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Concept of GIS and its applications in natural resource management: A review

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Abstract
The demands for management of natural resources requires both management of spatial data and information. Geographic Information Systems (GIS) is mainly referred to the broad collection of Information Management Techniques, which can store as well as analyze such information to contribute to the needs for planning and resource management. The benefits of using GIS has produced remarkable changes in such a way and rate at which geo-referenced data is produced, updated, disseminated and analyzed, making production and geographic information analysis is very efficient. GIS gives an abundant opportunity to monitor and manage natural resources at multi-spectral, multi-temporal and multi-spatial resolution. There is an urgent need to know and understand the specialized capabilities of an ever-expanding array of image sources as well as analysis techniques for natural resource managers. This review compiles the various applications of GIS techniques which can be used for NRM *i.e.,* natural resource management such as (Agriculture, soil, water, forest, and natural hazards). An powerful tool in excellent management of both sectors such as public and private. GIS is timesaving and very profitable.

Keywords: GIS, natural resources management

Introduction

Natural resources plays an important role in the welfare of developing countries (Huizing *et al.,* 2002) [42]. In many developing countries, natural resources are the base for survival. However, these developing countries have experienced, and will continue to experience in future, the severe degradation of these natural resources. Expansions in population, technology and economic activities led to an accelerated as well as unsustainable exploitation along with natural resources depletion (Satapathy *et al*., 2008) [95]. The severe degradation, especially the forest cover, will be leading to diminishing in soil erosion, soil fertility, it may cause increased severity of drought impact, and may also leads to further reduction in the ability to produce food and other resources such as biological which are demanded by the human and animal populations (*Ibid*). The fundamental resource for almost all human usage is Land. The usage of land resources is shaped by the interaction of 2 broad set of forces such as Human needs (Socio-economic) and Environmental features as well as processes (bio-physical)-human's action towards natural resources is the product of individual and group behaviors within the exact socio-economic and environmental settings. Natural resource is not distributed uniformly, but vary spatially and also in consequence the social and economic development challenges will vary spatially. In context of management the spatiality of natural resources is described as the development landscape i.e., it currently exists and also the potential pathways changes. Information related to spatial is the base for natural resource management Information.

Geographic Information Systems (GIS) it is an computer based information system which is designed to work with data or information i.e., referenced by spatial or geographic coordinates. Use of GIS is rapidly increasing, as regional, city, and environment planners, resource managers as well as the scientific communities is becoming aware of the capabilities of these systems like GIS which is offering to society (Star *et al.*,1990) [46]. GIS technology is having the ability to incorporate many different forms of data, and also can be used for analysis in many areas (Fleming *et al.,* 2005) [18]. Geographical data that is stored describes the objects from the real world in terms of their position on the earth with respect to a known coordinate system, and their attributes that are unrelated to their position, and their spatial interrelations with the objects around them (Burroughs *et al*., 1987) [77].

Many functions and benefits we get from the information given by GIS. In the early 1990's, spatial information had been used by public land managers, in order to estimate the types of forest and forest distribution in the US (RD Graetz *et al.*, 1993) [84]. GIS was also used to produce thematic mapped data DL Evans. (1994) [29] mapped forest density Levinsohn (1991) [2]. The global community had depended heavily on GIS for tropical forest assessment as well as its relation to the global warming Gillespie (1994) [1]. These systems were used to identify map areas of different social groups (Lee *et al*., 1995) [22] It was used to monitor and solve major urban problems of overpopulation (De Wit *et al*., 1992) [61] info is used in medical and public health applications, for example to trace wide-spread medical problems (GE Glass *et al*., 1992) and to coordinate planners, public health personnel Werner (1995) [82]. GIS also was of great usage in routing traffic and traffic control around the world as well as US Schniker (1993) [88]. GIS had been proved to be a success in EPA, this procedure is becoming a mandatory for any large projects in many places in the world (Johnston *et al*., 1994) [47]. GIS is used in a wide variety of NRM practices (Schreier *et al*., 1989) [39] It is used in evaluating damage from the natural disasters (Tsuji *et al*., 1996) [40] and monitoring pollution contamination of various types (Runyon 1994) [107].

GIS is integrated with knowledge bases which produce expert systems for NRM (Ji *et al*., 1992). It was mainly used for wild land protection and National Parks, management, and planning Wilcox (1987) [6]. GIS is used in watershed-related studies and also in decision-support systems for management Pickus (1992) [45] It is widely used in environmental monitoring (Ramsey *et al*., 1994) [33] e.g. monitoring land degradation and soil loss Roehl (1962) [50]. Additional this GIS use has been as a tool for the data collection about habitats as well as forming a habitat data bank McGargile (1994) [5]. GIS is used in landscape architecture, regional and urban planning and studying regional growth (Bou-Saab *et al*., 1992) [43]

Potential of GIS has led to the emergence of the multi-participant approach for GIS Fleming (2005) [18]. Historical records is also been used in GIS to identify changes in the forest cover. Between 1979 and 1984, the land resource inventory project is completed in Jhikhu Khola watershed present in Nepal (Schreir *et al*., 1992) [63].

The GIS contributes to use natural resource information include, a better visualization of spatial diversity of the resources (Huizing *et al*., 2002) [42], improved possibilities to analyze and integrate data from different sources as well as the possibility to assess impacts of alternative interventions (Cowan, 1988) [24]. GIS, with their capabilities for the spatial analysis and modelling of diverse data, which can enhance the ability to address several natural resources as well as environmental issues that have a spatial component (Nijkamp & Scholten, 1993) [73]. It can facilitate the organization, manipulation and analysis of diverse data often associated with above issues, and the data structures, and analytical techniques of GIS is incorporated into a wide range of management practices and decision-making operations that pertain specifically to the natural resources.

Problem statement

Developing countries had experienced severe environmental degradation as well as ecological deterioration in past century, with small or no real solutions to alleviate many of these problems. Information on variability and distribution of natural resources together with natural resource problems are much needed to enhance decision-making in natural resource management. Use of traditional methods for mapping as well as estimating potential risk areas is relatively very costly, as well as time, consuming and it is subjected to a variety of errors. Recently, advances in computing power, as well as the increasing availability of remote sensing data, has renewed an interest in using GIS in order to address a wide range of environmental issues and questions. The main challenges in developing countries are how to make the best usage of the sparse data available from different sources when an addressing urgent environmental problems

Natural resource management

NRM is a discipline for management of natural resources with a exact focus in, management which affects the standards of life for each gifts and future generations (Wikipedia, 2009) [113]. This involves in the manipulation of the resource for preserving or providing a product on a sustainable basis (Knight and Bates, 1995) [53]. The aim of NRM is managing natural resources so as to win a balance between their functions for the standard surroundings and their functions for standards of human life (Schmidt-Vodt & Shrestha, 2006) [95]. In order to achieve this aim NRM revolves around, however isn't restricted to, manipulation and the analysis of data from numerous sciences as well as disciplines.

According to Kliskey (1995) [51], management of resources provides structured processes during which decision-making as well as problem-solving occurs. Seasons (1989) defines the strategic designing method as an appropriate frameworks for coping the resource problems. Strategic designing is an disciplined effort in order to provide basic choice for shaping the character and to direct difficulty (Bryson & Roering, 1987) [15]. It is primarily involved in problem-solving, the linkages with an organisation's operational surroundings. The scope of the management method is where as wider than this, the main focus is on strategic designing method which provides a helpful structure among that to think about data and decision-support in the natural resource management (Kliskey, 1995) [51].

The parts of the strategic designing method, is likely the drawback identification, goals articulation, identification and analysis of arranging alternatives and their implementations, purpose to the importance of data in designing as well as problem-solving. There is a very little doubt that the prosperous outcomes of decision-making as well as problem-solving among the design method depends on the input of data and ulterior manipulation and the handling (Kliskey, 1995) [51]. During this context, generating the reliable data for an input within the designing method is significant.

In the context of the natural resource management, reliable, geographically specific data from a range of sources is needed. The particular ancient strategies of generating this data square measure comparatively expensive as well as time-consuming as they need intensive mapping and the observation programmes (Ononiwu, 2002) [73].

As a result, several developing countries will, neither the capacities nor the resources to undertake intensive mapping and observation programmes existing in geospatial data is usually either incomplete or out-dated and so not compatible with very trendy management needs (Kalensky, 1996).

Using GIS, beside remote sensing, features a distinct advantage over ancient strategies of mapping and observation natural resources (Joshi *et al*., 2006) [49].

Role of geographical data systems

In resource management, role of GIS is said to its functions (Densham, 1991) [28]. Since a GIS will be collate, manage, store, retrieve, analyze and to show disparate the spatially documented data (Nijkamp & Scholten, 1993) [73], this is ready to support numerous aspects of the resource management. Keeping with Densham (1991) [28], GIS functionalities, particularly the artful and analytical capabilities, will enhance the problem-solving surroundings in 2 ways. First, this matter will be soon examined to increase amount of understanding as well as to refine the definition. Secondly, the generation and analysis of different solutions to matter allows the identification of the potential conflicts and trade-offs and also unlooked-for impacts ensuing from projected solutions. These roles, GIS provides practicality for analysis and modeling, as so becomes a linking mechanism between a characteristic retardant, evaluating alternatives and the decision-making. What is more, GIS provides a additional integrated approach to problem-solving and an knowledge base understanding of the choice context (Kliskey, 1995) [51].

Major GIS applications in natural resource management (NRM)

One of the strongest and prosperous applications for GIS is addressing environmental issues (Goodchild, 1993) [37]. GIS is utilized in the event for the spatial databases, assessing of standing and trends of resource utilization and to support and for assessing numerous resource management choices (Clark, 1990). Some of the major spaces of application of GIS among the broad square measure a of natural resource management are highlighted in the below.

a) Natural resource inventory

Natural resource inventory (NRI) is the recording and assessment of the provision as well as condition of natural resources. A NRI provides relevant data which will formulate effective environmental policies and legislation, implement resource conservation programs, and enhance the public's understanding of natural resources and environmental conditions (Brown *et al*., 1998). GIS store and analyse inventory knowledge and estimate rates of resource amendment in response to management. Once the inventory knowledge square measure entered in GIS, maps will be generated to indicate the placement and extent of existing resources.

b) Hazard and risk assessment

Natural hazards like floods, droughts, cyclones, earthquakes, landslides and forest fires square measure in escapable. However, it's attainable to minimise the potential risk posed by such hazards by developing early warning methods, making ready and implementing developmental plans to supply resilience to such hazards and to assist in rehabilitation and post disaster reduction (Samir, 2002) [89]. GIS and remote sensing are utilized in the analysis, observation and mitigation of a large style of natural disasters. In keeping with Samir (2002) [89], GIS provides the info base from that the proof left behind by disasters that have occurred within the past will be understood, and combined with the opposite data to make hazard maps, indicating that square measure as are probably dangerous. As an example, landslide hazards are calculable and mapped of exploitation GIS-based applied mathematics models (Reis *et al*., 2009) [82]. Floods are fore seen, warned against and mapped by combining morphological data derived from digital piece of land models with hydrological models (Consuegra *et al*., 1995; Sanyal, 2003; Uamkasem & Simking, 2008) [23, 91, 107]. volcanic rock flow pathways are simulated and volcanic hazard maps are developed exploitation GIS techniques (Carrara *et al*., 1999) [19]. In most of those studies, GIS and remote sensing are wont to develop appropriate disaster management methods and activity frameworks for his or her observation, assessment and mitigation.

c) Change detection

Information concerning amendment is critical for change, land cowl maps and also the management of natural resources. Amendment detection by GIS could be a method that measures however the attributes of a specific space have modified between 2 or longer periods. Amendment detection typically involves scrutiny aerial picturesor satellite imagination of the world taken at completely different times (Yang, 1999) [112]. It's helpful in several applications like land-use changes, environs fragmentation, deforestation assessment, coastal amendment and concrete sprawl. For example, Ochego (2003) [72] used GIS to map forest loss and determine key factors concerned within the deforestation method. Laurance *et al*. (2001) [56] conjointly used GIS to predict regional-scale changes within the Brazilian Amazon. Prenzel & Treitz (2004) [76] applied amendment detection techniques in watershed studies to boost the capability of native governments to implement sound environmental management. Mitra (1999) [70] and Dahdouh-Guebas (2002) [26] analysed coastal environmental changes through qualitative analysis techniques.Regional-scale changes within the Brazilian Amazon. Prenzel & Treitz (2004) [76] applied amendment detection techniques in watershed studies to boost the capability of native governments to implement sound environmental management. Mitra (1999) [70] and Dahdouh-Guebas (2002) [26] analysed coastal environmental changes through qualitative analysis techniques.

Furthermore, Barnes *et al*. (2001) used GIS-based techniques to derive a amendment map by vegetation index differencing, image parceling, image differencing and image regression. statue maker *et al*. (2002) conjointly used GIS-based amendment detection techniques in infrastructure designing in urban areas, and for finding outregional growth and Sudhira *et al*. (2003) [102] detected, mapped and analyzed the physical pattern of sprawl on landscapes exploitation GIS. Altogether these studies, the essential principle of the amendment detection techniques was that the digital range of 1 date is completely different from the digital range of another date.

d) Suitability analysis

Suitability analysis could be a method of decisive the fitness of a selected landscape condition to support a well-defined activity or land use (Steiner, 1991) [99]. The essential premise of suitableness analysis is that every facet of the landscape has intrinsic characteristics that square measure to a point either appropriate or unsuitable for the activities being planned, which these relationships will be discovered through careful analysis and assessment (Marsh, 1998) [65]. Suitableness analysis involves the method of finding the most effective location to support some desired activity whereas minimising negative impacts on the surroundings (Church, 2000) [20]. GIS-based suitableness analysis has been applied in an exceedingly wide selection of things together with ecological approaches for outlining land suitableness and environs for animal and plant species (Store & Kanga, 2001; Dwivedi *et al*., 2006) [101], suitableness of land for agricultural activities (Bandyopadhyay *et al*., 2009) [7], landscape analysis and designing (Miller *et al*., 1998 as cited by Malczewski, 2004) [63], choosing optimum sites for public and personal sector facilities (Church, 2002) and regional designing (Jolly *et al*., 2001) [48].

e) Environmental observation

Monitoring is that the method of observant and decisive qualitative and quantitative transformations that will be occurring and to predict their future trends. GIS presents the chance of endeavor effective graphical and numerical observation of environmental and resource problems. Globally, GIS has been heavily depended upon for environmental observation (Tsou, 2004) [106] e.g. pollution observation (Briggs *et al*., 2000) [13] and observation land degradation and soil loss (Manoj, 2000) [64]. The power of a GIS to seamlessly integrate knowledge of variable structures (i.e. vector, raster, tabular) and of variable scales makes it key to the success of integrated resource observation efforts.

f) Environmental impact assessment

Environmental Impact Assessment (EIA) could be a call method that aims each to spot and anticipate the impacts on the natural surroundings, human health and quality of life, and to interpret and communicate the knowledge concerning those impacts. Given the spatial nature of the many environmental impacts, GIS are with success applied altogether EIA stages, i.e. from the acquisition, storage and show of thematic data relative to the vulnerability of the affected resources, to impact prediction and quantification, analysis and presentation for call support (Antunes *et al*., 1996) [4].

Crucial and obligatory parts of EIA square measure the prediction of the magnitude of environmental impacts, the planning of acceptable preventive or mitigation measures for negative impacts and also the sweetening of measures for positive measures (Satapathy *et al*., 2008) [95]. GIS are wont to develop simulation models for predicting the magnitude of environmental impacts (Fedra, 1993) [34]. The model results obtained, typically within the kind of maps showing the spatial distribution of values of a given environmental descriptor, are wont to estimate the extent of environmental impacts. Straight forward GIS techniques like overlay, classification, buffering, interpolation, etc have conjointly been wont to generate further data to support impact prediction (Antunes *et al*., 2001) [3].

More complicated uses of GIS for EIA have conjointly been rumored. Schaller (1992) [93] used GIS in complicated modelling illustration techniques. He made a visible illustration that he known as “Annoyance Mountain,” by combining population knowledge with the noise levels expected from the installation of a replacement airfield in metropolis. Full General *et al.* (1988) explored the potential of GIS as a repository of knowledge and accumulative impact assessment.

Sankoh (1996) [90] conjointly used GIS to get area resistance maps and determine route alternatives that best owed minimum conflict with the surroundings.

GIS have conjointly been used for economic valuation of the surroundings through the preparation of quantitymaps (Eade & Moran, 1996) [30]. This space of application has multiplied the sensible application of cost-benefit-analysis and consequently increased the role of economic valuation on EIA. Altogether these various case studies, GIS technology has incontestable nice potential to handle resource management problems.

GIS in developing countries

The growth of GIS in developing countries has occurred primarily over the past decade. According to Hastings and Clark (1991), much of the initiative of GIS resulted from the desire to apply computer technology to cartography, remote sensing, data management and environmental assessment. In Africa, for example, GIS installations are said to have started in the late 1970s (*Ibid*) with their transfer by international agencies (Yapa, 1991) [113]. This transfer encompassed the acquisition of computer software, hardware and the development of human capacity to apply the technology. A few successful GIS installations were also reported in Latin America in the early 1990s (Smith, 1992) [98]. According to Sheng *et al*. (1997) [97], the growth of the use of GIS has been facilitated by a significant decrease in the cost of hardware and modest reduction in the cost of software, along with the wider availability of digital spatial data. Currently, GIS is being used to address a range of spatial problems in the developing world. Common applications include land resource appraisal, urban and regional planning, population policy formulation, national agricultural development, natural resource management and disaster preparedness (Bishop *et al*., 2000) [11].

In spite of the perceived advantages and extensive applications of GIS, their deployment in developing countries has not been without problems. Various researchers have identified a variety of problems ranging from institutional barriers to technical constraints as well as limited human resources capacities. The difficulties and challenges of implementing GIS in developing countries include the susceptibility of GIS to the changing expectations and/or limited life spans of externally funded development projects, periodic licensing of software, financial constraints, poor vendor support, cumbersome bureaucratic procedures for the approval and procurement of technology, and failure of politicians to support GIS projects. They also include lack of trained personnel, unreliable communication networks and power supply, lack of organisational support to maintain GIS installations, inadequate support of GIS research and poor cooperation among government, academic and private sectors

In addition to the difficulties and challenges mentioned above, lack of suitable GIS datasets has been mentioned as a major constraint in the implementation of GIS in developing countries (ESRI, 2003) [32]. In such cases, the potential of GIS to address spatial problems is severely curtailed since the power of GIS application relies on the scope and quality of the data used. Although readily available in industrialised countries, spatial data in developing countries are often nonexistent or of poor quality. Kalensky (1996) asserts that the existing geospatial information in developing countries are often either incomplete or obsolete and thus not compatible with modern management requirements. Bishop *et al*. (2000) [11] lend credence to this view and state that where spatial data exist, they are often outdated or lamentably fragmented among and within various institutions and therefore unavailable for widespread use.

Levinsohn (1989) [59] asserts that institutional issues such as project planning and management, attention to changes in the institutional culture, and coordination and cooperation between organizations are the major causes of many GIS implementation failures, rather than technical issues. He argues that the scope of GIS implementation is governed by the institutional setting into which the system is to be implemented and advises that greater emphasis must be placed on dealing with institutional concerns if GIS is to achieve the potential that has been ascribed to it. Huizing *et al*. (2002) [42] lend credence to these views put forward by Levinson. They analysed the factors hindering the implementation of GIS for natural resources management and planning in Zimbabwe and observed that even where technical barriers of GIS implementation were overcome through the acceptance of lower data quality, the provision of minimum hardware and software, a short training course and demonstration of the developed applications, the response among key decision-makers still remained low. Thus, the application of GIS, in a developing country context, requires a context-sensitive approach and involves a variety of modifications to suit local needs in a manner that is compatible with the interaction between the technology and the specific social or institutional setting (Levinsohn, 1989) [59].

Use of GIS in natural resource management

a) Water Resource management

Water as a resource is very essential and crucial to support human existence. The availability of fresh water for the human usage has been declining over years together, whereas the demand of growing population is also increasing day by day. In this context, there is an urgent need for monitoring and to obtain a better understanding for usage, which provides information that can assist towards the development of an effective water management strategies as well as infrastructures. This can be a crucial importance, for particular regions on which the amount of water available is very limited. Understanding the usage of complex water system it requires a holistic approach to integrate the concepts as well as ideas from different disciplines for sustainable management of water resource. A field scale study, brings first insights in order to develop a detailed understanding the manifold processes of the water cycle. However, the political decisions were made at regional level and at national level, thus it is crucial to reasonably upscale field scale studies for regional or national level. Hydrological models are generally used for the purpose but it is very often suffer problems of data scarcity or lack of quality input data. Remote sensing technologies would then it can be a promising tool to integrate with the models for getting continuous input data in the data scarce regions. The launch of several Earth Observations (EO) sensors from advanced satellites provides world-wide continuous excellent measurements on various hydrological components which are the essential input data for hydrological modeling. The data gaps are due to lack of on-the-ground monitoring of the water resources around Kumar *et al.* J. Andaman Sci. Assoc. 20 (1):2015 4 the world are now available using the satellite acquisition. Thus, the satellite products as well as sophisticated computational techniques for the excellent management of water will be playing an important role in present and future of water resources. The satellite remote sensing for hydrological applications includes, it may not limited to rainfall Tropical Rainfall Measuring Mission (TRMM) and (Global Precipitation Measurements (GPM). Soil moisture (Soil Moisture Active Passive (SMAP) and Soil Moisture Ocean Salinity (SMOS); Mapping Evapotranspiration with Internalized Calibration (METRIC), Actual Evapotranspiration (Surface Energy Balance System); and Surface Energy Balance Algorithm for Land (SEBAL); Groundwater level monitoring by Gravity Recovery and Climate Experiment (GRACE) (Bastiaanssen *et al*., 1998; Liu, 2012; Sun, 2013) [9, 58, 103]. Using satellite data and GIS, water bodies like rivers, lakes, dams and reservoirs which can be mapped in 3D. The spatial water availability maps can be generated. The concerned authorities can use the information for identifying the sites or regions that is needed for effective protection and management and decisions are made regarding the sustainable management of the water resources in the identified regions.

b) Water quality monitoring

Water quality should be reguraly monitorized in order to manage and improve the quality for human consumption purpose. In- situ measurements as well as laboratory analysis of the water samples are currently used to evaluate the water quality. Though such measurements are very accurate for a point in time and space, they do not give either of the spatial or the temporal view of water quality needed for accurate assessment or management of excellent water bodies. Furthermore these are very expensive as well as time consuming and which cannot satisfy the regional or national monitoring need. Remote sensing and GIS techniques can be used to monitor water quality parameters (i.e., suspended sediments (turbidity), chlorophyll, and temperature). Optical as well as thermal sensors on boats, aircraft, and satellites provide both the spatial as well as temporal information needed to monitor changes in the water quality parameters for excellent development of management practices in order to improve water quality. Remote sensing has been also used to measure the chlorophyll concentrations spatially and also temporally it is based on empirical relationships with the radiance or reflectance (Ritchie *et al*., 1994) [84]. The empirical relationships (algorithms) between concentration of suspended sediments with radiance or reflectance for a specific date as well as site were developed to predict the water quality for several years together (Ritchie and Cooper, 1991) [83].

c) Agriculture

An increased emphasis on the potential utility of using platforms of GIS to obtain real-time assessments of the agricultural landscape. Precision agriculture is a production system which promotes variable management practices within a field, according to the site conditions. This system is always based on new tools and sources of information which is provided by modern technologies like geographic information systems (GIS), GPS, and yield monitoring devices, soil as well as plant and pest sensors, remote sensing, and the variable-rate technologies for the applicators of inputs. Satellite remote sensing, in conjunction with the GIS is widely applied and been recognized as a powerful and effective tool in detecting the land use and also land cover changes. This provides an cost-effective multi-spectral and multi-temporal data, and it turns them into the information valuable for understanding and monitoring the land development patterns. GIS technology provides a flexible environment for storing, analyzing, and displays digital data necessary for change detection and also database development. Satellite imagery is used to monitor discrete land cover types by spectral classification or to estimate biophysical characteristics of land surfaces via., linear relationships with the spectral reflectances or indices. In Andaman Island, GIS is used to identify and map rice-growing areas and assessment of soil constraints.

d) Soil science

In nature soil properties are spatially variable, therefore it can be estimated as a continuous variable rather than point values to have higher accuracy as well as wide applications (Burrough 1993) [17].

Further, this ancient methodology of soil analysis and interpretation is extremely heavy, time-consuming, and thus becoming expensive So, kriging and its variants has become widely recognized as an important spatial interpolation technique in land resource inventories. In this context, with the advancement of the geographical information system, the predictive soil-mapping techniques is developed. The in -situ point measurements of quality of soil will be made a regression analysis with an exhaustive satellite-derived indices and the correlation is upscale to the larger areas spatially. The spatial maps are also an ideal input for the spatially distributed models. Gopal Krishan *et al*., (2009) [38] suggested that vegetation cover, slope and erosion status derived from remote sensing data in order to delineate 4major land degradation categories *viz*., undegraded, moderately degraded, degraded and severely degraded. Similarly, GIS is successfully used for natural resource mapping and also soil taxonomic study by Velmurugan and Carlos, (2009) [109].

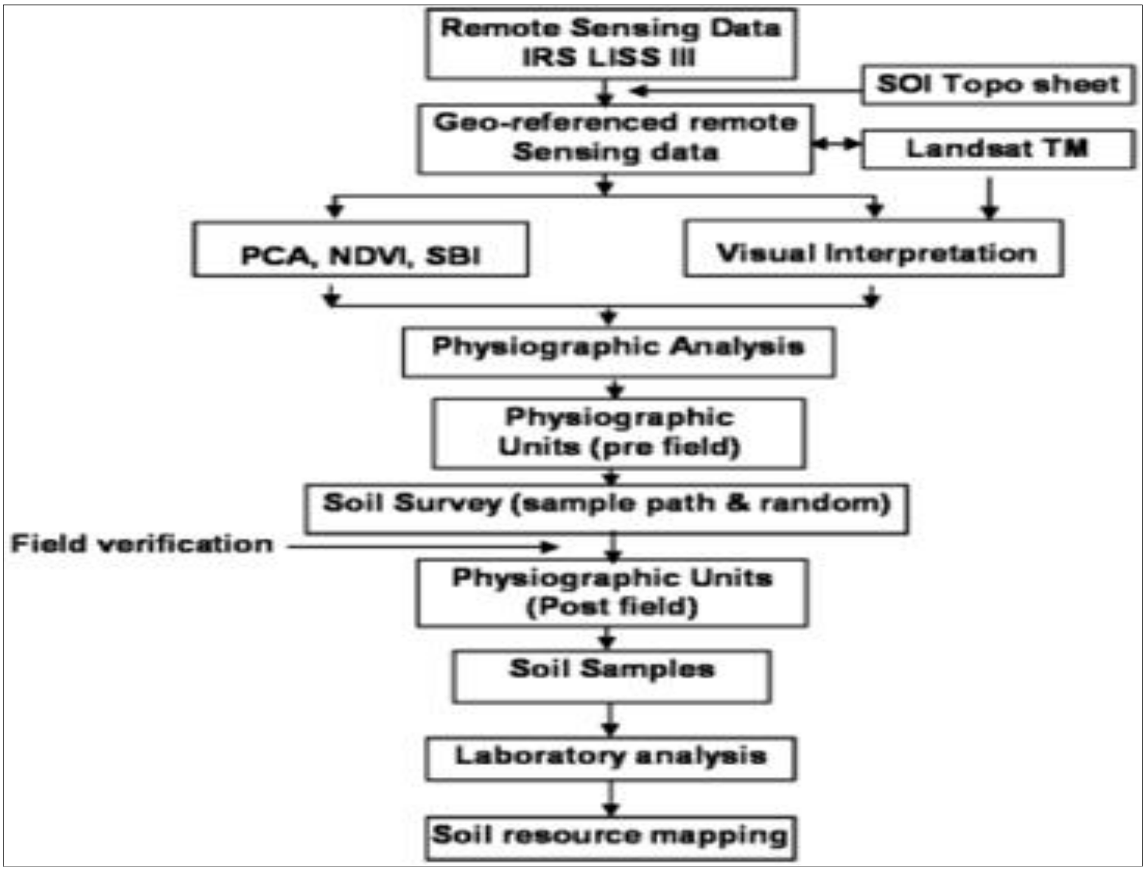

Fig 1: Procedure for land resource mapping

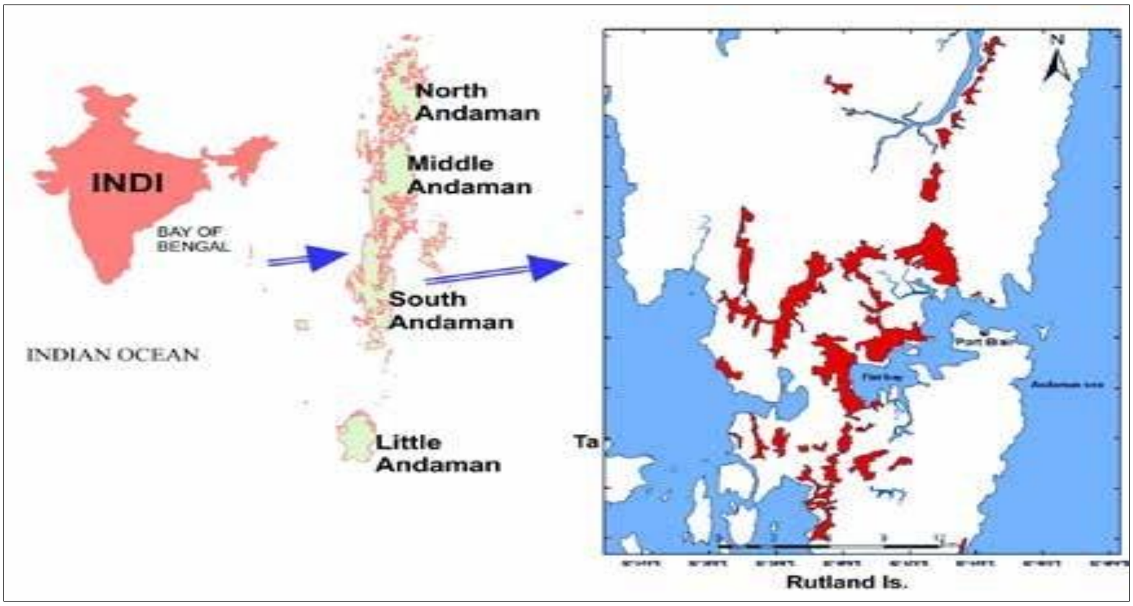

Fig 2: Mapping of rice growing areas of South Andaman

e) Crop-irrigation demand monitoring

Agriculture is the major consumer of water, utilizing > 70% of the global fresh water. Therefore, the role of irrigation water plays an significant part in increasing the land productivity. Land surface evapotranspiration (ET) is one of the major components of the water balance that is responsible for water loss (Michailidis *et al*., 2009) [67] and this is the prime interest for environmental applications, such as optimizing irrigation water use, performance of irrigation system, crop water deficit, etc. Also, poor irrigation timing along with insufficient applications of water are universal factors that limit agriculture production in many arid and semi-arid agricultural regions. In the context of these problems, GIS has been emerged as an effective tool to monitor irrigated lands over a variety of climatic conditions and locations over the last few decades. This involves in determining when and how much to irrigate by monitoring the plant water status, by measuring rates of evapo-transpiration and also by estimating crop coefficients. The effective usage of surface water and regular monitoring of consumptive use of water using GIS and RS techniques is a topic of great interest for irrigation water policy makers.

f) Crop modelling

It is possible to combine crop models with remote sensing data in such a way to evaluate yield variables from remote sensed data for exact each time step in the model simulations, therefore the use of remote sensing allows us to fill the missing model parameters during the recalibration on the field scale (Batchelor *et al.*, 2002) [10]. In addition to getting data from crop models in field scale-remote sense it allows transferring the results from the field scale to the regional scale (Priya and Shibasaki, 2001) [77]. There are many ways to use remote sensing data with crop models (Wiegand *et al.*, 1986 and Dele´colle *et al.*, 1992) [110]. 1 way is to estimate LAI (leaf area index) values by remote sensing for calibrating into the crop models. Another way is early estimates of the final yield but this method also needs many remote sensing data during the growing season in order to use in crop models. Baret *et al*., (2006) has combined remote sensing observations with crop models for providing the stress quantification through assimilation approaches. Crop and soil models with GIS is used to detect methane emission from the crop fields (Matthews *et al*., (2000) [66] similarly it is used for estimating global food production and also impacts of global warming using GIS and crop model.

g) Forest management and wildlife habitat analysis

Forest is an vital organ of our ecosystem; its impact human lives in several ways, despite of having huge importance that the world forest is been declining at an timely alarming rate. Being a renewable resource, forest cover can be regenerated through the process of sustainable management. Hence, using GIS techniques, a forest manager will be able to generate information regarding forest cover; types of forest which are present within an area of interest, human encroachment extent into forest land/protected areas, the encroachment of desert like conditions etc., This information is very crucial for the development of the forest management plans and also in the process of decision making to ensure that effective policies should be put in place to control and also to govern the manner in which forest resources can be utilized.

h) Application in natural disaster management

Multi-temporal spatial extensive data is required for management of natural disasters such as earthquakes, flooding, volcanic eruptions and landslides. So in such an context, satellite remote sensing is an ideal tool which offers information over large areas and at very short time intervals, which can be utilized in various phases of the natural disaster management, such as preparedness, prevention, reconstruction, relief, early warning and monitoring. Along with RS, GIS techniques are required to handle very huge spatial data sets, therefore gaining importance in disaster management (Van Westen, 2000) [108].

Conclusion

With the rising pressure on natural resources due to the growing human population day by day, Geographic Information System is used to manage these precious limited resources in an effective as well as in an efficient manner. Geospatial information is very useful in the identification as well as analysis of factors that affect the utilization of these natural resources. Hence, having detailed understanding of these factors, the sound decisions can be arrived at that will ensure the sustainable usage of natural resources in order to meet the needs of the current as well as future generation

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