

Introducing an Integrated Monitoring System for Natural Ecosystems: The Example of Strofilia Wetlands in Western Peloponnese, Greece

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ABSTRACT : Nowadays the science of remote sensing and satellite data, constitute modern scientific tools, as they provide important information and make research easier in many scientific fields. This research article presents an integrated system for continuous monitoring of the vegetation and the human impact on the Natura 2000 protected areas of Strofilia Forest and Kotychi lagoon (Natura 2000 codes: GR 232001 and GR233006 respectively) with contemporary methods of remote Sensing and Telemetry. More specifically, aerial photographs and still images obtained from the Landsat satellite were used for visualization of spectral signatures and detection of changes in vegetation and land-uses. Water quality data was checked via sensors measuring hydrological parameters in order to detect temporal changes. Finally, an on-line database system, whose main structural characteristics are illustrated in this paper, was created to assist field work and help data collection and assessment. The efficiency and accuracy of this type of monitoring for the conservation of natural environment is discussed.

Key words: Biomonitoring, Natura 2000, Wetlands, Greece, Remote Sensing, Database

INTRODUCTION

Today there is an increasing interest in environmental monitoring for a variety of specific applications, with great impact especially on natural resource management and preservation, economy and people's life and health. Typical uses encompass, for example, Earth observation, meteorology, natural resource monitoring, agricultural and forest monitoring, pollution control, natural disaster observation and prediction, and critical infrastructure monitoring (De Capitani, 2013). Remote sensing is the science and art of obtaining information about an object, area or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area or phenomenon under investigation (Lillesand et al., 2008). Using remote sensing for habitat mapping and monitoring offers multiple advantages over traditional field mapping, such as faster map production, insight into inaccessible terrain (e.g. large wetlands, remote mountain areas, restricted military areas), and increased repeatability of the mapping process (Buiten & Clevers 1990). Wetlands, our main monitoring ecosystem type, perform a wide range of functions that are essential for

supporting plants and animal life and help maintain environmental quality. These functions include: enrichment of aquifers, flood control, coastal stabilization and retention of sediments, nutrients and toxic substances; carbon absorption and support of food chains. The misuse of wetlands means a reduction of their ability to provide useful services and, in many cases, valuable products (Gerakis, 1996). The destruction and degradation of wetlands is a common feature across the Mediterranean region, especially in industrialized countries. According to the Greek Biotope/Wetland Centre – EKBY, the main causes of Greek wetlands' degradation are (Gerakis & Koutrakis, 1996; Gerakis & Anagnostopoulou, 2002) the change in the hydrological regime, the depletion of wetland resources, the change in water quality and the loss of wetland area.

The study area of Strofilia forest - Kotychi lagoon is located in the northwestern part of the Peloponnese region, Greece and is a site of particular ecological importance (Fig. 1). It is a breeding and nesting station for thousands of migratory birds along their journey between Europe and Africa. It includes two areas of

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the Natura 2000 network, GR232001 and GR233006, with the latter being protected by the International Ramsar Convention. It occupies an area of approximately 134 km² and consists primarily of a set of internal wetlands and marshy areas (Kalogria Prokopos, Lamia, Kotychi); the mixed Aleppo (*Pinus halepensis*) and Umbrella pine (*Pinus pinea*) forest of Strofilia situated parallel to the sea front of Killini bay, from which it is separated by coastal dunes and sandy flats; farmland; scattered communal and private pastures; 18 villages and sea-side rock cliffs which bear an ancient monument. The rapid establishment of activities and the resulting changes in land-use, transforming traditional rural areas into urban areas, can be particularly harmful for the environment when occurring without a strategic planning (Salvati & Mavrakis, 2014). Our study area of Strofilia-Kotychi has suffered from the usual problems that occur in natural ecosystems used by man for recreation and other activities. More specifically we have: expansion of settlements, sand extraction from the coastal zone, effects of tourism-recreation activities (trampling, elevated noise levels etc.), expansion of cultivated areas and quarries, aquifer pollution from agricultural activities, uncontrolled grazing and trampling of the natural vegetation mainly by cattle.

The whole study area is characterized by high biodiversity due to the great variety of habitats that comprise it and the rich flora and fauna present. According to Natura 2000 standard data forms, eighteen (18) habitat types are found, of which four are of conservation priority (Dafis *et al.*, 1997). The flora of the area consists of about 500 plant taxa, two of which are Greek endemics, namely: *Colchicum parlatoris* and *Centaurea niederi* which is also a Red Data Book species, characterized as Vulnerable (VU), and a priority species of Directive 92/43/EEC (Georgiadis *et al.*, 1990). The lagoons of the area are a migratory birds' breeding and wintering nesting station. More than 350 bird species have been recorded, 110 of which are included in the Annex I of the Birds Directive 2009/147/EC. Also other than birds, 47 species of vertebrates have been recorded from the area, while the sandy beach front west of the wetland, has been reported as a nesting site for the sea turtle *Caretta caretta*, a priority species of the Directive 92/43/EC also classified as E (Endangered), at the IUCN Red List of Threatened Species (1996, ver.2.3). The annexes of the same Directive also state the presence of seven species of amphibians and reptiles in the region, three species of mammals and two fish species of which *Valencia letourneuxi* is a priority species for conservation characterized as CE (Critically Endangered), at the IUCN Red List of Threatened Species (2006, ver.3.1).

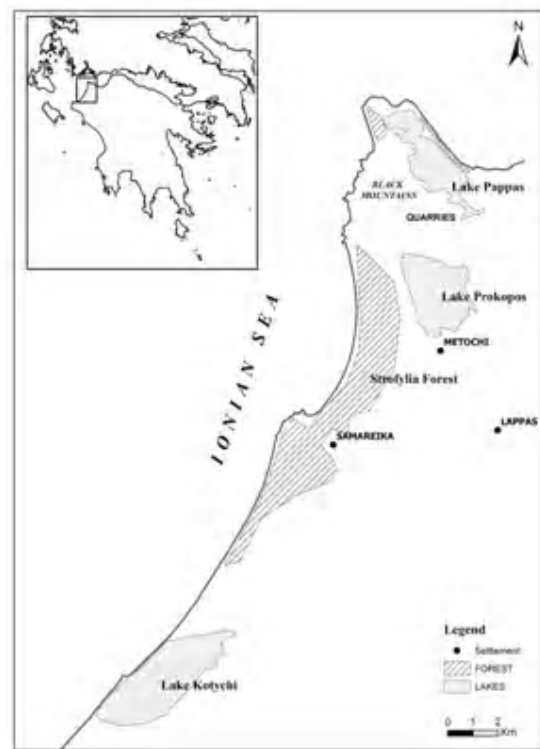


Fig. 1. Orientation map of the study area

Considering the high biodiversity and hence the conservation value of the area the establishment and operation of a monitoring system is judged as imperative in order to detect and prevent environmental change and general disturbance occurring at the wetland and forest ecosystems. As biomonitoring we usually define a series of repeated studies (surveys) that are designed to discriminate disturbances. The two main reasons for the development of a biomonitoring programme for the area are the increasing anthropogenic impacts on natural ecosystems and the simultaneously growing interest in the conservation and protection of these ecosystems (Grujter, 2006). Management plans in natural areas are either integrated or focused on species and habitats; evaluation and monitoring are indispensable tools, both in the original design, and the changes that may be required along the way, then the objectives of management are better approached (Spanou *et al.*, 2007). The present study shows a modern way of designing and implementing a biomonitoring programme via the use of remote sensing methods combined with classic field data collections, surveys and analyses.

MATERIALS & METHODS

In order to design and implement a monitoring programme, we had to set the monitoring base-line

status which describes and evaluates the situation of the ecosystem at the beginning of the monitoring process and on which every further change will be referenced and recorded (Hellawel, 1996). In order to achieve this we have used aerial photos, satellite imagery and data from a wireless sensor network that we have installed in certain sampling sites of the study area. For the description and characterization of vegetation and land use, data was verified and identified by fieldwork collections and observation at sampling sites. All collected data were imported into a, specially designed for that purpose, database to allow classification and evaluation. Geographic information system (G.I.S) software (ArcGIS Ver.9.2) was used to combine all data, create base-line thematic maps and record changes between present status and status of the years 1972 and 2007. This is an open database which allows us to update the information at regular intervals. Aerial photographs, for the years 1972 and 2007 in scale ca. 1:40,000, were used to identify land use changes between those years. To measure area changes over time, we have created ortho-photomaps, for each year respectively, in order to distinguish spatial differences in this thirty-five years period. The area was divided into smaller sections and certain sections have been chosen to be compared for these two years. These particular sections were chosen as, during fieldwork, we have realized that they were the ones suffering greatest human impact. Satellite remote sensing is an important tool for environmental applications. It is being used with great success in mapping and recording of land cover change. The advantage is that data can be collected with great frequency and accuracy, providing information for both the spectral characteristics of the cover/land use, and for the space, shape and size.

(Green *et al.*, 1994). The ability to obtain various types of satellite images, particularly those with very high spatial resolution (pixel <1m), made the purchase of satellite data even more competitive since there are no longer any restrictions or lengthy bureaucratic procedures. For example, Landsat 7 ETM+ satellite has a relatively easy image capture process via the website <http://glovis.usgs.gov> simply by identifying the area you are interested in, you may download the data in your computer and process it by using the appropriate programmes. Landsat 7 ETM+ satellite images of our study area were processed by using two different software programmes. The first one is the Frame and Fill (Source Forge, 2013) software which essentially makes the analysis of the data retrieved from the satellite. Frame and Fill replaces the no-data (zero-value) pixels in the original image. The second programme is ERDAS Imagine (ERDAS, 2006) in which by importing the resulted image from Frame and Fill we have managed to pseudo colour the images by changing the channels and bands (Frequency bands) of the RGB colour model.

The proper use of remote sensing data requires careful pre-processing to eliminate a series of errors, changes and alterations which, if remain, will degrade the quality of the final information and lead respectively to false or distorted conclusions (Mather, 2004). Therefore, the images were geometrically corrected, geo-referenced to Universal Transverse Mercator Projection (WGS 84) and reduced to the study area. They were also radiometrically and atmospherically corrected to minimize the effect of atmospheric scattering (Chaves, 1996) so that the observed changes within the image are due to real variations of the areas

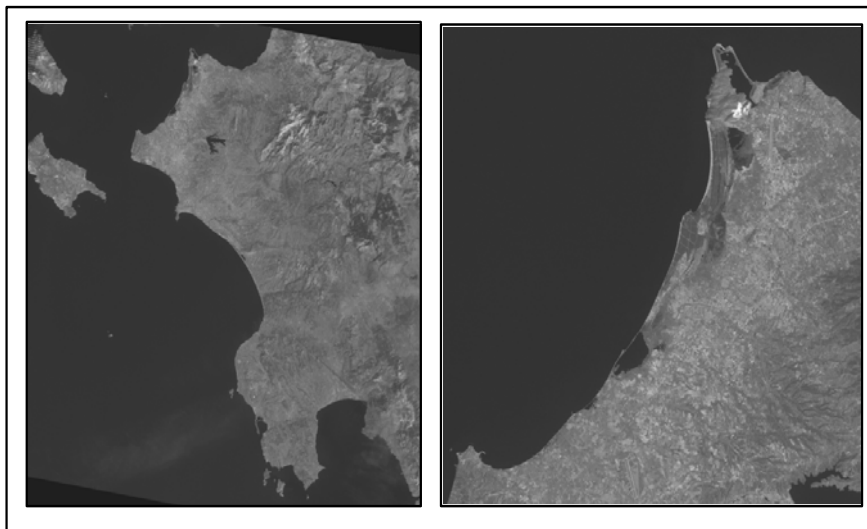


Fig. 2. Landsat satellite images, of the study area, combining bands 4,5,1

and not to various atmospheric conditions (Richter, 1996). By making all possible combinations and by pseudocolouring the frequency bands we have identified the main units of the landscape area which constitute the object of our measurements. The band combination selected as optimal for our survey was 5-4-1 (AMNH-CBC, 2003). At this combination healthy vegetation appears in shades of red, brown, orange and yellow. Soils may be green and brown, urban features are white, blue and gray, light blue areas represent recently deforested areas and reddish areas show regeneration of vegetation and probably sparse grasslands.

The clean, deep water appears very dark in this band combination. Shallow water or deposits appear as shades of light blue (Fig. 2). Vegetation covers most of the soil surface on earth. Remote sensing can exploit the way the vegetation reflects the electromagnetic energy and helps us obtain information about the vegetation. The combination of a low visible reflectance and high reflectance in the near infrared is unique for most vegetation types and thus is known as the spectral signature of vegetation. Using the 5-4-1 frequency bands of the Landsat satellite, we have observed each band separately and then used a combination of three of these bands outputting a new satellite image.

Using the ArcGIS software we have created a thematic map, presenting land use and vegetation cover of our study area. Via the ArcGIS platform we have measured the area changes for each land use type for the time period 1972-2007 (Table 1). Two sensor systems (North and South Station) have been installed inside Kotychi lagoon in order to record water parameters. Measurements for the years 2004, 2005 and 2006 during the months of July, August, September, October have been analyzed. The parameters measured were: water temperature, salinity, pH, dissolved oxygen, conductivity, turbidity and chlorophyll. Using basic principles of SQL (Structured Query Language) and principles of Windows Programming we have created an on-line database system in order to insert sampling data based on the vegetation sampling forms and Standard data forms of the Natura 2000 programme.

The design and establishment of a modern and continuous bio-monitoring programme, concerning the status of the ecosystems and the human impacts they sustain, requires a comprehensive system which will detect changes in terrestrial ecosystems, through remote sensing techniques (aerial photography, satellite imagery) and, in combination with telemetry sensor system methods, will monitor the ecological parameters of aquatic and wetland ecosystems and their changes. The monitoring programme that has been conducted for the Strofilia - Kotychi area includes:

- i) Collection of information material. Information material includes aerial and satellite images, topographical, geological, soil, hydrological maps and orthophotomaps, habitat or vegetation maps and maps of land use along with relevant literature.
- ii) Fieldwork, in order to: identify habitat types in situ, samples of flora and fauna, record ecological observations and human impacts, photograph vegetation, species and landscape/habitats.
- iii) Design of the monitoring programme:
 - Evaluation of preliminary stage data.
 - Definition of the monitoring objectives.
 - Individual areas of monitoring defined.
 - Installation of telemetry systems (sensors) on site.
 - Select data analysis method.
 - Creation of an on-line database for recording and storing data of flora, fauna, habitat types, topography, geology, pedology, hydrology and observed human impacts.
 - Configuration of the final monitoring plan (frequency, period, methodology).
- iv) Evaluation of all changes.

RESULTS & DISCUSSION

Mediterranean ecosystems are experiencing environmental vulnerability due to climate change, soil degradation, forest fires, land-use changes, vegetation deterioration, and landscape fragmentation (Salvati & Mavrakis, 2014). Data analysis revealed spatial changes, between the years 1972 and 2007 (Fig. 3) mainly in the quarries of Araxos area, Samareika settlement and its surrounding crops and in the sand dunes of the coastal area (Table 1).

Using the capabilities of geographic information systems (ESRI, 2009) we have created a Land use map, of our study area. To achieve this we had to combine photographs of the area, aerial photographs and satellite images from Landsat satellite and also from Google Earth since the latter allows zoom in and out. The habitat map of Natura 2000 programme was very useful for the final version of our map.

In Kotychi lagoon two sensor systems (North and South Station) were installed in order to record water parameters. By installing a sensor system in selected locations of a region we can monitor both biological and abiotic factors via one single network. One of the most important advantages of wireless networks is that they can help acquiring remotely control data in real time, which rarely leads to additional laboratory work. The sensor network for the systematic recording of the physicochemical parameters of the water in the lagoons of Prokopos and Kotychi was installed via LIFE EU-Programme funding. The measurements, provided to us by the local Environmental Management Body, were for the years 2004, 2005 and 2006 and

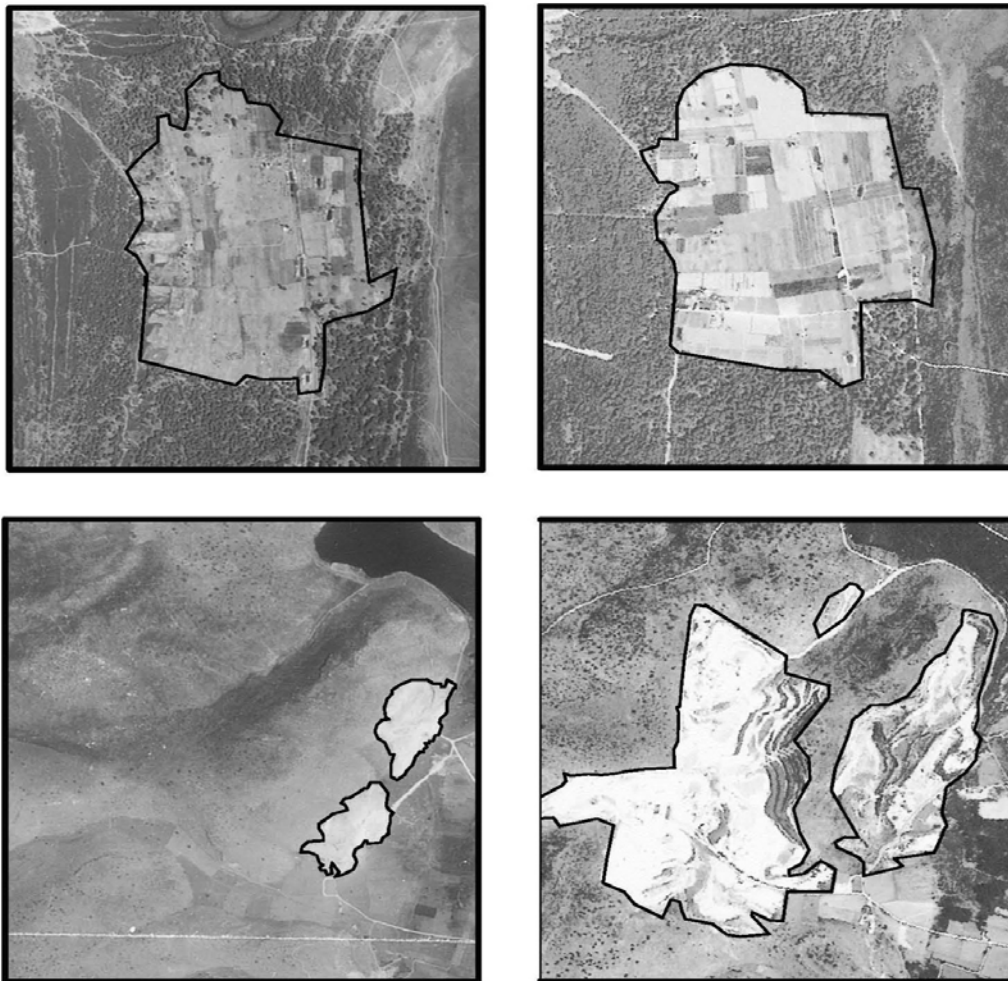


Fig. 3. Aerial photos from 1972 and 2007 showing in detail characteristic land use changes

concerned the months of July, August, September and October. Their values, obtained in csv (comma separated value) format, have been processed by appropriate software and were compared to the water parameters for these years.

The measured parameters were: water temperature, salinity, pH, Dissolved Oxygen, Electrical conductivity, turbidity and chlorophyll. By processing this data we have observed both the annual variations and changes of individual parameters for the 3 years that the sensor system was operating. Fig. 5 presents the comparison of the values of some of the parameters measured by the sensor system of the South station, for these three years. A major fluctuation of Salinity between the years 2004 and 2005-2006 is observed, something that needs to be examined since the period between July and September was quite dry and there is no way that rainfall could have affected the measurements. Temperature and Turbidity fluctuations are smaller and are attributed to climatic conditions. Depth, as

expected, as well as pH is not varying significantly between the three years of sampling.

The quick development and widespread adoption of Internet technologies allows servers to make their services and resources available to users anywhere anytime. A Database Management System (DBMS) is a software package that aims at systematic storage, searching and managing of data (Meloni, 2006). Using principles of php and SQL (Structured Query Language), we have created a database for data input sampling based on our sampling form used to record data for this specific area. The basic data that was used to create the database include the same parameters that we take into account during the fieldwork. The key fields created for data entry are:

1. "Insert Geological Substrate"
2. "Insert Habitat Type"
3. "Insert Species"
4. "Insert Sampling"
5. "Insert Sensors Data"

Table 1. Comparison table of the measured (land use) areas

	1972	2007	
Sections	Area (m²)	Area (m²)	Change [m², (%)]
Quarries of Araxos	121,156	1,040,000	918,844 (2,98)
Strofilia Forest	15,494,902	15,330,000	-164,902 (0,54)
Sand dunes of the coastal area	994,727	1,091,065	96,338 (0,31)
Community of Samareika	781,880	870,001	88,121 (0,29)
Black Mountains	12,474,257	11,555,457	-918,800 (2,98)
Forest area of Lake Pappas	881,571	861,830	-19,741 (0,06)
Total	30,748,493	30,748,353	

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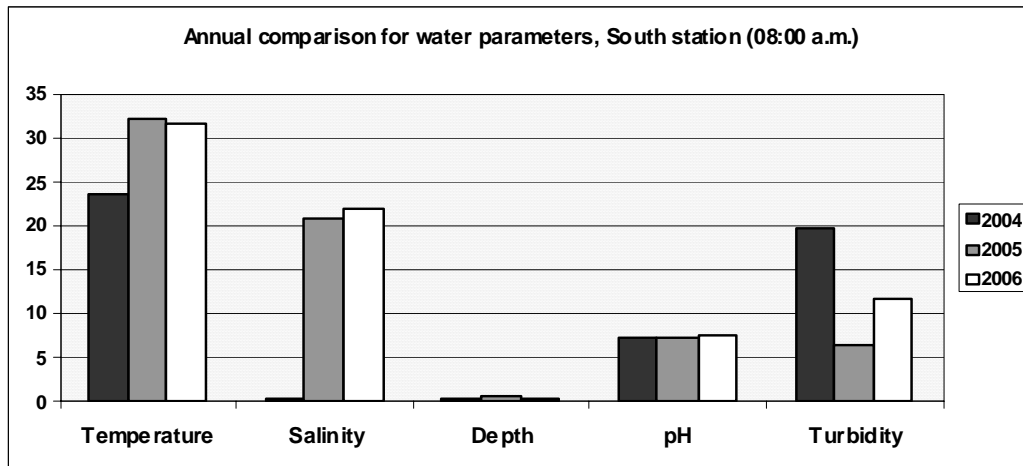


Fig. 5. Environmental Parameters Comparison

Then the user, by selecting the appropriate field, opens the sub-form where he/she can fill in the fields of his/her interest or make changes to existing data. For example, by selecting the 'Insert Habitat Type' from the main menu of the base a sub-habitats form opens as a drop-down list, in which the user can fill-in the following fields: Habitat Type Name, Area, Type of Geological substrate (which if inserted in the entry its description appears automatically and the user can simply select it), Conservation Review of Habitat Type (categorized as: A, B, C), Impacts, Habitat Type Photo, Impacts Photo. In the entry 'Insert Species' we can enter all the species that are present in the area of interest by entering data in the following fields: Species name, Animal or Plant, Bibliography. In the field "Bibliography" supplementary information about the data (metadata) is also stored, including information about existing environmental studies, monitoring locations, and data quality. In the field 'Insert Sampling'

we can save all the above mentioned parameters and data collected during field work. Note that we have added here a quite useful tool for automatic insertion of the N and W coordinates directly from Google Earth (Fig. 7), so the user, by pressing the option 'Check the Map', opens a new window where he can find the exact location of his sampling (Fig. 8).

By selecting with our mouse in the sampling area the 'check the map' option a new window appears which enables us to select our exact location. After selecting our sampling location, by closing the new window, coordinates are entered automatically. Finally with the selections:

- Export Habitat Types,
 - Export all Species,
 - Export all SAMPLING
- all stored data is displayed in columns so that it can be imported into processing software (i.e. Excel).



Fig. 6. Welcome Screen of the online database



Fig. 8. Automatic entry of Coordinates

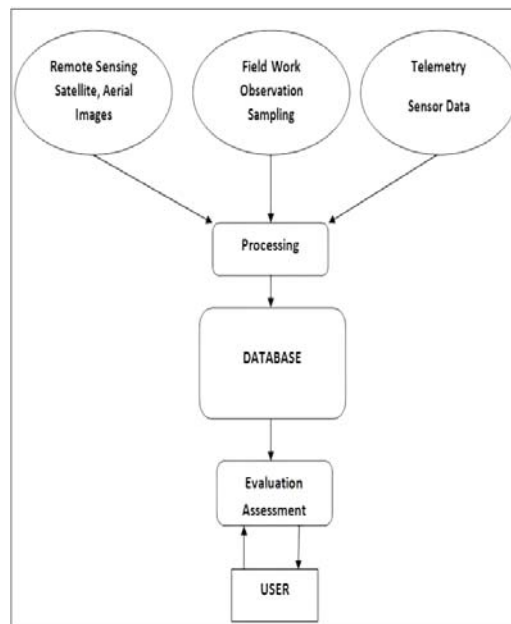


Fig. 9. Diagram of the monitoring and database system

CONCLUSION

Satellite remote sensing has the potential to support complex simulation models as well as environmental and geotechnical studies, which depend on the ability to monitor environmental parameters distribution through records at appropriate spatial and temporal scales and the analysis of relevant data, depending on the angle of the involved scientific discipline. These computer models, in combination with analysis tools which form a Geographic Information System (GIS), apart from creating and studying a particular map, may display every possible future scenario and every possible map. From the analysis of remote sensing data we have observed changes in the area occupied by the quarries, settlement and crops of

the Samareika area and the sandy beach that stretches to the west of the forest where hotels and tourist facilities are located. Also the sensor stations of the lake Kotychi recorded a series of changes in hydrological parameters, during their three-year operation, which were analyzed by using a suitable programme. Therefore the continuous monitoring programme of the Strofilia and Kotychi ecosystems should focus on both the locations where changes in area took place and also in the monitoring and recording of water quality parameters. The frequency of observations of the diachronic follow-up can be determined based on expected disruptions and the economic potential of the local Environmental Management Body (i.e. every five years).

The database that was created allows input of habitats, sampling of vegetation, flora and fauna and observations that were made during field work acting as an environmental monitoring management system. This database may be used, with appropriate modifications, for the monitoring of almost every type of natural area and may contain records on physical, chemical, and biological analyses and measurements. The important part is that the database is online and offers the option of importing data from anywhere and any computer, mobile phone or PDA that has access to the internet and provides the ability to export and represent data in a csv format.

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