except some small scale studies, serious GIS and RS applications in plant studies in Turkey were started in 1995 with the support of the World Bank and Global Environmental Facilities (GEF) Projects. Consequently, some important technological investments about this subject have been done since 1996. Within the frame of these supports, several governmental and non-governmental organizations have focused to any aspects of the studies related to forestry, agriculture, cultivation, sustainable use, and conservation of plant genetic resources. Ministry of Environment, Ministry of Agriculture and Rural Affairs, and Ministry of Forestry can be shown as good examples in which in-situ studies have been conducted. However within the period between 1996 and 2003, the most of the studies were limited by the land cover and land use classification studies as well as creating digital database of basic covers such as topographical, soil, geological, and forest maps of Turkey. Within this period, digital topographic, soil, and geological maps (1/25000 scale) of Turkey were developed by Turkish Army (HGK: General Commandership of Mapping), General Directorate of Rural Affairs (KHGM) and General Directorate of Mineral Research and Exploration (MTA), respectively. Ministry of Forestry also completed the digital forest stand maps (1/25000 scale) of Turkey. Moreover, some of the studies made the climatic raster maps available (Dogan 2007a, 2007b). Establishing digital database of these basic covers, more specific and detailed modeling studies have emerged since 2005. Two of these modeling studies were found outstanding, and they were summarized below.

Mapping plant biodiversity

Using GIS and RS tools, a significant study of us showed that modeling and mapping plant biodiversity of Nallihan forest ecosystem of Turkey are possible (Dogan & Dogan

2006). In this study we employed Shannon–Wiener (SWI), Number of Species (NS), and Simpson (SIMP) indices (Table 1) and a complementary digital database including topography (elevation, slope, aspect), geology (formation classes), soil (great soil groups, soil depth, and erosion classes), climate (maximum-minimum-mean temperatures, precipitation, wind speed, sunshine fraction, potential evapotranspiration, and water vapor pressure), and covers derived from a LANDSAT ETM+ satellite image (normalized difference vegetation index (NDVI), land-use, and land-cover classes). We also collected geo-referenced field data from the established 56 quadrats (50 × 20 m) to calculate these indices. We used principle component analysis (PCA) and multiple regression for data reduction and model development, respectively. At the end of the study, we developed three models for indices (Table 2), and produced three diversity maps (Figure 1). Validity of the models were tested by using residual maps, and they were found robust. PCA results showed that elevation and climatic factors formed the most important components that are effective determinants of plant species diversity, but geological formations, soil, land cover and land-use characteristics also influenced plant diversity. Considering the different responses of the models, we found that SWI model is suitable for rare cover types, while SIMP model might be appropriate for single dominant land covers in the study area (Magurran 1988; Molles 1999; Nagendra 2002; Dogan & Dogan 2006).

Mapping plant community composition

The normalized difference vegetation index (NDVI) is one of the most frequently used index in plant applications (Bonneau & al. 1999; Edwards & al. 1999). It is a ratio-based index featuring a linear relationship between the near-infrared (LANDSAT ETM+ band 4) and red (ETM+ band 3) spectral bands, and can be calculated as (B4-B3)/(B4+B3) (Tucker 1979; Sabins 1987; Campbell 1996; Jensen 1996; Bonneau & al. 1999; Edwards & al. 1999; ERDAS 2003; USGS 2006). The NDVI produces a single band of data with values ranging from 21 to + 1, where higher values indicate more, or healthier, vegetation (Bonneau & al. 1999; Edwards & al. 1999). NDVI values can be stretched to an unsigned 8-bit image varying between 0 and 256 in ERDAS Imagine software (ERDAS 2003). Values close to 256 indicate the highest possible density of green leaves, while values close to 0 indicate the lowest possible density of green leaves or bare areas.

However NDVI potential to map plant community composition had not been known until we revealed. Utilizing collected geo-referenced cover-abundance (Braun-Blanquet, BB) data from 1077 quadrats in the field and NDVI values derived from a LANDSAT ETM+ satellite image, we developed a methodology to map plant commu-

Table 1. Shannon–Wiener, Number of Species, and Simpson indices (Molles 1999; Magurran 1988)

Shannon–Wiener (SWI)	Number of Species (NS)	Simpson (SIMP)
$H' = -\sum_{i=1}^{s} p_i \text{ loge } p_i$	$NS = \sum_{i=1}^{n} \text{species}$	$D = \sum_{i=1}^{s} p_i^2$
p_i: the proportion of individuals belonging to the *i*th species in the dataset of interest.		

Table 2. Developed models for Shannon–Wiener, Number of Species, and Simpson indices (Dogan & Dogan 2006).

Shannon–Wiener index = 22.296 + (0.008 * ELEV) + (1.688 * META) + (0.944 * MINTS) + (0.097 * PRCPA) + (0.226 * GEO) + (0.071 * ORGM) + (0.020 * CACO3)+(0.005 * SOILG)+(0.139 * SPVSD) - (0.981* METS) - (1.068 *MAXTA) - (0.289 * MINTA) - (0.143 * PRCPS) - (0.168 * PETAN) - (0.032 * PETSE) - (0.004 * STR) - (0.008 * TEXTR) - (0.378 * PH) - (0.081 * SLDPT) - (0.002 * NDVI)
Number of species index = -244.804 + (0.136 * ELEV) + (0.340 * ORGM) + (0.175 * CACO3) + (4.935 * TEXTR) + (11.565 * SOILG) + (1.099 * GEO) + (0.026 * NDVI) + (0.365 * SPVSD) + (23.089 * META) + (4.766 * METS) + (3.804 * MAXTA) + (6.697 * MINTA) + (1.152 * PRCPS) + (3.932 * PETSE) - (5.642 * PH) - (0.395 * STR) - (0.402 * SLDPT) - (2.079 * MINTS) - (0.204 * PRCPA) - (10.770 * PETAN)
Simpson index = 10.424 + (0.437 * MINTA) + (0.087 * PRCPS) + (0.028 * PETSE) + (0.079 * TEXTR) + (0.004 * ORGM) + (0.030 * SLDPT) + (0.269 * PH) + (0.001 * NDVI) - (0.002 * ELEV) - (0.009 * META) - (0.220 * METS) - (0.293 * MAXTA) - (0.428 * MINTS) - (0.064 * PRCPA) _ (0.027 * PETAN) - (0.003 * STR) - (0.064 * GEO) - (0.001 * SOILG) - (0.011 * CACO3) - (0.053 * SPVSD)
Abbreviations: *ELEV, elevation; ORGM, organic matter; STR, saturation; TEXTR, texture; SOILG, big soil group; SLDPT, soil depth; GEO, geological formations; SPVSD, supervised classes; INDEXES, Shannon– Wiener, Simpson, NS indices; META, annual mean temperature; METS, seasonal mean temperature; MAXTA, annual maximum temperature; MAXTS, seasonal maximum temperature; MINTA, annual minimum temperature; MINTS, seasonal minimum temperature; PRCPA, annual precipitation; PRCPS, seasonal precipitation; PETAN, annual potential evapotranspiration; PETSE, seasonal potential evapotranspiration.*

nity composition of Tersakan Valley in Turkey (Dogan & al. 2009). Using bivariate correlation analysis, the relationships between 26 classified NDVI maps and BB were revealed, and the classified NDVI map with the strongest correlation was chosen. We further examined this relationship by using scatter plots, histograms and paired samples t-tests. Our results showed that the NDVI (equal-interval 15) classes between 4 and 8 corresponded with the BB classes between 1 and 5, respectively. Using this relationship, we determined the spatial distribution of 43 different plant community compositions in GIS (Fig. 2). Consequently, we revealed some unknown characteristics of the NDVI and showed that these characteristics might have the potential to produce plant community composition maps. The relationships between NDVI and plant cover abundance indicated two main advantages. First, these relationships guided to the detection of plant community composition borders on a spatially explicit basis. Second, they supported to monitoring processes that reveal temporal changes. We found that these two advantages are very important with respect to LANDSAT ETM+ data sets in various institutions whose websites allow access to spatial scales and time resolutions. Consequently, we not only developed a reliable community composition map but also produced a dependable spatial database that could be the basis for future monitoring studies. We proved that the NDVI has the capacity to determine cover-abundance classes more quantitatively and impartially compared to the conventional BB method. From this point of view, we strongly suggested the use of the NDVI in quantitative evaluation of cover abundance. Moreover, our final map contained a data-

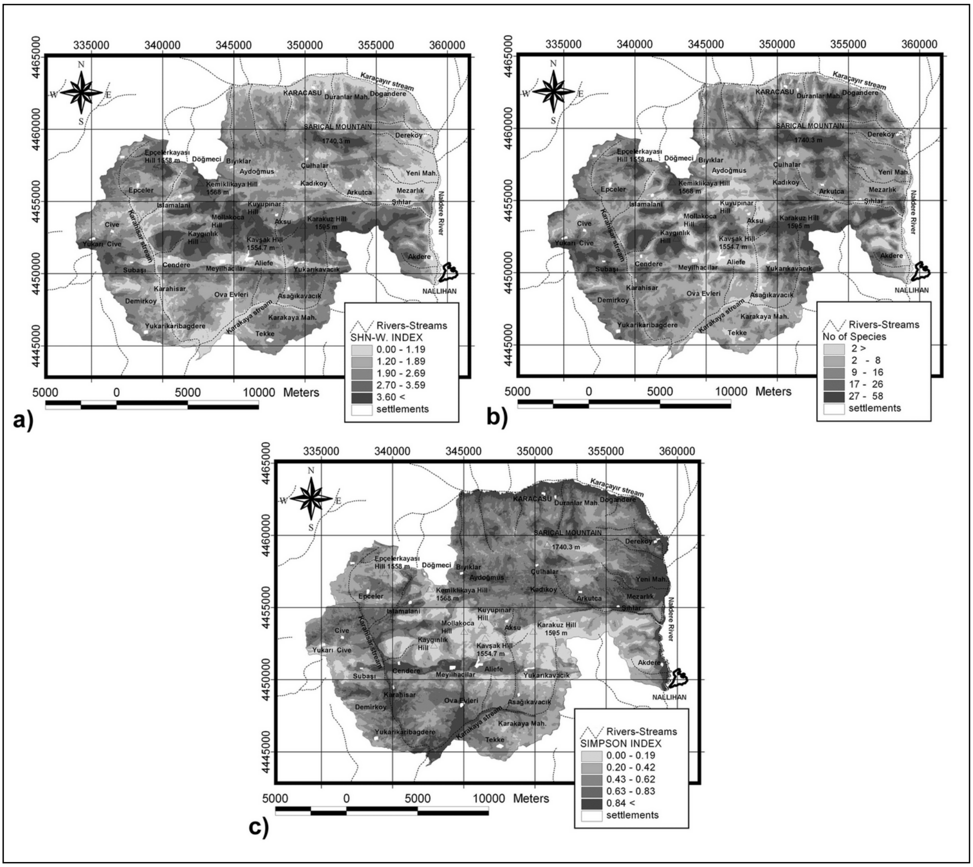

Fig. 1. Plant species diversity model maps of Shannon–Wiener (a), Number of Species (b), and Simpson (c) indices (Dogan & Dogan 2006).

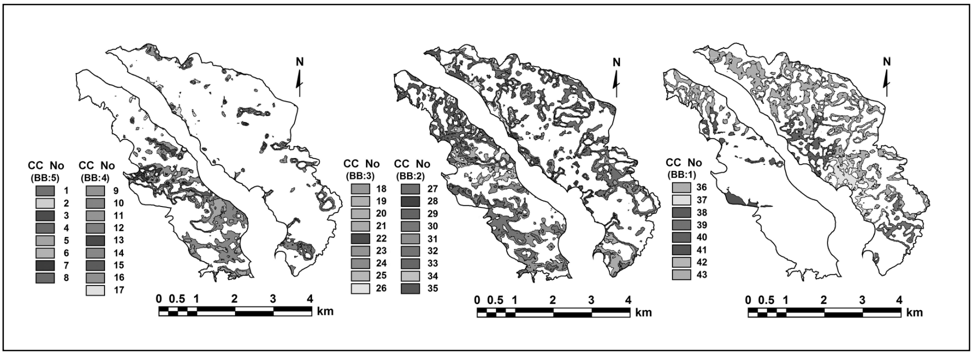

Fig. 2. Detected Community Compositions (CC) by NDVI classes and their corresponding Braun Blanquet (BB) Values (Dogan & al. 2009). NOTE: Species within each CC were listed in Dogan & al. (2009).

base that holds information about degradation degree. These findings could be of importance for researchers studying habitat fragmentation.

Conclusion

The lack of quantitative and spatially explicit data has resulted in simplistic representations of plant species distribution in Turkey until recently. Within this context, GIS usage, detailed complementary data, particular geo-referenced field data, and high-quality continuous spatial data obtained from satellite imagery may constitute a good basis for the preparation of detailed plant bio-diversity and community composition maps and the execution of suitable conservation strategies.

References

Anon. 1992: Agenda 21: Rio Declaration on Environment and Development. The United Nations Conference on Environment and Development, 3-14 June 1992. Rio de Janerio. U.N. Publication (http://www.igc.apc.org/habitat/agenda21/rio-dec.html).

Anon. 1997: Antalya declaration. XI. world forestry congress forestry for sustainable development, 13-22 October. Antalya, Turkey (www.wasmeinfo.org/icsme2001.htm).

Bonneau, L. R., Shıelds, K. S. & Civco, D. L. 1999: Using satellite images to classify and analyze the health of hemlock forests infested by the hemlock woolly adelgid. – Biol. Invas. **1:** 255-267.

Burrough, P. A. 1986: Principles of geographical information systems for land resources assessment. – Monographs on Soil and Resources Survey, **12.** – London.

Campbell, J. B. 1996: Introduction to Remote Sensing, 2nd ed. – New York.

Constanza, R. & Maxwell, T. 1991: Spatial ecosystem modeling using parallel processors. – Ecol. Modelling **58:** 159-183.

Dogan, H. M. 2007a: Climatic Portrayal of Tokat province in Turkey developing climatic surfaces by using LOCCLIM and GIS. – J. Biol. Sci. **7(7):** 1060-1071.

— 2007b: High Resolution Climatic Surfaces of Nallihan Ecosystem in Turkey; A Convenient Methodology to Create Climate Maps. – J. Appl. Sci. **7(5):** 654-662.

— & Dogan, M. 2006: A new approach to diversity indices - modeling and mapping plant biodiversity of Nallihan (A3-Ankara/Turkey) forest ecosystem in frame of geographic information systems. – Biodiv. Conserv. **15:** 855-878.

—, Celep, F. & Karaer, F. 2009: Evaluation of the NDVI in plant community composition mapping: a case study of Tersakan Valley, Amasya County, Turkey. – Int. J. Remote Sensing **30(14):** 3769-3798.

Edwards, M. C., Wellens, J. & Al-Eisawi, D. 1999: Monitoring the grazing resources of the Badia region, Jordan, using remote sensing. – Appl. Geogr. **19:** 385-398.

ERDAS 2003: Erdas Field Guide, 7th ed. – Atlanta.

Jensen, J. R. 1996: Introductory Digital Image Processing: A Remote Sensing Perspective, 2nd ed. – Englewood Cliffs.

Magurran, A. E. 1988. Ecological diversity and its measurement. – New Jersey.

Molles, M. C. Jr., 1999: Ecology, concepts and applications. – Boston.

Nagendra H., 2002. Opposite trends in response for the Shannon and Simpson indices of landscape diversity. – Appl. Geogr. **22(2):** 175-186.

Tucker, C. J. 1979: Red and photographic infrared linear combinations for monitoring vegetation. – Remote Sensing Environm. **8:** 127-150.

USGS. 2006: LANDSAT Project. United States Geological Survey (USGS). – Available online at: http://landsat7.usgs.gov/index.php (accessed 18 October 2006).

Addresses of the authors:
Hakan Mete Dogan,
(corresponding author) Gaziosmanpasa University, Agricultural Faculty, Soil Science Department, Tokat/Turkey. E-mail: hmdogan@hotmail.com
Musa Dogan,
Department of Biological Sciences, Middle East Technical University, Ankara/Turkey. E-mail: doganm@metu.edu.tr
Ferhat Celep,
Department of Biological Sciences, Middle East Technical University, Ankara/Turkey. E-mail: fcelep@metu.edu.tr