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On the Design of Environmental Protection Networks

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Abstract

During the last decades, it has come to the attention of many scientists, working on the fields of environmental protection, that there is a tendency for the appearance of extreme environmental phenomena (floods, extreme temperatures, prolonged dry seasons etc). Additionally the frequency of these phenomena tends to shorten, which means that although they started as rare, nowadays they are more common. Many scientists believe that their appearance is directly connected to the global climate change; nonetheless however since they become more frequent there is a need for developing monitoring methods in order to protect sensitive regions from their destructive force. Additionally the protective actions must be implemented in a new framework, which mainly consists on budget cuts, personnel reductions etc. The purpose of this paper is the presentation of a methodology which can be used in order to deploy monitoring networks, which can be modular and installed in problematic regions. Additionally we present a case study of the proposed methodology for a Greek area of special interest.

Key words

Environment, Network, Monitoring, GIS.

Introduction

It is difficult to define precisely the environment, but in general, it embraces the social, geographical, physical and biochemical conditions under which we live. Conceptually it can be divided into the social and natural environment. The former is created by human activities, including industrial complexes, cities, villages etc., while the latter is a system comprising from the atmosphere, hydrosphere, lithosphere, cryosphere and biosphere. The components of the natural environment undergo changes on a range of temporal and spatial scales, which impact upon the social and economic activities of human society (Peng et al, 2002).

A profound feature of the environment is that its processes take place over a wide range of time scales, from micro-seconds to millions of years, and even billion of years if geological processes are also considered. The spatial domain of the environment depends upon the time scales we are interested in. In general it extends from the upper levels of the stratosphere to the upper levels of the lithosphere.

In the new millennium, human society faces unprecedented challenges arising from environmental changes brought about by both natural and human-induced processes. Some of these challenges are the following: Global warming caused by the extensive usage of fossil fuels, industrial activities and deforestation (Nordell Bo, 2003; Akerlof et al, 2013). Desertification, the drought affected areas on Earth total almost 48.8 million square kilometers (about 1/3 of the total land surface) and ¾ of this area is experiencing desertification, affecting about 1 billion people (Stringer, 2008; Barrow, 2009). Water resources, water covers about 71% of the Earth’s surface, but water resources in many regions of the world are limited (Tan and Wang, 2010; Kaldellis and Kondili, 2007). Regarding air water and soil pollution, studies made on air pollution show the rapid increase of air pollution in the recent history (Downing and Watson, 1974). Studies, on rivers in the region of Paris, France showed elevated concentrations of Atrazine which is one of the most important contaminants. Measured concentrations exceeded the value of 100 mg/l most of the time, thus proving that the aquifers drained by the three rivers of the area are contaminated (Tisseau et al, 1996). Similar results were found in Greece (Vryzas et al, 2009), Croatia (Jurisic et al, 2012), Bulgaria (Georgieva et al, 2010) etc. Soil pollution has also increased due to the uncontrolled usage of pesticides (Taiwo and Oso, 1997), and the lack of management of household and industrial waste (Ren, 2003; Travis and Arnold, 2008; Ienciu et al, 2012). Soil erosion, caused by the usage of inappropriate cultivation systems in agricultural production (Domuta et al, 2012) and due to the change in land uses after human interventions (Brejea et al, 2011).

Finally, concerning natural disasters. According to the frequencies of their occurrence worldwide in the last three decades, the most serious disasters are the following: floods, tropical cyclones, tornados, and whirlwinds, earthquakes, thunderstorms, landslides and avalanches (Loayza et al, 2012;Irasema, 2002; Zhao et al, 2012).

It is evident that there is a constant threat for the environment, and scientists must make enormous efforts to accurately monitor every threat, in order to provide solutions. Additionally under the scope of the economic crisis, which includes more countries every day, modular, cheap and above all accurate systems must be produced, which will allow researchers to monitor endangered areas more efficiently. The purpose of this paper is to present a methodology, using a combination of Geographic Information Systems (G.I.S) and Wireless Networks for deploying measurement networks, which based on simple and cheap commercial products, will allow scientists to deploy cost effective monitoring systems. Although GIS have been used extensively in the past, by many researchers (Vanek, et al, 2010) for mapping resources, finding the best agricultural practices in a region (Rathonyi et al, 2010), or acting as a spatial decision support system (Halbich and Vostrovsky, 2011), in this effort we take a step forward by combining the spatial analysis provided with a wireless network communication technology in an effort to provide a new methodology for designing measuring networks.

Materials and methods

In order to design the network, initially we must create the Digital Elevation Model (DEMs) of the study area, and then we apply the viewshed analysis. This is done because we design to deploy a wireless communication network. In order for the various parts of the network to communicate we must make sure that there is direct optical contact.

To develop the Digital Elevation Model (DEMs) and perform the viewshade analysis the following steps were implemented:

1. Acquisition of maps in various scales, aerial photographs and satellite images of the study area.
2. Geo-reference of the maps using the proper projection system.
3. Development of the following digital layers: Forest Boundaries, Contour lines, Stream Network, Land-uses (based on CORINE 2000), TIN (Triangular Irregular Networks), Map with the Station Network.

Once the above mentioned geographic information is digitized, the problematic locations regarding our case study are determined. These locations are found by utilizing the Intersect Tool of the Arc Toolbox. For example if we want to find locations with extensive erosion then we use the intersection tool among the slope, geology and land-use layers. This will allow us finding the locations where the stations that would take the measurements should be placed.

Measuring sensor

The proposed sensor is of general use, the measurement values can vary significantly based on the research needs (measuring water quality, soil conductivity, rain height etc).

Traditionally measurements are recorded with various types of individual instruments e.g. oscilloscopes, multi-meters etc. In addition, the need to record the measurements, analyze and visualize the collected data is becoming more important in the field of measurement and control of electrical signals information.

A measuring system displays or records a quantitative output that corresponds to the variable measured that is the input amount. Measurement systems do not react to the value of the input quantity, but they only display it in a way that is understandable by the user.

There are many ways that collected data can be transmitted between the sensors and a computer. The protocols that can be used for the transmission are different in nature. These protocols can vary from very simple such as the RS-232 (serial) to very sophisticated protocols, such as the CAN or IEEE - 488. CAN is used primarily in the in automotive industry. The IEEE - 488 is the GPIB (General Purpose Interface Bus) protocol.

The measurable values in nature are analog, so the design and development for the transmission of the data, in general needs to follow the provisions in Figure 1. Specifically the measurement process can be divided into different stages. An example of a thermometer will be used that is a very simple measurement process. In this case, the sensing functions, the signal conditioning and its display are all incorporated in the thermometer and are an integral part of the instrument. The signal conditioning is essentially the conversion of air heat in the movement of mercury in the thermometer. Many measurement systems are more complex and it is useful to separate them into individual sections that are the sensor, the signal adjustment unit and the recording or display unit. (Tsardaklis, 2007).

Based on Figure 1, the data acquisition system can be determined. Thus, the data acquisition system is an electronic interface system between the analog world (physical quantities such as pressure, temperature, weight, etc.), that are recorded by the sensors and the digital world (A / D converters, computers, microprocessors).

Initially, the measured physical quantity is the analogue value that is derived from the natural world and measured by the sensor. Then this information passes to the A / D and the value is converted from analog to digital. Therefore, in the final phase it will be transmitted to the computer.

The data transmission in the proposed sensor network will be done wirelessly using the wireless data transfer standard 802.11x.

Wireless data networks

In 1997, the foundations for the first wireless computer network with a maximum data transmission speed of 2Mbps in the 2.4 GHz band were laid based on the protocol 802.11. The protocol was established by the IEEE Institute in order to serve initially the needs of small computer networks (WLAN-Wireless Local Networks). The Spread Spectrum technology has been the backbone for the development of the 802.11, and its successors. Originally, it was used for military purposes, which necessitated the use of secure communication lines at multiple levels to prevent eavesdropping and interference. It took almost two years for the Institute to present the new standard IEEE 802.11b (also known as Wi-Fi), that would replace its predecessor, ensuring that it could reachspeeds of 11 Mbps at the frequency of 2.4 GHz. The main advantage of the new model was the higher data transmission speeds. There were also other minor differences between the two protocols.Since then a variety of flavors has been presented with differences mainly in range and data transfer speeds (Table 1).

The choice of the technology used for the wireless transfer of the data collected from the network of sensors is very important because it will determine the majority of the overall costs of the network.

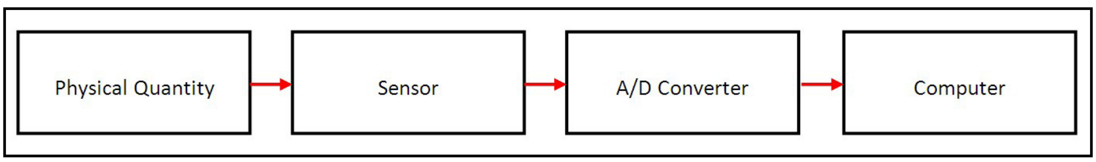
Based on Table 1 the range of the networks can vary from 100m to 5000 m. It must be noted that these ranges are under optimal conditions and with the use of directional antennas. Each protocol technology has a different installation cost and also requires a different number of antennas. (Andreopoulou et al, 2004).

In our case, the objective is to maintain full communication (complete coverage) with the smallest possible number of stations in order to have the least imposition on the area aesthetically, while also reducing the installation costs by using the least number of relay stations.

Viewshade analysis

To find and choose the best and most efficient technology a viewshade analysis is performed using ArcMap software. The map with the transmission stations is used as the input map, based on this map and with the use of the viewshade analysis we create new polygon layers containing the limits of each wireless protocol from Table 1 as buffers around the transmision stations.

To perform the viewshade analysis, initially a new point-layer is created that contains information



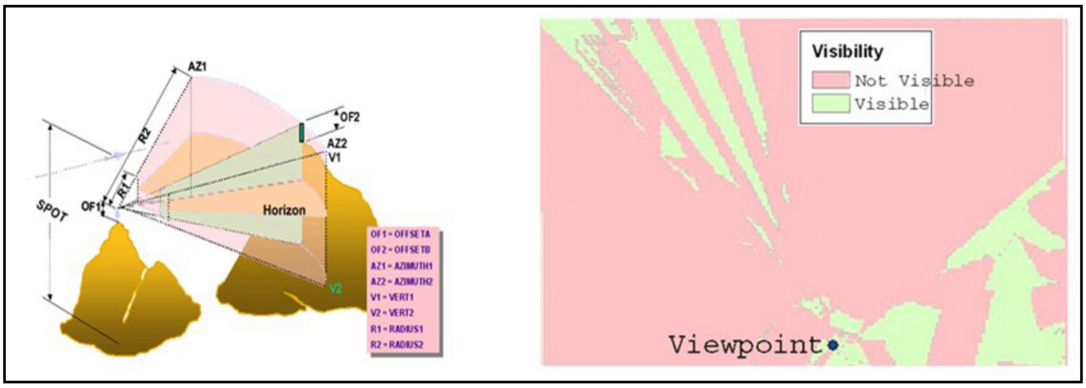
Source: own processing

Figure 1:The functioning system of the sensor.

Technical Specifications of 802.11x Technologies						
Protocol	Release Date	Frequency (GHz)	Bandwidth (MHz)	Data Rate (Mbits/s)	Range (indoors) (m)	Range (outdoor) (m)
Initial	6/1997	2.4	20	1,2	20	100
A	9/1999	5	20	6-54	35	5.000
B	9/1999	2.4	20	1-11	35	140
G	6/2003	2.4	20	6-54	38	140
N	10/2009	2.4/5	20/40	7.2-150	70	250
ac (Draft)	11/2011	5	80/160	433-6.93 (Gbit/s)	70	-

Source: IEEE

Table 1: Technology Networks 802.11



Source: own processing

Figure 2: Schematic representation of the variables of the viewshade analysis and the result.

about the locations of the erosion stations. Theviewshade analysis identifies areas that are visible from one or more observation points or linear objects. Each area in the exported information layer takes a value that indicates how many observation points are visible from this area. If there is only one point of view, each area that is visible from the observation point takes a value of 1. All the other areas take a value of 0.

A validation of the basic parameters of visibility analysis is conducted by introducing the appropriate fields in the database-layer information. The schematic graphical representation of the way the analysis is done can be seen in Figure 2. The observation point is at the top of the mountain on the left (OF1 position in image). The direction of the field of view is illustrated by the cone which is turned to the right. Additionally, we can determine the height of the point of observation (e.g. in the case of observation towers), the direction of the observation etc. (ESRI, 2011).

Overall we can control nine characteristics of the viewshade analysis.

1. The elevation of the ground at the observation position (Spot).
2. The vertical distance in the ground units that is added to the Z axis of the observation position (OffsetA).
3. The vertical distance in the ground units that is added to the Z axis of the each checkpoint (OffsetB).
4. The starting point of the horizontal angle of vision in order to limit the control range (Azimuth 1).
5. The end point of the horizontal angle of vision in order to limit the control range (Azimuth 2).
6. The upper end point of the vertical angle for limiting the control range (Vert 1).
7. The lower end point of the vertical angle for limiting the control range (Vert 2).
8. The inner radius that limits the control distance when we recognize areas that are visible from each observation point (Radius 1).

9. The external radius that limits the control distance when we recognize areas that are visible from each observation point (Radius 2).

Results and discussion

A case study of the proposed methodology

An application of the suggested methodology, on the design basis, has been done regarding the suburban forest of Seich Sou. This forest acts as an area of protection for the city of Thessaloniki, and for many years has been the receptor of great pressure caused by the expansion of urban fabric to the area of the forest (Figure 3). Additionally the increase in the mean temperature of our planet (the climate change phenomenon) has also caused major changes (Zaimes and Emmanouloudis, 2007). Based on these facts it is evident that there is a need to study the effects of these phenomena to the area of the suburban forest. In this case study we find the most suitable areas for the installation of an erosion measuring network.

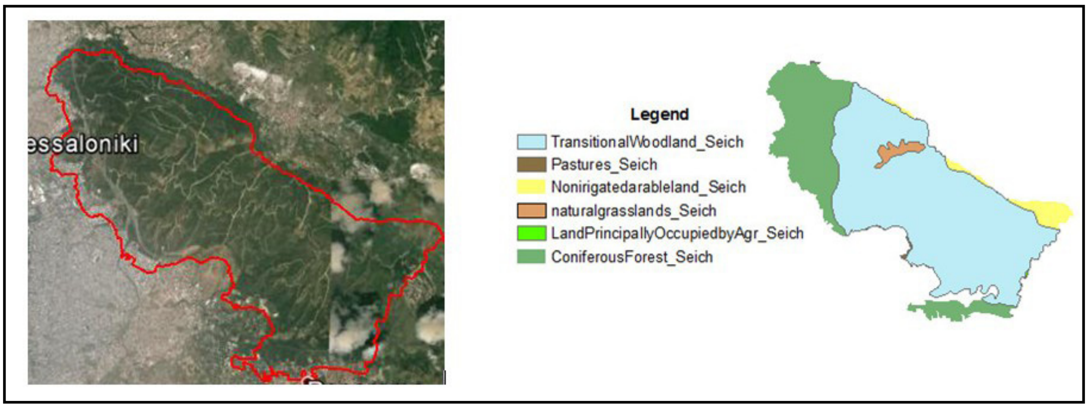
Erosion does not occur steadily and constantly throughout the year. In contrast certain soil conditions need to be established for erosion to occur. Erosion rates can also differ from year to year depending on climatic conditions (Zaimes et al, 2006). The above facts clearly indicate that to properly understand the phenomenon of erosion continuous measurements are required. Most erosion measurement methods that are frequently used today are point methods that measure erosion at a specific moment of time (Sapountsis et al, 2006; Sapountsis et al, 2009).

For the creation of digital terrain models (DTM) the digital contour map was used. This layer contains a database that maintains information on the elevation of each contour line. Afterwards with the use of 3D Analyst software ArcMap the TIN is created. Figure 4illustrates how the digital elevation model process is started. In this figure the digitized boundary of the suburban forest is depicted with red while the contour lines are with green. The output information layer after its completion is characterized by a pseudo three-dimensional look that allows the decision maker to have a more complete picture of the study area. Based on this layer, the points to perform the analysis will be selected that will be used for the viewshade analysis based on their location and other characteristics.

To implement the viewshade analysis method two files are required. The first file consists of a Digital Terrain Model (DTM), while the second file contains the data points that illustrate the locations of antennas that will transmit the data to the central data collection station.

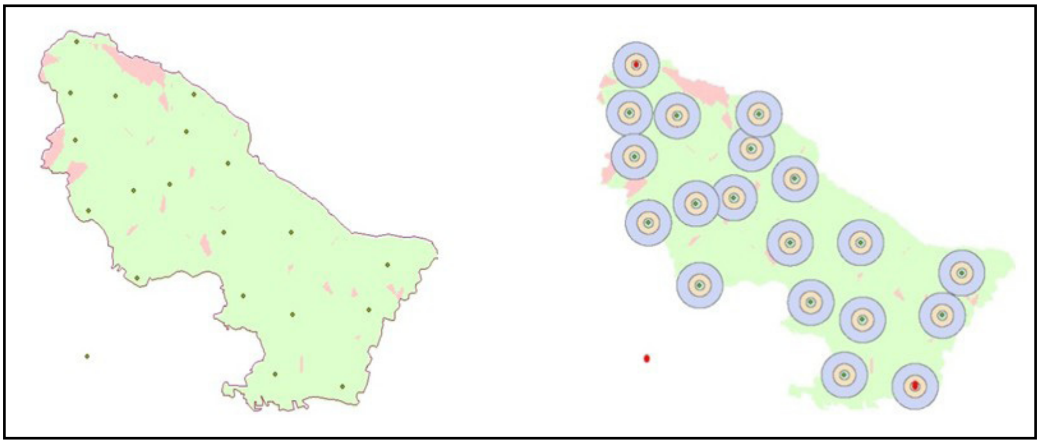
The next step after finding their location is the introduction of the antenna characteristics (height from the ground, emission angle, etc.). In figure 4 the light green color indicates the areas that are covered by the pillars while in red are the areas outside the coverage. It is quite clear that the majority of the pilot area is covered by the suggested network.

The map in Figure 4 also shows with concentric circles starting from inside towards the outside, representing the networks ranges of 100 m, 140 m and 250 m. Obviously none of them is sufficient for the implementation of the proposed measurement network. So for the implementation of this network the 802.11a protocol should be used that has a maximum potential range of 5000 m,



Source: own processing

Figure 3: Satellite image of the SeichSou boundaries (in red) and main Land Uses in the area.



Source: own processing

Figure 4: The results of the visibility analysis, and the location (in red) of the transmission station based on technology protocol 802.11a

in combination with the other protocols.

For the complete coverage of the entire area of the forest a total of 3 stations will be required that will include sources of transmission and collection according to the 802.11a protocol. The locations of these stations are shown in Figure 4 with red dots.

The results for the suggested locations can be seen in Figure 5. The reason a combination of technologies used for the implementation of the wireless network instead of one single technology, was the significant reduction in the installation costs and the reduced levels of radiation. Additionally, it is evident that the use of 802.11a technology stations provides the network with the ability to operate even if one or more technology stations malfunctions or is removed for maintenance.

Source: own processing

Figure 5: The resulting network.

Conclusion

Nowadays it is more crucial than ever to protect the environment. Extreme weather conditions in conjunction with the increase in human activities and population have led the planet to a crucial point where is urgent for researchers to suggest actions that will help mankind to overcome the problem. One of main problems environmentalists have to deal with is the lack of sufficient data to support decision making, due to the fact that the monitoring of environmental phenomena is both time intensive and money consuming. The purpose of this paper is to present a cost benefit methodology, for designing and deploying environmental measuring networks.

The methodology is based on the combination in the well established knowledge of Geographical Information Systems and Wireless communication networks. Based on these tools, we try to demonstrate a methodology of finding the optimum coverage of an area using GIS analysis techniques. Additionally we present a case study, based on real data from the suburban forest surrounding the east side of the city of Thessaloniki, Greece.

Recommendations

In the future the proposed methodology can be improved by using the 3G technology to transfer the erosion measurements. This technology is based on using the existing infrastructure of mobile phones in order to achieve data transmission. The complete coverage of the large territories is crucial in order to make the adoption of this data transmission technology. However we must underline the fact, that up until now there are vast areas with no GSM coverage or incomplete coverage, and that data rates still are a significant disadvantage which affects the adoption of GSM technologies.

In the case study of the suburban forest, although there is the possibility of using this technology it was not chosen because it would increase operating costs although there is the possibility of installing the server in a position very close to the erosion measurement network.

The time series produced by the network of sensors can be used to supply data to an artificial neural network (ANN) that in combination with the expected values of rainfall can create a map that will display areas that pose the greatest risk of future erosion phenomena. This will help towards the reduction of the administrative costs of the forest by pointing out this before they are eroded.

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