Using Geographic Information System (GIS) For Environmental Applications

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1. ABSTRACT:

This report addresses the importance of the Geographic Information System (GIS) as a useful tool for planning and managing issues that have direct affect on human life and the environment. The report comprises several sections which include: definition of the GIS, historical developments, general applications of GIS, environmental applications of GIS, case study and conclusions.

The case study mentioned in this report illustrates the use of GIS to assess exposure of residents to agricultural pesticide in the province of Limburg, Belgium.

2- Definition of GIS

The term Geographic Information System (GIS) is defined as a system of hardware, software and procedures to facilitate the management, manipulation, analysis, modelling, representation and display of geo-referenced data to solve complex problems regarding planning and management of resources [1 -2].

3- Introduction

In the past, it has seen numerous well-publicized catastrophic natural disasters occurred throughout the world, including the tsunami of Asia and the Pacific Ocean, several hurricanes of the USA, and major earthquakes of Pakistan, India, Turkey and Armenia. What each of these events has in common aside from the extent of loss of life, livelihood and materials, was the lack of preparedness of authorities to react to each event. Now that the events have passed and communities are back on the road to recovery, many observers are commenting on what could have been done better. There is an old saying of being “wiser after the event” which seems particularly true when such extreme events occur. Now the GIS technology has a role to play to be better prepared to handle great events [3-4].

A **geographic information system (GIS)** is in the strictest sense, a computer system capable of integrating, storing, editing, analyzing, sharing, and displaying geographically-referenced information. In a more generic sense, GIS is a tool that allows users to create interactive queries (user created searches), analyze the spatial information, edit data, maps, and present the results of all these operations. More specifically, GIS is a system for capturing, storing, analyzing and managing data and associated attributes which are spatially referenced to the earth [5].

Geographic information science is a technology that can be used for scientific investigations, resource management, asset management, environmental impact assessment (EIA), urban planning, cartography, criminology, history, sales, marketing, and route planning and it is taught as a degree program by several universities. GIS might allow emergency planners to easily calculate emergency response times in the event of a natural disaster, a GIS might also be used to find wetlands that need protection from pollution, or a GIS can be used by a company to find new potential customers similar to the ones they already have and project sales due to expanding into that market. The previous mentioned examples are just fraction of GIS program capabilities and applications at the present time [6].

4- Historical developments of GIS

Geographic information systems have emerged in the last decade as an essential tool for urban and resource planning and management. Their capacity to store, retrieve, analyze, model and map large areas with huge volumes of spatial data has led to an extraordinary proliferation of applications. Geographic information systems are now used for land use planning, utilities management, ecosystems modeling, landscape assessment and planning, transportation and infrastructure planning, market analysis, visual impact analysis, facilities management, tax assessment, real estate analysis and many other applications [7-8]

5- General Applications of GIS

The applications of Geographic Information Systems (GIS) are involve in solving real-world problems. For example, use in the studies of natural disasters, geohazards, water resources, hydrologic and hydraulic modeling, urban planning, and terrain analysis. Such as: GIS can be used to map locations. GIS allows the creation of maps through automated mapping, data capture, and surveying analysis tools, People map quantities, like where the most and least are, to find places that meet their criteria and take action, or to see the relationships between places. This gives an additional level of information beyond simply mapping the locations of features, mapping densities while you can see concentrations by simply mapping the locations of features, in areas with many features it may be difficult to see which areas have a higher concentration than others. A density map lets you measure the number of features using a uniform a real unit, such as acres or square miles, so you can clearly see the distribution and it can be used to find out what's occurring within a set distance of a feature as well as the GIS can be used to map the change in an area to anticipate future conditions, decide on a course of action, or to evaluate the results of an action or policy [9-10].

6- Why using Environmental GIS?

GIS is used every day to help protect the environment. As an environmental professional, you can use GIS to produce maps, inventory species, measure environmental impact, or trace pollutants. The environmental applications for GIS are almost endless

- One of the main benefits of GIS is better resource management both within and outside an organization. A GIS can link data sets together by common data, such as addresses or latitude and longitude, which helps members of the public, private environmental companies, and governmental departments share their data. By creating a shared database, information that can be collected once and be used [11]

7- GIS Applications in the Environment of the developing world

Published research studies demonstrated how GIS data is being used to show cause effect relationships between environmental conditions and health of the developing world. Many case studies demonstrate how GIS can be used to monitor tropical diseases, water quality, environmental toxicology, and overall rural health. The publications also demonstrates how GIS can provide health researchers, planners, program managers, and policymakers with novel information about the distribution and interaction of disease risk factors, patterns of morbidity and mortality, and the allocation of health resources.

In the developing world, GIS has been used for many years in the agricultural, natural resource, urban and regional planning, and tourism sectors. The health sector, however, has only recently begun to use this powerful tool. Many developing countries currently utilizing GIS for environmental applications such as:

- Water Resources
- Forest Resources
- City Planning
- Pollution Monitoring
- Waste Management

8- Case Study

Case 1: Indicators to Assess the Exposure of Residents to Agricultural Pesticide in the province of Limburg, Belgium.

In this study researchers developed two indicators to assess the exposure of residents to agricultural pesticide use and applied it in a case-control study on bladder cancer in the province of Limburg, Belgium. The first indicator used a distance-weighted measure of crop area for specified crops (fruit trees, fruit bushes and vegetables). The second indicator used a distance-weighted measure of pesticide use. Researchers used information at three scale levels: (a) information at individual's level, such as distance to crop fields; (b) information at the level of the municipality, such as time-series of crop area; and (c) regional information, such as pesticide use. Pesticide use data were available per group of pesticides (fungicides, herbicides, insecticides, growth regulators and group of other pesticides). Indicators were calculated for each individual in the case-control study. The indicators were calculated per year for a period of 20 years, taking into account address history. Variation of pesticide use and toxicity with time was addressed by a relative risk factor. A very strong correlation was found between the area of fruit trees and bushes and the use of fungicides as well as the use of "other pesticides", indicating that these groups of pesticides are predominantly used in fruit production. The indicator for fruit trees is highly skewed to the right, indicating a high number of subjects with low potential exposure to fruit trees. Pesticide pressure indicators are less skewed as they combine application to multiple crops; the highest skewness is found for fungicides corresponding with the distribution for fruit trees. Statistical analysis revealed no association between the indicators and the incidence of bladder cancer. The results show that, using GIS, it is possible to reconstruct potential environmental pesticide exposure accounting for changes in pesticide use, crop area and residence history. Validation of the method with measured exposure is considered essential in view of its future application in other studies.

1. The conceptual spatial models used by environmental modelers differ in significant ways from the spatial data models provided in current GI systems.

    - [The term "conceptual spatial model" refers to the analog models used to constrain or inform data collection activities and/or used during the conceptualization of process models.]

- By definition, environmental models are environmentally determined. Thus since many environmental phenomena are fields, environmental models are fundamentally continuous. Hence, environmental *modelers* generally have a continuous view of the world and most seem to find this compatible with the cell grid or point grid data models. Therefore, there are no *fundamental* differences between the disciplines.

2. The objects of study, traditional sampling designs and modeling techniques used by individual environmental science disciplines lead to discipline specific conceptual spatial models.

    - If environmental modelers generally do perceive their phenomena as continuous or see their phenomena as being environmentally determined, then it seems that their conceptual spatial models do not differ significantly.
    - However, objects of study do vary from superimposed continuously varying phenomena (e.g. climatology) to objects embedded in continuous matrices (e.g. mining geology) to independent objects (e.g. entomology). However, environmental determinism is a fundamental principle in the prediction of the occurrences of many of the phenomena and so they can all be seen to exist within a continuous matrix or at least on a continuous probability surface.
    - In some sciences, traditional data collection and representation techniques have relied on the discretization of space and of phenomena, particularly in soils, geology and vegetation mapping. In these cases, data collection requires experts who can interpret all the environmental clues, some of them unspecified and unmeasureable, and make conclusions about the distribution of classes of the phenomenon being mapped. In such cases, the data which is ultimately recorded (i.e. mapped) is not the fundamental observed phenomena, but an inferred classification.

- However, environmental modelers in these same fields are now working with models based on field (i.e. continuous) variables. Classes can be extracted as needed for any set of criteria and/or by using various statistical techniques.
- Thus, significant conceptual differences may not be within the different sciences, but between the scientists and the managers.
- At the management end of modeling applications, continuous results are too difficult to integrate conceptually, particularly when there are several environmental gradients involved. Thus classifications of results of continuous analysis are needed.

3. However, it is possible to deconstruct these differences such that the fundamental common characteristics of conceptual spatial models can be identified and measured
    - There are no fundamental differences. Continuous fields, in some cases with embedded objects, may provide the unifying theme.
4. However, it is possible to conceive of a continuous environment composed of homogeneous discrete units such as watersheds. The scale of the process determines if this is possible since in many regional scale models, processes below the watershed level are insignificant. This permits an assumption of homogeneity even within a continuous context.
5. These characteristics can be used to develop interoperable interfaces, data models or other elements of GI systems which will enable environmental modelers to use them more efficiently.
6. Interoperability can be based on a common conceptual reality. Objects and phenomena should be conceptualized within their physical environment and their attributes and relationships expressed in ways which allow interfaces to translate these generic qualities into system specific values. This means that reality would form the central interface between different environmental models and databases. All data passed through the interface would be returned to the appropriate variation of a continuous model and then redefined as required for specific software.

- It is possible to design a software product which would assist environmental scientists and managers to itemize the critical elements of the environment and to understand and express the relevant spatial and a spatial components [12].

9- Conclusions

- Powerful tool in facilitating data handling and visualization
- Provide geospatial air quality models at any time and any location any one can access the Air Quality Status (AQS) of that area. "what if" scenarios
- Beneficial for environmentalists, planners and decision makers so that they can reliably generate, simulate and analyse more information about environmental parameters.
- Management and cost effective
- It is a specialized endeavour that can easily be carried out incorrectly.
- GIS does not depend on technical choices alone. Organizational and institutional factors frequently are a greater barrier to successful GIS use. To make this innovation a useful component of a decision-making process, a community should carefully consider all facets of GIS implementation – technical, organizational, legal, and administrative.

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