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Species and Ecosystems Stages of Biodiversity Evaluation Using Remotely-Sensed Data

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Abstract

Knowledge of historical variations in landscapes offers helpful insights into present species and ecosystems biodiversity stages and supports future strategies on management, decision and conservation. The covers and arrangements of constant vegetation patches are important indicators of keeping resources. Patchiness attributes, as descriptors of resource preservation potentials in landscapes, can be obtained from the remotely-sensed imagery. The objective of this study is to assess land use change and the related biodiversity variations in the landscape of Attica, Greece. Remotely sensed images are geo-corrected and introduced in the image processing software packages. Representative indicators regarding the species (sparse vegetation - α diversity, medium vegetation - β diversity, dense vegetation - γ diversity) and ecosystems (landscapes - eco-zones) biodiversity stages are picked and measured through selective indices. The purposes of the current paper are to estimate the current status, trends and changes in the preferred indicators of the important landscapes and appraise the geographic coverage and extent of the landscapes' patterns and types.

Keywords: Biodiversity Economics, Environmental Indicators, RS metrics, NDVI, Landscape Assessment, Species and Ecosystems Stages

1. Introduction

In the last decades, human impacts on the land has increased enormously varying landscapes with imperative environmental consequences such as biodiversity loss, deforestation, soil erosion and desertification.

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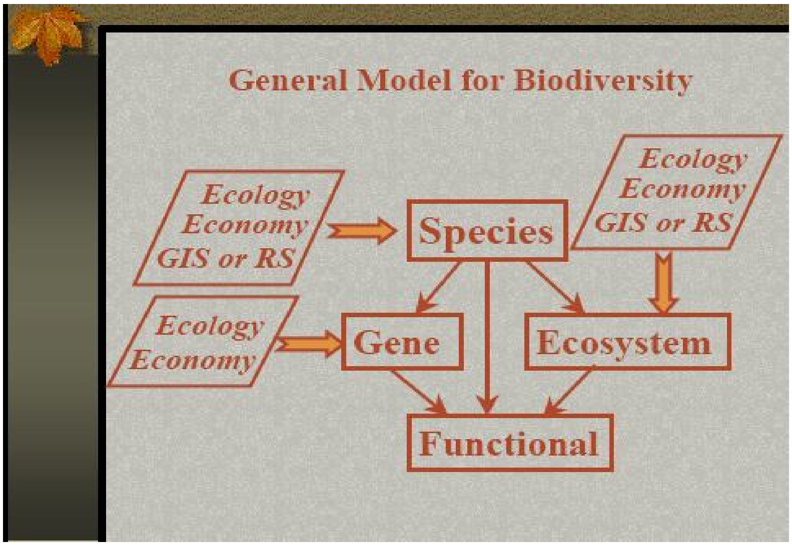
In addition, human impacts through agriculture and industry persuade variations in climate and earth capacities (Giordano & Marini, 2008; Tagil, 2007; Greco etc, 2005; Lopez-Bermudez and Garcia Gomez, 2003). Humans impacts escort harmful effects on the sustainable resource usage. The environmental progress supervision of sustainable development requires indicators on natural status (Hall, 2001). Environmental indicators with the augment of scientific understanding and educated employment express sustainable use of natural resources. ANZECC (2000) presents 75 indicators mainly with the use of remote sensing.

A key aspect in the examination of Biodiversity is the description of the phrase "biodiversity". Turner etc. (1999) points up that biodiversity economics comprises four stages as: Genes, Species, Ecosystems and Functions. Afterwards, there is given a new approach to the biodiversity of economics. Four stages of Biodiversity have three ways of assessments, i.e. Economic (U.S. Environmental Protection Agency, 2002), Environmental (Peter etc, 2008) and GIS (Strand etc, 2007) appraisals of Biodiversity as implemented by Petrosyan (2010) in Figure 1. Making parallel in Fischer & Lindenmayer (2007), Foley etc (2005), Fazey etc (2005), Foody (2003), Jensen (2000) and Turner etc (1999) characterizations, two stages of biodiversity can be portrayed as:

- Species = Classes = Biodiversity = Habitats:
  - α diversity;
  - β diversity;
  - γ diversity;
- Ecosystems = Landscapes = Ecozones.

Figure 1: Economic, Environmental and GIS Appraisals of Biodiversity Stages



Source: Petrosyan (2010)

A new table is obtained from Fischer & Lindenmayer (2007), Foody (2003) and Jensen (2000) papers emphasizing on Species and Ecosystems stages of biodiversity concept. Table 1 depicts themes, issues, definitions of 2 Biodiversity stages as per candidate metrics using RS inputs.

Table 1. Themes, Issues, Definitions of Species and Ecosystems Biodiversity Stages as Per Candidate Metrics Using RS Inputs

Theme / Issue / Definition	Indicator	Candidate Metrics	Potential RS input
Species: The range of environments suitable for a particular species			
Threatening process / Sub-division of habitat for particular species	Native vegetation clearing	Adjacency of land-cover types, biophysical attribute patterns, contagion, dominance, elevation, erosion index, fractal dimension, hydrologic modification, patch per-unit-area index, patch statistics, square pixel model, slope, texture, zone fragmentation index	Monitor land cover change
	Aqua-habitat destruction		Monitor land cover change
	Vulnerability to flooding		
	Fire regimes		Estimate canopy moisture content, map drought
Biodiversity states / States of habitat for particular species	Extent of native vegetation	Adjacency of land-cover types, biophysical attribute patterns, contagion, dominance, fragmentation, patch statistics (number, total area, average size, largest size, distance between, ratio perimeter to area, shape, fractal dimension, square pixel model, etc.), patch per-unit-area index, Shannon diversity, zone fragmentation index	Map land cover
	Wildlife habitat suitability		
	Extent of aquatic habitats	Adjacency of land-cover types, biophysical attribute patterns, contagion, dominance, elevation, erosion index, fractal dimension, geochemical attributes, hydrologic modification, patch statistics, slope, patch per unit area index, square pixel model, zone fragmentation	Map land cover
	Water quality		
	Populations of selected species	Biophysical attribute patterns, diversity, dominance, erosion index, fragmentation, patch per-unit-area index, slope, texture, patch statistics, square, pixel model, zone fragmentation index	Map land cover and link to bio-geographical models
	Forest plant species richness		
Species Conservation and Management	Terrestrial protected species	Adjacency of land-cover types, biophysical attribute patterns, geochemical attributes, diffusion rates, diversity, dominance,	Recovery plans
	Map&monitor		Monitor land

Theme / Issue / Definition	Indicator	Candidate Metrics	Potential RS input
/ The range of environments suitable for particular species	land cover Stream of bio conditions Area revegetated	elevation, erosion index, fragmentation, patch per-unit-area index, slope, percolation threshold, square pixel model, texture, zone fragmentation index	cover, estimate biophysical variables Monitor land cover
Ecosystems: A human-defined area ranging			
Use and management / A human perspective of land-cover types and environmental gradients in a landscape	Changes in land use	Adjacency of land-cover types diversity, biophysical attribute patterns, diffusion rates, dominance, elevation, erosion index, fragmentation, geochemical attributes, patch per-unit-area index, patch statistics, percolation threshold, Shannon diversity, slope, square pixel model, texture, zone fragmentation index	Monitor land cover
Erosion / Characterized landscape by strong contrast in vegetation patches and surrounding matrix	Potential for erosion	Adjacency of land-cover types, biophysical attribute patterns, contagion, dominance, elevation, erosion index, fractal dimension, hydrologic modification, patch per-unit-area index, patch statistics, slope, square pixel model, texture, zone fragmentation index	Map land cover, link to environmental data
Landscape Preservation &Management / Range of natures apt as landscape preservation	Earthly protected areas Landscape sustainability	Biophysical attribute patterns, contagion, dominance, fragmentation, fractal dimension, patch per-unit-area index, patch statistics, square pixel model, zone fragmentation index	Recovery plans on landscape stage

Remote sensing (RS) and Geographic Information Systems (GIS) as the utilization of satellite imagery proffer means to observe protected ecosystems (Nagler etc, 2009; Melesse etc, 2007; McDermid etc, 2005; Symeonakis and Drake, 2004). The Normalized Difference Vegetation Index (NDVI) is the most regularly used technique to supervise and map vegetation changes through the use of satellite imageries (Tagil, 2007; Yemefack etc., 2006; Mahiny and Turner, 2005; Seaquist etc., 2003; Parodi, 2002; Argialas, 2000, Ayanz, 1996).

In this paper, an investigation of the usefulness of spatial techniques like Remote Sensing and GIS are performed to assess land use changes and the related biodiversity variations. NDVI is calculated to assess vegetation changes for the time period of three (3) continues years during the period of 1984-2002 years. Classification into three (3) classes is performed correspondingly. Landscape metrics are computed to pilot vegetation states as per species and ecosystems biodiversity stages.

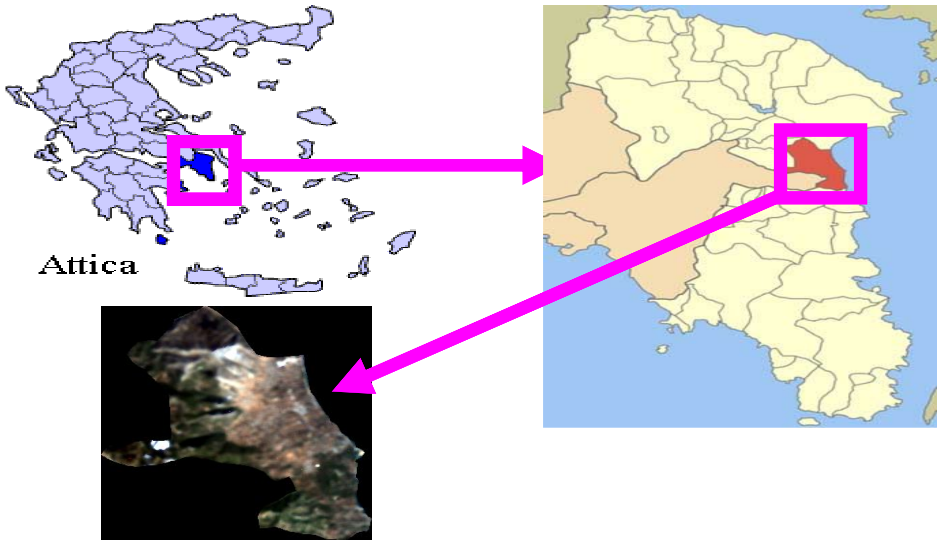
2. Materials and Methods

2.1. Study Area

The city of Neas Makris in Figure 2 is located in the northeastern part of Attica of Greece. The area was known as Plesti, which was renamed as Neas Makris because many Greeks moved there after Greek military disaster in Asia Minor. The majority of the population was rural till 1970s. As housing developments arrives to the area, the population approaches to be established. According to Greek statistics captured from national statistical service of Greece (2001) and from Wikipedia (free encyclopedia), the population of Neas Makris is 14,809, the area is 36.662 km^2 and the density is 404 /km^2.

The Penteli mountains are covered with forests having allocation to the west and southwest. The Petalies Gulf is mainly wrapped with farmlands setting to the north except from the downtown part of Neas Makris. Beaches lay on the eastern part where hotels and restaurants (tavernas) set in the area of the shoreline. Neas Makris is located on the north east of Athens (Attiki Odos) and the Eleftherios Venizelos Airport, south east of Greece and south west of Grammatiko.

Figure 2: Neas Makris, Attica, Greece



General and specific records affecting to the Municipality of Neas Makris are the followings (Kosioni-Koen and Papastergiou-Mitsopoulou, 2004):

- Nomination and protection of historical data for the landscapes of Athens;
- Environmental pollution reduction;
- Implementation of political residence;
- Incorporation of shaped areas for the urban planning;
- Flood and earthquake prevention;
- Reconstruction of neighborhoods, interception of flooring, improvement of town, control of treatments and densities;
- Redistribution, operation and organization of development for the urban planning;
- Qualitative interferences of big scaling;
- Supports to the developments of the secondarily urban centers;
- Formation of recreated systems, such as big towns and nets connecting green lands, archeological areas, coastlines, sidewalks and cyclists;
- Survey of Olympic hospitalities in all camps of Agia Andrea and Neas Makris;
- Survey of Olympic works in Marathona and North of Neas Makris;
- Improvements and upgrades of all roads to Marathona;
- Operation of new jetports Eleftherios Venizelos in Spata;
- Reorganization of hierarchical subsystems of seaports;

- Construction of new big roads, railways and train lines with the length of Athens roads and Stavro-Rafinas highways.

2.2. Data Sets

Five (5) Landsat Thematic Mapper (TM) and two (2) Landsat Enhanced Thematic Mapper Plus (ETM+) satellite images are used in the current paper. The whole information for seven (7) satellite images is shown in Table 2.

Table 2: RS Data Used

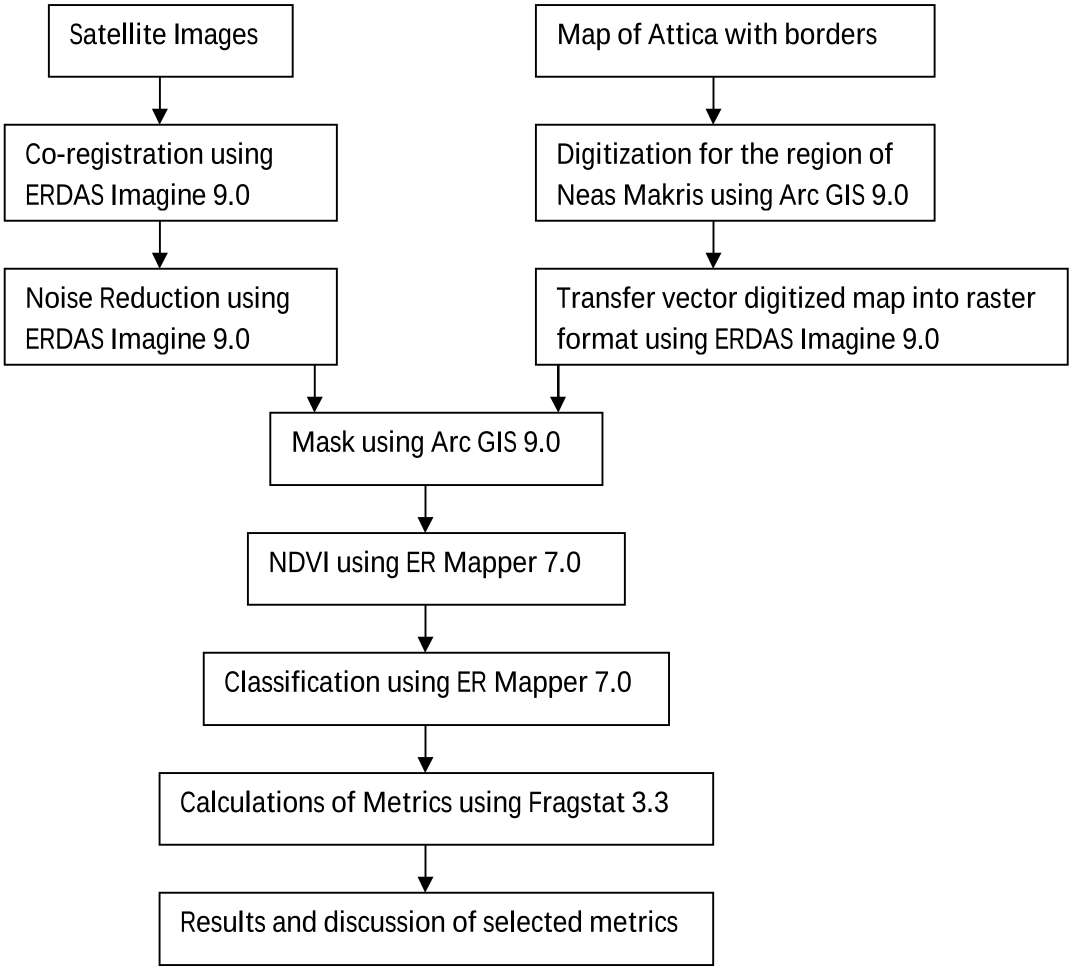
No.	Type of data used	Resolution	Acquisition Date
1.	Landsat TM image	30m	23 / 10 / 1984
2.	Landsat TM image	30m	13 / 08 / 1987
3.	Landsat TM image	30m	04 / 07 / 1990
4.	Landsat TM image	30m	14 / 09 / 1993
5.	Landsat TM image	30m	14 / 08 / 1996
6.	Landsat ETM+ image	30m	05 / 07 / 1999
7.	Landsat ETM+ image	30m	14 / 08 / 2002

2.3. Methodology

The active occurrence perceptive requires analysis of the land use change. The related biodiversity variations are identified and computed through landscape metrics. Erdas (Leica) (ERDAS, 2005, 1997), ArcGIS software ESRI (Koutsopoulos and Androulakis, 2005; ESRI, 1997, 1994), ER Mapper (ER MAPPER, 2005) and Fragstat (McGarigal and Marks, 1995) software are used to analyse species and ecosystems stages of biodiversity metrics. The complete methodology is shown in Figure 3 as a flowchart of this paper using remotely sensed data.

As the area of the original images is much larger than the required study area, subsets of five (5) Landsat TM and two (2) Landsat ETM+ are performed using ERDAS Imagine 9.0 software. To observe the necessary operation on the images, at least co-registration is desirable. All seven (7) images (see Table 2) are co-registered associated with 30 GCP points, which are distributed through the whole area of the expanse of Neas Makris. The RMS_{error} for all images are between 0 and 1 accepted as pass level. The pixel error is less than 1 pixel to have accurate results in the classification of vegetation for Landsat TM (ETM+) images. Noise reduction is implemented in the elimination of noises from the images. Automatic periodic noise removal is realized to each image of seven (7) Landsat TM (ETM+) images presented in Table 2.

Figure 3: Flowchart of Complete Methodology



Map of Attica with borders for prefectures is expressed in Figure 2. Digitization for the region of Neas Makris using Arc GIS 9.0 is executed manually. The format of the digitized prefecture of Neas Makris is a vector format. The vector format of the digitized map is transformed into the raster format to match Neas Makris prefecture with the satellite images. The mask of each satellite image is accomplished with the raster format of digitized map of Neas Makris. The consequential retrieved images are five (5) Landsat TM and two (2) Landsat ETM+ satellite images for Neas Makris prefecture.

NDVI is a quasi-continuous area. NDVI is computed as a normalized divergence between the reflectance of two (2) biologically important bands in the electromagnetic spectrum.

Actively, an energy supply for photosynthesis has the subsequent procedures:

- Absorption of the red wavelengths (RED), i.e. Band 3 of Landsat TM (ETM+);
- Reflection of the short infrared wave (NIR), i.e. Band 4 of Landsat TM (ETM+).

The difference between two bands is proportional to the photosynthesis capacity. The central reason of the relationships between NDVI and vegetation is the reflection of the strong vegetation in proportion to the near infrared component of the electromagnetic spectrum (Tagil, 2007; Schreiber, 2006; Parodi, 2002).

Therefore, NDVI index is operated as: $NDVI = \frac{BAND4 - BAND3}{BAND4 + BAND3} = \frac{NIR - RED}{NIR + RED}$

The NDVI values are proportional real numbers in the range of –1.0 and 1.0. NDVI values have the following meanings (Tagil, 2007):

- Negative NDVI values stands for water bodies;
- Zero NDVI values represents non vegetative areas;
- Positive NDVI values symbolizes vegetative regions;
- NDVI values of [0.1;0.7] corresponds to the lower density of vegetation in direction to higher density of healthier green canopy.

NDVI is determined using ER Mapper 7.0 for all seven (7) satellite images in the region of Neas Makris. The minimum and maximum NDVI values of each image are retrieved from the apt histograms and represented in Table 3.

Table 3: Min and Max values for NDVI

Type of data used	Date of Acquisition	NDVI Values	
		MIN	MAX
Landsat TM image	23 / 10 / 1984	-0.08	0.34
Landsat TM image	13 / 08 / 1987	0	0.30
Landsat TM image	04 / 07 / 1990	-0.02	0.27
Landsat TM image	14 / 09 / 1993	-0.01	0.35
Landsat TM image	14 / 08 / 1996	-0.03	0.33
Landsat ETM+ image	05 / 07 / 1999	-0.14	0.29
Landsat ETM+ image	14 / 08 / 2002	-0.32	0.08

The minimum and maximum values for NDVI are correspondingly applied to each image with the emphasis on the vegetation range of [±0.08;±0.35] as per results presented in Table 3. Each image with its own min and max values of NDVI is classified into three (3) equal classes, which are applied to the apt histograms using ER Mapper 7.0 software. Categorization of remotely sensed data requires the each pixel assignment of the image to the class. The electromagnetic spectral information in the original and altered bands is employed to portray each class pattern and to differentiate between classes (Ayanz and Biging, 1997). All classified Landsat TM and ETM+ images are saved as 8-bit binary images. Fragstat 3.3 program is used to examine species and ecosystems stages biodiversity concept (Figure 1 and Table 1). The inputs are seven (7) classified data into three (3) classes with 30m cell size of 8-bit binary images, 316 number of rows and 282 number of columns. RS metrics computations, results and discussions are performed according to biodiversity perception as per species and ecosystems stages

3. Results and Discussion

3.1 Results

In the paper of Petrosyan and Karathanassi (2011), an extensive investigation of the literature has been performed to gather, categorize and evaluate all landscape metrics based on RS data appearing in the literature through their use. Metrics classification results in six (6) out of seven (7) groups in the combination of the 2nd (Shape) and 3rd (Core) groups as pointed in Table 4.

Table 4: RS Metrics Categorization as per Authors Papers

No	Groups	Categories	Authors Papers	Tables	RS Metrics	Figures
1.	Area / Density / Edge	10	22	5	Number of Patches (NP)	4
					Patch Density (PD)	5
					Largest Patch Index(LPI)	6
					Mean Value Patch Area (AREA_MN)	7
2.	Shape	13	17	6	Mean Value of Shape Index (SHAPE_MN)	8
					Mean Value Contiguity Index (CONTIG_MN)	9
3.	Core			7	Mean Value Core Area (CORE_MN)	10
4.	Isolation Proximity	2	15	8	Mean Value Proximity Index (PROX_MN)	11
5.	Connectivity	2	5	9	Connectance Index (CONNECT)	12
6.	Contagion Interspersion	8	12	10	Interspersion Juxtaposition Index (IJI)	13
7.	Diversity	9	20	11	Shannon's Diversity Index (SHDI)	14
					Shannon's Evennes Index (SHEI)	15

Each group is further classified into categories with a brief description of some RS metrics. Each category represents an index of (Species) Class or (Ecosystems) Landscape Metrics. A table as per authors papers utilizing remote sensing data and programs is given to each index. Generally, 32 papers are used to be referenced for each index during constructions of tables. In addition, all types of RS data, i.e, very high, high, medium resolution, aero-photographs and even simulated data, are counted accordingly per author's efforts (Petrosyan and Karathanassi, 2011). Categorization of metrics is initially established by the Fragstat program through the adaptation of other RS programs. The results running Fragstat 3.3 program are given in Tables 5-11 in accordance with the groups of metrics as per Table 4.

Table 5: Area / Edge / Density

METRICS	YEAR																											
Year	1984				1987				1990				1993				1996				1999				2002			
Type	SVC1	MVC2	DVC3	L	SVC1	MVC2	DVC3	L	SVC1	MVC2	DVC3	L	SVC1	MVC2	DVC3	L	SVC1	MVC2	DVC3	L	SVC1	MVC2	DVC3	L	SVC1	MVC2	DVC3	L
CA	268	2.2C	643	8C	578	2.2C	328	8C	343	2.4C	445	8C	1.1C	1.9C	251	8C	1.1C	1.6C	412	8C	1.5C	1.5C	198	7.9C	C	1.9C	225	7.9C
CPLAND	3	28	8	-	7	28	4	-	4	29	6	-	14	23	3		15	19	5	-	18	18	2	-	13	23	3	-
NP	217	362	269	853	262	366	247	880	234	419	377	C	489	457	221	C	181	402	215	803	292	506	159	962	348	526	161	C
PD	3	5	3	11	3	5	3	11	3	5	5	13	6	6	3	15	2	5	3	10	4	6	2	12	4	7	2	13
LPI	0.1	0.5	0.1	0.5	0.1	0.2	0.1	0.2	0.1	0.5	0.1	0.5	0.2	0.3	0.1	0.3	0.4	0.2	0.1	0.4	0.5	0.2	0.1	0.5	0.2	0.2	0.1	0.2
TE	50C	208C	188C	223C	138C	171C	105C	207C	96C	165C	105C	183C	167C	186C	87C	220C	212C	197C	108C	258C	188C	198C	26C	206C	179C	194C	19C	196C
ED	6	26	23	28	17	21	13	26	12	21	13	23	21	23	11	27	26	25	13	32	24	25	3	26	22	24	2	25
LSI	29	70	42	7	40	68	32	7	31	67	38	6	55	60	28	7	53	62	35	8	53	61	25	7	48	63	26	6
AREA_MN	1	6	2	4	2	6	1	4	1	6	1	3	2	4	1	3	7	4	2	4	5	3	1	3	3	4	1	3
AREA_AM	2	17	5	13	4	11	2	9	3	14	2	11	5	9	3	7	16	8	4	10	13	6	3	9	6	8	3	7
AREA_MD	1	3	1	2	1	5	1	2	1	3	1	1	1	2	1	1	3	2	1	2	3	2	1	2	2	2	1	2
AREA_RA	5	37	11	37	11	19	6	19	6	38	6	38	15	22	8	22	32	16	8	32	36	18	6	36	17	20	7	20
AREA_SD	1	8	2	6	2	5	1	4	1	7	1	5	2	4	1	3	8	4	2	5	6	3	1	4	3	4	2	3
AREA_CV	94	132	104	161	97	88	87	120	101	119	98	160	110	109	127	126	120	101	102	129	125	105	104	133	108	112	112	117
GYRATE_MN	101	444	189	274	172	416	110	255	115	364	98	209	176	257	93	191	498	290	159	300	328	214	103	229	208	235	116	207
GYRATE_AM	190	C	388	905	335	714	194	590	233	788	193	643	390	518	246	452	C	559	326	772	752	449	217	576	437	482	262	451
GYRATE_MD	67	255	112	135	109	345	90	135	67	270	67	97	105	159	45	105	225	202	90	180	213	135	67	135	127	157	67	112
GYRATE_RA	435	2.4C	902	2.4C	952	1.6C	457	1.6C	525	2C	457	2C	1.2C	1.3C	677	1.3C	2.3C	1.4C	660	2.3C	1857	1.5C	542	1.9C	1.3C	1.3C	610	1.4C
GYRATE_SD	95	532	194	396	170	359	96	290	118	369	97	279	197	251	121	217	588	278	163	372	350	230	109	270	219	231	131	218
GYRATE_CV	94	120	103	145	99	86	88	113	103	101	99	134	112	98	130	114	118	96	103	124	107	107	105	118	105	98	113	106
NLSI	0.5	0.4	0.5	-	0.5	0.4	0.5	-	0.5	0.4	0.5	-	0.5	0.4	0.5	-	0.5	0.5	0.5	-	0.4	0.5	0.5	-	0.4	0.4	0.5	-

Table 6: Shape

METRICS	YEAR																											
Year	1984				1987				1990				1993				1996				1999				2002			
Type	SVC1	MVC2	DVC3	L	SVC1	MVC2	DVC3	L	SVC1	MVC2	DVC3	L	SVC1	MVC2	DVC3	L	SVC1	MVC2	DVC3	L	SVC1	MVC2	DVC3	L	SVC1	MVC2	DVC3	L
SHAPE_MN	1.8	3.2	2.2	2.5	2.2	3.2	1.8	2.5	1.8	2.9	1.7	2.2	2.2	2.5	1.6	2.2	3.3	2.8	2.1	2.7	2.8	2.4	1.8	2.4	2.3	2.5	1.9	2.3
SHAPE_AM	2.4	5.2	3.3	4.6	3.1	4.4	2.4	3.9	2.6	4.4	2.4	3.9	3.3	3.7	2.6	3.5	5.6	4.0	3.1	4.5	4.2	3.5	2.5	3.8	3.4	3.6	2.8	3.4
SHAPE_MD	1.7	2.9	2.0	2.1	1.9	3.1	1.9	2.1	1.7	2.8	1.6	1.9	1.9	2.3	1.4	1.9	2.7	2.5	1.9	2.5	2.5	2.0	1.7	2.1	2.0	2.2	1.7	2.0
SHAPE_RA	2.8	6.4	4.5	6.4	4.7	6.1	3.0	6.1	3.3	6.1	3.0	6.1	5.3	5.2	3.7	5.3	7.0	5.8	3.8	7.0	5.5	5.7	3.2	5.7	5.2	5.2	3.6	5.2
SHAPE_SD	0.7	1.7	1.1	1.5	1.0	1.5	0.7	1.3	0.8	1.5	0.7	1.2	1.1	1.2	0.8	1.1	2.0	1.3	1.0	1.5	1.3	1.2	0.7	1.2	1.1	1.1	0.8	1.1
SHAPE_CV	40	55	50	59	45	48	39	53	43	50	42	55	50	48	48	52	61	48	49	56	46	49	40	50	46	44	43	46
FRAC_MN	1.1	1.2	1.1	1.2	1.1	1.2	1.1	1.2	1.1	1.2	1.1	1.1	1.1	1.2	1.1	1.1	1.2	1.2	1.1	1.2	1.2	1.2	1.1	1.2	1.2	1.2	1.1	1.2
FRAC_AM	1.2	1.3	1.2	1.3	1.2	1.3	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.3	1.2	1.2	1.3	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
FRAC_MD	1.1	1.2	1.2	1.2	1.1	1.2	1.1	1.2	1.1	1.2	1.1	1.1	1.1	1.2	1.1	1.1	1.2	1.2	1.1	1.2	1.2	1.2	1.1	1.2	1.2	1.2	1.1	1.2
FRAC_RA	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.3	0.2	0.3
FRAC_SD	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
FRAC_CV	6.0	7.4	7.1	7.6	6.3	7.0	5.9	7.1	5.9	7.4	6.2	7.3	6.8	6.8	6.2	7.0	7.8	6.9	6.9	7.4	6.1	6.6	5.4	6.6	6.1	6.0	5.6	6.1
PARA_MN	779	695	742	734	721	659	770	712	752	683	789	740	741	687	790	731	699	710	759	724	662	709	762	706	689	686	756	701
PARA_AM	709	589	664	615	662	574	712	605	678	552	718	590	669	565	717	613	616	638	698	637	558	639	715	606	604	583	710	599
PARA_MD	741	685	711	704	711	677	722	704	741	682	741	718	714	691	778	711	688	691	722	694	684	698	741	698	698	698	741	704
PARA_RA	857	939	481	939	561	975	656	975	933	985	656	985	970	961	417	970	908	944	659	944	970	933	213	970	966	939	214	966
PARA_SD	110	117	102	123	98	142	103	135	114	165	114	149	122	163	86	144	126	113	90	121	128	122	71	128	129	124	66	128
PARA_CV	14	17	14	17	14	21	13	19	15	24	14	20	17	24	11	20	18	16	12	17	19	17	9	18	19	18	9	18
CIRCLE_MN	0.8	0.9	0.8	0.0	0.9	0.9	0.8	0.0	0.8	0.9	0.8	0.0	0.8	0.9	0.8	0.0	0.9	0.9	0.8	0.0	0.9	0.9	0.8	0.0	0.9	0.9	0.8	0.0
CIR	0	1.	1	0	0	1	0	0	0	1	0	0	0	1.	0	0	1	1	0	0	1	1.	0	0	1	1.	0	0

METRICS	YEAR																											
Year	1984				1987				1990				1993				1996				1999				2002			
Type	SVC1	MVC2	DVC3	L	SVC1	MVC2	DVC3	L	SVC1	MVC2	DVC3	L	SVC1	MVC2	DVC3	L	SVC1	MVC2	DVC3	L	SVC1	MVC2	DVC3	L	SVC1	MVC2	DVC3	L
CLE_AM	.9	0	.0	.0	.9	.0	.9	.0	.9	.0	.9	.0	.9	0	.9	.0	.0	.0	.9	.0	.0	0	.9	.0	.0	0	.9	.0
CIRCLE_MD	0.9	1.0	0.9	0.0	0.9	1.0	0.9	0.0	0.9	1.0	0.9	0.0	0.9	0.9	0.8	0.0	1.0	1.0	0.9	0.0	1.0	0.9	0.9	0.0	0.9	0.9	0.9	0.0
CIRCLE_RA	0.6	0.6	0.4	0.0	0.5	0.6	0.6	0.0	0.6	0.6	0.6	0.0	0.6	0.6	0.4	0.0	0.6	0.6	0.6	0.0	0.6	0.6	0.4	0.0	0.6	0.6	0.4	0.0
CIRCLE_SD	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.2	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0
CIRCLE_CV	19	15	17	-1.0	14	13	18	-1.0	17	17	19	-1.0	16	16	18	-1.0	15	14	17	-1.0	12	15	15	-1.0	14	12	13	-1.0
CONTIG_MN	0.3	0.3	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
CONTIG_AM	0.3	0.4	0.4	0.4	0.4	0.4	0.3	0.4	0.3	0.5	0.3	0.4	0.3	0.4	0.3	0.4	0.4	0.4	0.3	0.4	0.5	0.4	0.3	0.4	0.4	0.4	0.3	0.4
CONTIG_MD	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
CONTIG_RA	0.5	0.6	0.4	0.6	0.4	0.6	0.3	0.6	0.6	0.7	0.3	0.7	0.6	0.6	0.3	0.6	0.6	0.6	0.3	0.6	0.6	0.6	0.1	0.6	0.6	0.6	0.1	0.6
CONTIG_SD	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.1
CONTIG_CV	21	26	22	26	23	31	18	30	26	35	21	33	26	35	17	32	26	24	16	25	28	27	12	28	29	29	11	29
PAFRAC	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.7	1.8	1.7	1.8	1.7	1.8	1.7	1.8	1.8	1.8	1.8	1.7	1.8	1.8	1.8	1.8	1.7	1.8	1.7

Table 7: Core Area

METRICS	YEAR																											
Year	1984				1987				1990				1993				1996				1999				2002			
Type	SVC1	MVC2	DVC3	L	SVC1	MVC2	DVC3	L	SVC1	MVC2	DVC3	L	SVC1	MVC2	DVC3	L	SVC1	MVC2	DVC3	L	SVC1	MVC2	DVC3	L	SVC1	MVC2	DVC3	L
TCA	268	2.2C	643	3.2C	578	2.3C	328	3.2C	343	2.5C	445	3.2C	C	1.8C	251	3.2C	1.2C	1.5C	412	3.2C	1.5C	1.5C	198	3.1C	C	1.9C	225	3C
CPLAND	3	28	8.0	-	7	28	4.1	-	4	29	5.5	-	14	23	3.1	-	15	19	5.1	-	18	18	2.5	-	13	23	2.8	-
NDCA	217	362	269	853	262	366	247	880	234	419	377	C	489	457	221	C	181	402	215	803	292	506	159	962	348	526	161	C
DCAD	2.7	4.5	3.4	11	3.3	4.6	3.1	11	2.9	5.2	4.7	13	6.1	5.7	2.8	15	2.3	5.0	2.7	10	3.7	6.4	2.0	12	4.4	6.6	2.0	13
CORE_MN	1.2	6.2	2.4	3.7	2.2	6.1	1.3	3.6	1.5	5.6	1.2	3.0	2.2	3.9	1.1	2.7	6.6	3.8	1.9	3.9	5.0	2.9	1.2	3.2	3.0	3.5	1.4	3.0
CORE_AM	2	17	5.0	13	4	11	2.3	9	3	14	2.3	11	5	9	3.0	7	16	8	3.9	10	13	6	2.6	9	6	8	3.1	7
CORE_MD	0.8	3.2	1.4	1.6	1.3	4.6	1.1	1.6	0.8	3.4	0.8	1.2	1.3	2.2	0.5	1.4	2.7	2.4	1.1	2.2	2.7	1.8	0.8	1.6	1.6	1.9	0.8	1.6
CORE_RA	5	37	11	37	11	19	6	19	6	38	6	38	15	22	8	22	32	16	8	32	36	18	6	36	17	20	7	20
CORE_SD	1.2	8.2	2.5	5.9	2.1	5.4	1.2	4.3	1.5	6.7	1.2	4.9	2.4	4.3	1.4	3.4	7.9	3.8	2	5	6.2	3	1.3	4.3	3.2	3.9	1.6	3.5
CORE_CV	94	132	104	161	97	88	87	120	101	119	98	160	110	109	127	126	120	101	102	129	125	105	104	133	108	112	112	117
DCORE_MN	1.2	6.2	2.4	3.7	2.2	6.1	1.3	3.6	1.5	5.6	1.2	3.0	2.2	3.9	1.1	2.7	6.6	3.8	1.9	3.9	5	2.9	1.2	3.2	3	3.5	1.4	3
DCORE_AM	2	17	5.0	13	4	11	2.3	9	3	14	2.3	11	5	9	3.0	7	16	8	3.9	10	13	6	2.6	9	6	8	3.1	7
DCORE_MD	0.8	3.2	1.4	2	1.3	4.6	1.1	2	0.8	3.4	0.8	1	1.3	2.2	0.5	1	2.7	2.4	1.1	2	2.7	1.8	0.8	2	1.6	1.9	0.8	2
DCORE_RA	5	37	11	37	11	19	5.6	19	6	38	5.6	38	15	22	8.1	22	32	16	8	32	36	18	6.5	36	17	20	7.3	20
DCORE_SD	1.2	8.2	2.5	5.9	2.1	5.4	1.2	4.3	1.5	6.7	1.2	4.9	2.4	4.3	1.4	3.4	7.9	3.8	2.0	5.0	6.2	3.0	1.3	4.3	3.2	3.9	1.6	3.5
DC	9	1	1	1	9	8	8	1	1	1	9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

METRICS	**YEAR**																											
Year	**1984**				**1987**				**1990**				**1993**				**1996**				**1999**				**2002**			
Type	**SVC1**	**MVC2**	**DVC3**	**L**	**SVC1**	**MVC2**	**DVC3**	**L**	**SVC1**	**MVC2**	**DVC3**	**L**	**SVC1**	**MVC2**	**DVC3**	**L**	**SVC1**	**MVC2**	**DVC3**	**L**	**SVC1**	**MVC2**	**DVC3**	**L**	**SVC1**	**MVC2**	**DVC3**	**L**
ORE_CV	4	32	04	61	7	8	7	20	01	19	8	60	10	09	27	26	20	01	02	29	25	05	04	33	08	12	12	17
CAI_MN	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
CAI_AM	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
CAI_MD	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
CAI_RA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CAI_SD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CAI_CV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 8: Isolation Proximity

METRICS	YEAR																											
Year	1984				1987				1990				1993				1996				1999				2002			
Type	SV C1	MV C2	DV C3	L	SV C1	MV C2	DV C3	L	SV C1	MV C2	DV C3	L	SV C1	MV C2	DV C3	L	SV C1	MV C2	DV C3	L	SV C1	MV C2	DV C3	L	SV C1	MV C2	DV C3	L
PROX_MN	4	32	9	17	9	29	3	16	5	30	3	15	8	21	3	12	33	15	5	16	30	13	3	16	17	19	4	16
PROX_AM	7	91	18	69	16	51	6	40	10	75	6	58	15	47	8	33	86	30	10	49	72	25	6	46	35	42	8	37
PROX_MD	3	11	5	6	5	17	2	6	2	13	3	4	4	9	2	5	9	10	3	7	12	7	2	6	8	9	2	7
PROX_RA	26	201	60	201	56	113	14	113	32	210	13	210	40	126	17	126	168	89	18	168	200	67	17	200	93	106	19	106
PROX_SD	4	49	10	35	9	29	3	23	6	42	3	30	8	26	4	19	45	18	5	27	38	14	3	25	20	23	4	21
PROX_CV	112	151	121	202	108	99	86	144	113	136	90	202	108	122	118	155	136	117	92	163	130	112	107	157	119	123	114	133
ENN_MN	100	83	96	91	102	81	100	93	116	83	97	95	89	82	104	89	99	87	96	92	78	84	100	85	85	81	109	87
ENN_AM	90	71	83	75	86	72	92	77	89	70	92	75	85	70	93	77	68	80	91	77	67	77	93	73	70	72	94	73
ENN_MD	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90
ENN_RA	750	120	390	750	4710	335	891	4710	3658	156	665	3658	624	481	810	810	3395	421	487	3395	330	481	551	581	1458	115	1077	1458
ENN_SD	71	14	42	45	289	26	65	163	251	17	50	125	29	30	82	45	251	24	44	123	25	29	59	36	91	14	128	74
ENN_CV	70	17	44	49	283	32	64	176	216	21	51	131	33	37	79	51	253	27	46	133	31	35	60	42	107	17	118	86

Table 9: Connectivity

METRICS	YEAR																											
Year	1984				1987				1990				1993				1996				1999				2002			
Type	SV C1	MV C2	DV C3	L	SV C1	MV C2	DV C3	L	SV C1	MV C2	DV C3	L	SV C1	MV C2	DV C3	L	SV C1	MV C2	DV C3	L	SV C1	MV C2	DV C3	L	SV C1	MV C2	DV C3	L
CONNECT	0.8	0.6	0.7	0.7	0.8	0.6	0.7	0.7	0.8	0.5	0.5	0.6	0.4	0.5	0.8	0.5	1.1	0.5	0.8	0.7	0.8	0.4	1.0	0.5	0.6	0.4	1.1	0.5
COHESION	79	92	86	91	85	91	79	89	81	91	79	89	86	89	81	88	92	89	84	90	91	87	80	89	87	88	82	88

Table 10: Contagion Interspersion

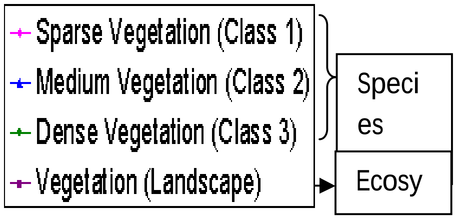
METRICS	YEAR																											
Year	1984				1987				1990				1993				1996				1999				2002			
Type	SV C1	MVC2	DV C3	L	SV C1	MVC2	DV C3	L	SV C1	MV C2	DV C3	L	SV C1	MV C2	DV C3	L	SV C1	MV C2	DV C3	L	SV C1	MV C2	DV C3	L	SV C1	MV C2	DV C3	L
CLUMPY	0.5	0.4	0.5	70	0.5	0.4	0.5	69	0.5	0.4	0.4	72	0.4	0.5	0.5	66	0.5	0.4	0.5	62	0.5	0.4	0.5	67	0.5	0.4	0.5	69
PLADJ	47	56	50	54	50	57	47	55	49	59	46	56	50	58	46	54	54	52	48	52	58	52	46	55	55	56	47	55
IJI	31	23	14	20	29	35	33	31	25	36	24	29	26	31	34	28	31	28	35	29	9	16	32	14	3	15	19	11
DIVISION	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
MESH	0.1	4.7	0.4	5.2	0.3	3.0	0.1	3.4	0.1	4.	0.1	4.2	0.7	2	0.1	2.7	2.4	1.5	0.2	4.1	2.3	1.1	0.1	3.5	0.8	1.8	0.1	2.8
SPLIT	103C	1.7C	20C	1.5C	26C	2.7C	8.4C	2.4C	63C	2C	62C	1.9C	12 C	4C	86C	3C	3.3C	5.4C	40C	2C	3.4C	7.3C	123C	2.3C	9.6C	4.3C	89C	3C
AI	48	56	51	54	51	57	47	55	50	59	47	56	50	58	47	54	54	53	48	53	59	53	47	55	55	57	48	56

Table 11: Diversity **Where C=1000.**

METRICS				YEAR			
Year	**1984**	**1987**	**1990**	**1993**	**1996**	**1999**	**2002**
Type	**L**	**L**	**L**	**L**	**L**	**L**	**L**
PR	8	8	8	8	8	8	8
PRD	0.1	0.1	0.1	0.1	0.1	0.1	0.1
RPR	267	267	267	267	267	267	267
SHDI	0.8	0.8	0.7	0.9	1.0	0.9	0.9
SIDI	0.4	0.4	0.4	0.5	0.6	0.6	0.5
MSIDI	0.6	0.6	0.5	0.8	0.9	0.8	0.8
SHEI	0.4	0.4	0.4	0.4	0.5	0.4	0.4
SIEI	0.5	0.5	0.5	0.6	0.7	0.6	0.6
MSIEI	0.3	0.3	0.3	0.4	0.4	0.4	0.4

classes are as:

RS metrics are calculated to observe the state of the land. NDVI is computed to monitor the condition of vegetation. Categorization of three (3) equal classes is performed to the distribution with the defined min and max values of NDVI in Table 3. The



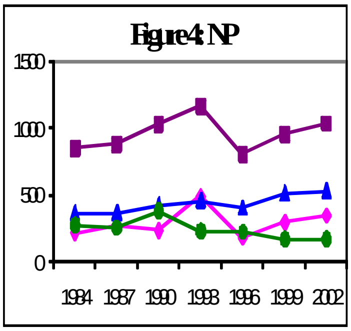


Figure 4: NP

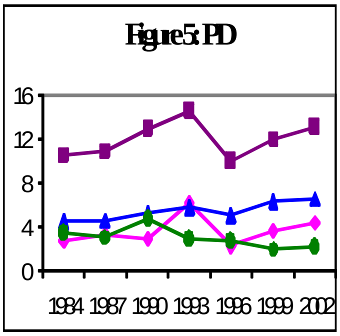


Figure 5: PD

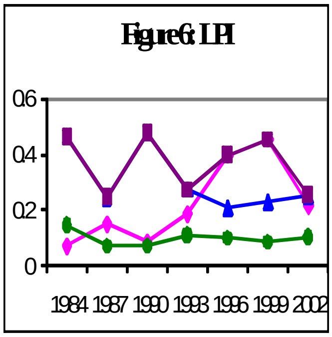


Figure 6: LPI

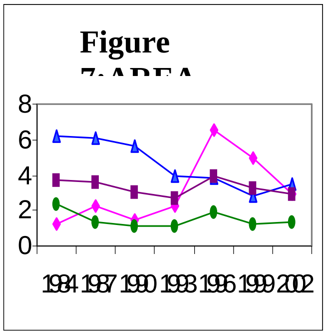


Figure
7: AREA
0 2 4 6 8
1984 1987 1990 1993 1996 1999 2002

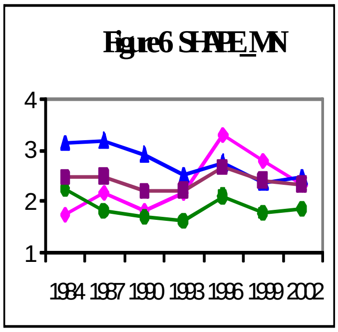


Figure 6 SHAPE_MN
1 2 3 4
1984 1987 1990 1993 1996 1999 2002

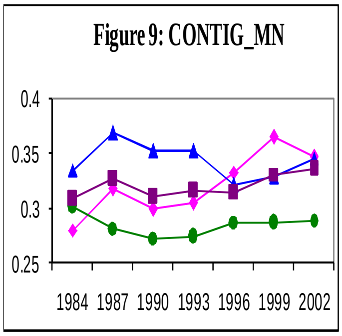


Figure 9: CONTIG_MN
0.25 0.3 0.35 0.4
1984 1987 1990 1993 1996 1999 2002

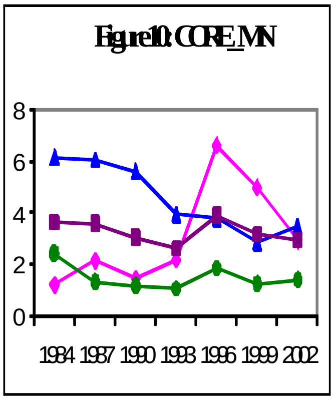


Figure 10: CORE_MN
0 2 4 6 8
1984 1987 1990 1993 1996 1999 2002

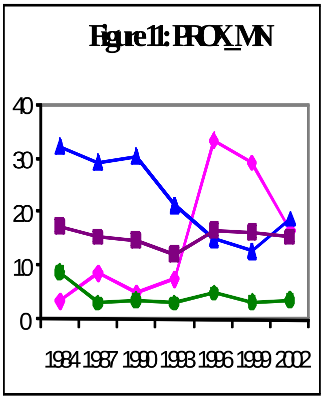


Figure 11: PROX_MN
0 10 20 30 40
1984 1987 1990 1993 1996 1999 2002

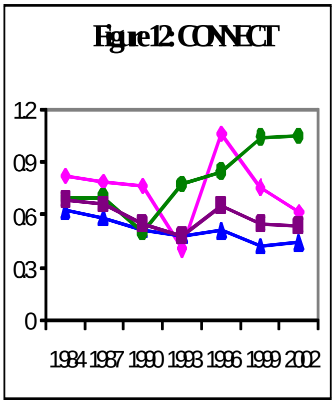


Figure 12: CONNECT
0 0.3 0.6 0.9 1.2
1984 1987 1990 1993 1996 1999 2002

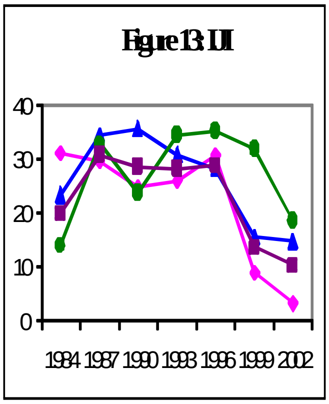


Figure 13: IJI
0 10 20 30 40
1984 1987 1990 1993 1996 1999 2002

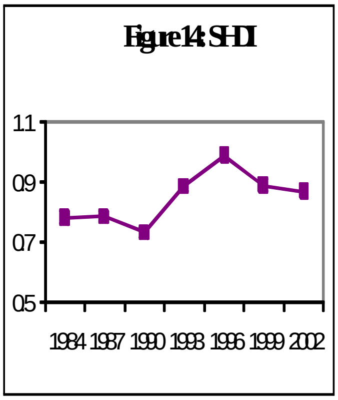


Figure 14: SHDI
0.5 0.7 0.9 1.1
1984 1987 1990 1993 1996 1999 2002

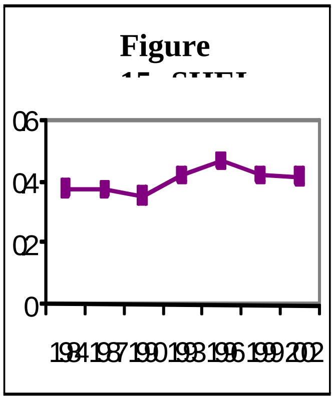


Figure
15: SHEI
0 0.2 0.4 0.6
1984 1987 1990 1993 1996 1999 2002

3.2 Biodiversity Indicators at Species (Classes) Stage

The biodiversity metrics at species stage assess the summative properties of the patches and fit into a particular class or patch type (Giordano & Marini, 2008). The time series of classified satellite images are the sources for the landscape metrics computation at species stages using Fragstat software as a tool. Graphs of species biodiversity stage are depicted on Figures 4-13, issued as per Table 4, combined in Tables 5-10 & applied as:

- Pink = Sparse Vegetation (SV) = Class 1 (C1) = α diversity;
- Blue = Medium Vegetation (MV) = Class 2 (C2) = β diversity;
- Green = Dense Vegetation (DV) = Class 3 (C3) = γ diversity.

3.2.1 Sparse Vegetation (Class 1 - α diversity)

Sparse vegetation (SV = C1 = α diversity) in this paper represents the minor class of landscape (Tables 5-10 and Figures 4-13). Furthermore, sparse vegetation (class 1) corresponds to α diversity in species biodiversity stage. The study shows an increase with some variations in the number of patches (NP) (Figure 4), the patch density (PD) (Figure 5), the largest patch index (LPI) (Figure 6) and mean value of patch area (AREA_MN) (Figure 7) during the period from 1984 to 2002. In addition, the highest values of mean shape index (SHAPE_MN) (Figure 8), mean contiguity index (CONTIG_MN) (Figure 9), mean core area (CORE_MN) (Figure 10), mean proximity index (PROX_MN) (Figure 11) and connectance index (CONNECT) (Figure 12) are in the year of 1996. There is also a decrease in the interspersion juxtaposition index (IJI) (Figure 13) mainly between 1996 and 2002.

3.2.2 Medium Vegetation (Class 2 - β diversity)

Medium vegetation (MV = C2 = β diversity) in the current study is characterized as the major class of landscape (Tables 5-10 and Figures 4-13). Moreover, medium vegetation (Class 2) goes with β diversity in species biodiversity stage. The study explains a small increase in the number of patches (NP) (Figure 4) and the patch density (PD) (Figure 5) during the period from 1984 to 2002.

Furthermore, there is a decrease in the values of the largest patch index (LPI) (Figure 6), mean value of patch area (AREA_MN) (Figure 7), mean core area (CORE_MN) (Figure 10), mean proximity index (PROX_MN) (Figure 11) and the interspersion juxtaposition index (IJI) (Figure 13) from the time period from 1984 to 2002. Moreover, there is a somehow stability in the in the values of mean shape index (SHAPE_MN) (Figure 8), mean contiguity index (CONTIG_MN) (Figure 9) and connectance index (CONNECT) (Figure 12) during the period from 1984 to 2002.

3.2.3 Dense Vegetation (Class 3 - γ diversity)

Dense vegetation (DV = C3 = γ diversity) in the present study is illustrated as the medium to minor class of landscape (Tables 5-10 and Figures 4-13). Additionally, dense vegetation (class 3) matches with γ diversity in species biodiversity stage. The study shows stabilization with small variation in terms of the number of patches (NP) (Figure 4), the patch density (PD) (Figure 5), the largest patch index (LPI) (Figure 6), mean value of patch area (AREA_MN) (Figure 7), mean shape index (SHAPE_MN) (Figure 8), mean contiguity index (CONTIG_MN) (Figure 9), mean core area (CORE_MN) (Figure 10) and mean proximity index (PROX_MN) (Figure 11) from the time period from 1984 to 2002. Furthermore, there are augments in the values of connectance index (CONNECT) (Figure 12) and variations in the values of the interspersion juxtaposition index (IJI) (Figure 13) in the years of 1990 and 2002.

3.3 Biodiversity Indicators at Ecosystems (Landscape) Stage

Landscape metrics measure the aggregate properties of the complete patch mosaic at Ecosystems (Landscape) stage in Tables 5-11 (Giordano & Marini, 2008). Graphs of ecosystem biodiversity stage are depicted on Figures 4-15, issued as per Table 4, combined in Tables 5-11. Figures 4-15 depict the most relevant metrics performed at ecosystems level for the study. As seen from Figure 4 and Figure 5, the patch number (NP) and patch density (PD) in the current study area increased correspondingly during the years of 19984-1993 and 1996-2002. The largest patch index (LPI) (Figure 6) has huge variations. The values of the mean value of patch area (AREA_MN) (Figure 7), the mean value of shape index (SHAPE_MN) (Figure 8), the mean value of core area (CORE_MN) (Figure 10), the mean value of proximity index (PROX_MN) (Figure 11) and are decreased for the periods of years from 1984 to 1993 & from 1996 to 2002 and increased for the time period of 1993 to 1996.

There is kind of stability in the mean value of contiguity index (CONTIG_MN) (Figure 9). The values of the connectance index (CONNECT) (Figure 12) and interspersion juxtaposition index (IJI) (Figure 13) are increased for the years of 1984 – 1987, stabilized for the years of 1987 – 1996 and decreased for the years of 1996-2002. There is a kind of stabilization for the time period of 1984 – 1990 and 1996 – 2002 and augment for the years of 1990 – 1996 for the Shannon Diversity (SHDI) (Figure 14) and evenness (SHEI) (Figure 15) indices. Shannon's diversity index is a popular appraisal of diversity in ecology applied to landscapes as a measure of the equitability in NP as per proportional area distribution along with patch types. Shannon evenness index is accepted diversity appraisal employed in ecology signifying the evenness of the area distribution in company with the different patch types (McGarigal etc, 2002).

4. Conclusion

The investigations of species biodiversity stage explain that the landscape of the study area is dominated with the medium vegetation (MV = C2 = β diversity), followed by dense vegetation (DV = C3 = γ diversity) and sparse vegetation (SV = C1 = α diversity). During the study period of (1984 – 2002), medium and dense vegetation are decreased while sparse vegetation is increased. Therefore, an increase of urban areas expresses a change from the vegetated spots to the non-vegetated areas.

The current work expounds on the analysis of species and ecosystems biodiversity stages achieved in terms of landcover and landscape change by means of remote sensing and GIS techniques in an area prone to land change from vegetated to the less vegetated area in Neas Makris, Attica, (Greece) during the period 1984–2002. For this reason, a set of indicators is setup and a quantitative characterization of biodiversity stages is performed. Seven (7) Landsat TM (+ETM) data as inputs to Erdas Imagine, GIS, ER Mapper and Fragstats software are generally supportive in providing techniques to monitor landcover and landscape evolution in the study period. Further research is required to better understand the development of landcover and landscape in the areas where the variations are occurring from the vegetated regions to the non-vegetated areas.

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