Sustainable Development in Mountain Ecosystem at Watershed Level - A Geospatial Approach

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Abstract

Humans have been exploiting the natural resources from the day life originated on earth. They have always overburdened the nature in order to fulfill their ever-increasing demands. All such activities greatly affect the regeneration capacity of any natural system. For sustainable development of any natural system the regeneration of basic natural resources like land, water and vegetation is very important because with the regenerating resource base there is greater scope for identifying alternative and sustainable livelihoods. The natural resources in a fragile mountain ecosystem are under severe strain for the past few decades due to their over exploitation for meeting the ever increasing demands for livelihood. Sustainable management of these natural resources is the biggest challenge today in these ecosystems and is essential in providing food and feed for human and livestock and environmental security. This can best be achieved by employing the concept of watershed management that aims at integrated use of all the available resources including human and livestock on a sustained basis. For sustainable development of an area identification of the most frequent hazards taking place over past few years in the area may play a vital role in assigning priorities and the creation of database of mountain at watershed level is therefore essential so that proper planning strategies can be made. Remote sensing integrated with geospatial techniques provide a powerful tool for the mapping, assessing, evaluating and analyzing the present, past and future status of the natural resources of a watershed. The present paper explains a geospatial approach for sustainable development of Garhwal Himalayas at watershed level. The present study clearly shows that in Huinyal watershed, the resource utilization and distribution pattern are responsible for the degradation of the natural resources available in the area. The identification of critical and vulnerable areas using geospatial techniques is strong input for the policy planning and proper management aimed at sustainable development of a watershed. The geospatial analysis

shows that 25% of the area in the Huinyal watershed is under high-risk zone which needs special attention.

1. Introduction

So long as the earth preserves her forests and wildlife, man's progeny will continue to exist. This is the Hindu approach towards conservation of ecology (Upanishads). Human beings use natural resources available on earth such as land, water, vegetation, minerals and many others to make a living and to shape their culture. In doing so they change the earth surface enormously. Proper management of available natural resources is vital in today's world where overexploitation by the growing population is taking place at a very fast pace. This overexploitation of natural resources is responsible for all kinds of pollution viz. air, water as well as declining biodiversity and falling water tables. It is quite shocking to know that about 50% of the world's forest has shrunk due to logging. About 65% of the cropped land experienced significant impact on the soil quality (World Resources, 2000-2001).

India being one of the most densely populated nations of the world suffers from a variety of environmental problems. Therefore, it requires a multidisciplinary approach involving inputs from various fields for proper risk assessment to check the problem of environmental degradation at its earliest.

2. Sustainable Development

Development that meets the need of the present without ignoring the needs and options of the future is said to be sustainable. It involves practices of using the available natural resources, keeping in mind the regeneration capacity of that ecosystem. That is to say that their should be a balance between the two processes for minimizing environmental degradation. The World Commission on Environment & Development (WCED, 1987) defined sustainable development as that which meets the needs of the present without compromising the ability of the future generations to meet their own needs. Environmental protection is one of the three components of 2002 Johannesburg declaration. It said that the three components of sustainable development, economic development, social development and environmental protection are interdependent and mutually reinforcing pillars. The declaration emphasizes environmental protection as the only way to have long-term economic progress. Managing the natural resources available is the prime objective and an essential requirement for, sustainable development. Since the natural resources are vulnerable, vulnerability assessment should be considered as part of any developmental process. Initial initiatives should be taken at a local level and then replicated to national level, because sustainable development can only result through participatory planning, considering the role of individual stakeholders as well.

3. Vulnerability Assessment- an indicator for sustainable development

The problem of environmental degradation is more severe in hilly areas where people are poor with small land holdings and poor productivity, where poor accessibility forces them to utilize whatever is easily available. The natural resources in a fragile mountain ecosystem are under severe strain for the past few decades due to their over exploitation for meeting the ever increasing demands for livelihood. In recent years, the growing concern over the environmental degradation of mountain ecosystems has gradually placed mountain issues in environmental and political agenda (Heywood *et al*., 1994). An example of this growing interest was the formulation of a Mountain Agenda for the UN in 1992. Over exploitation of watershed resources by growing population has resulted in its degradation in most parts of the world (FAO, 1985). Land, water and vegetation are the most vital resources for the survival of man and are needed to be managed efficiently. Sustainable management of these natural resources is the biggest challenge today in these ecosystems and is essential in providing food and feed for human and livestock and environmental security. This can best be achieved by employing the concept of watershed management which aims at integrated use of all the available resources including human and livestock on a sustained basis. For sustainable development of an area identification of the most frequent hazards taking place over past few years in the area may play a vital role in assigning priorities. The assessment of the natural resources, infrastructure facilities and anthropogenic pressures are the essential inputs for the vulnerability assessment in a watershed. In turn the vulnerability assessment can be effectively utilized in the planning for the sustainable development of the watershed and conserving its natural resources. The creation of database of mountain at watershed level is therefore essential so that proper planning strategies can be made that would contribute to the sustainable development of the area.

4. Role of Geo-spatial Technology

Due to high relief and terrain complexity, mountainous areas require a 3-dimensional representation for spatial modeling. Geospatial tools constitute a versatile and varied range of techniques whose full potential is yet to be realized especially if we talk about disasters in Indian context. Several organizations are developing regional and national scale monitoring programs in which GIS plays a central role. Remote sensing integrated with geospatial techniques provide a powerful tool for the mapping, assessing, evaluating and analyzing the present, past and future status of the natural resources of a watershed. Remotely sensed data may not be sufficient alone to act, as indicators for sustainability studies but it can be helpful when integrated with socio- economic dataset.

5. Huinyal Watershed- A Case Study

Huinyal Watershed constitutes an important watershed of Huinyal basin and Garhwal Himalayan range and forms a part of Tehri district. It lies between 30^0 05' N to 30^0 25'N and 78^0 15' E to 78^0

30'E. The average altitude varies from 600 to 2800 meters (approximately) above sea level. The watershed under study covers an area of approximately 260 Sq.kms approximately.
(Figure 1)

Physiography

The watershed falls under the middle Himalaya, composed of weak sedimentary and metamorphic formation. The slope varies from 3-5% to 50%. There are several streams negotiating through numerous scarpments, making the area topographically more complex. High hills in the north are imposing structures at about 2800 metres falling steadily to 600 metres msl at the southernmost tip of the watershed.

Drainage

The large part of the Garhwal is drained by major system of the Ganga River. Huinyal River is also part of the Bhagirathi system, which ultimately joins the Alaknanda at Deoprayag to form the main channel of the Ganga river.

Climate

Wide variations in the climatic conditions are found over different parts of Garhwal. The watershed enjoys a humid type of sub-tropical to temperate climate often subjected to extremes of weather conditions and experiences moderate to heavy rainfall during monsoon and winter period. Seasonal snowfall is common at higher altitute during winter.

Geology

The Himalayan Mountain chain, of which Garhwal is a part, is amongst the youngest mountains in the world. Geologically the area is unique in a sense that five different age groups of rocks were identified in the study area viz. Quartzite, shale, limestone, slate, and phyllite. All the rock types found in the area are structurally controlled and exposed in the northern slope. The northern slope is mostly weathered and covered by thick vegetation as compared to the southern slope. The southern slope exposes mostly quartzite, phyllite and states of Nagthat and Chandpur.

Soils

The nature and type of soil found in watershed varies from place to place. These are brown to grayish brown and dark gray in colour with moderate to high concentration of pebbles. Therefore, it has an important bearing on the life and well being of the people of this region.

Vegetation

The watershed is endowed with dense vegetation. The terrain complexity and altitudinal variability supports various temperate, subtropical and tropical species. Chir pine (*Pinus roxburghii*) is a dominant species in subtropical region largely confined to lower reaches of the watershed and south facing slopes. Oak (*Quercus leucotrichophura*) is another valuable species dominating in the cooler region. The notable presence are ***Ficus palmeta, Salix wallichiana, Acer ablongam, Rhododendron arboreum, Barberi asiatica, Ustica parviflora***. Sal (***Shorea robusta***) has a characteristic presence in the lower hills adjacent to the valley area. Deodar (*Cedrus deodara*) and Blue pine (***Cedrus wallichiana***) and their associated species enrich the higher altitude areas.

Socio-economic Condition

The socio-economic condition of the area is not so good and people are mostly dependent on agriculture. Being a hilly terrain the villages are scattered all around the area in small clusters. The villages lack basic infrastructure facilities and due to this the overall development of the area is hindered. The houses are scattered due to the hilly terrain and without a proper connectivity. A significant number of the villages are inaccessible due to poor connectivity of the roads.

Material & Methods

Data used

- Satellite Data of Landsat TM , April 2001
- Topographic sheets number 53J/7 and 53J/8
- Field compass
- Field Performa/Questionnaires
- Population census 1991, from the respective block offices
- Forest Working Plan Report
- Relevant literatures/reports

Software

- ERDAS IMAGINE 8.5
- ARC VIEW 3.2a

Preparation of base maps

Base maps including road, settlement, village, drainage, contour, and watershed boundary were prepared with the help of Survey of India toposheets 53J/7 and 53J/8.Data inputting was done through head-on digitizing in ArcView 3.2a with UTM projection. With the help of digitized contours, DEM was generated. Geology maps were delineated using the reference map compiled by J. Rupke and R.P. Sharma based on photo geological & field studies. Geomorphology and Landslide maps were generated from LANDSAT image.

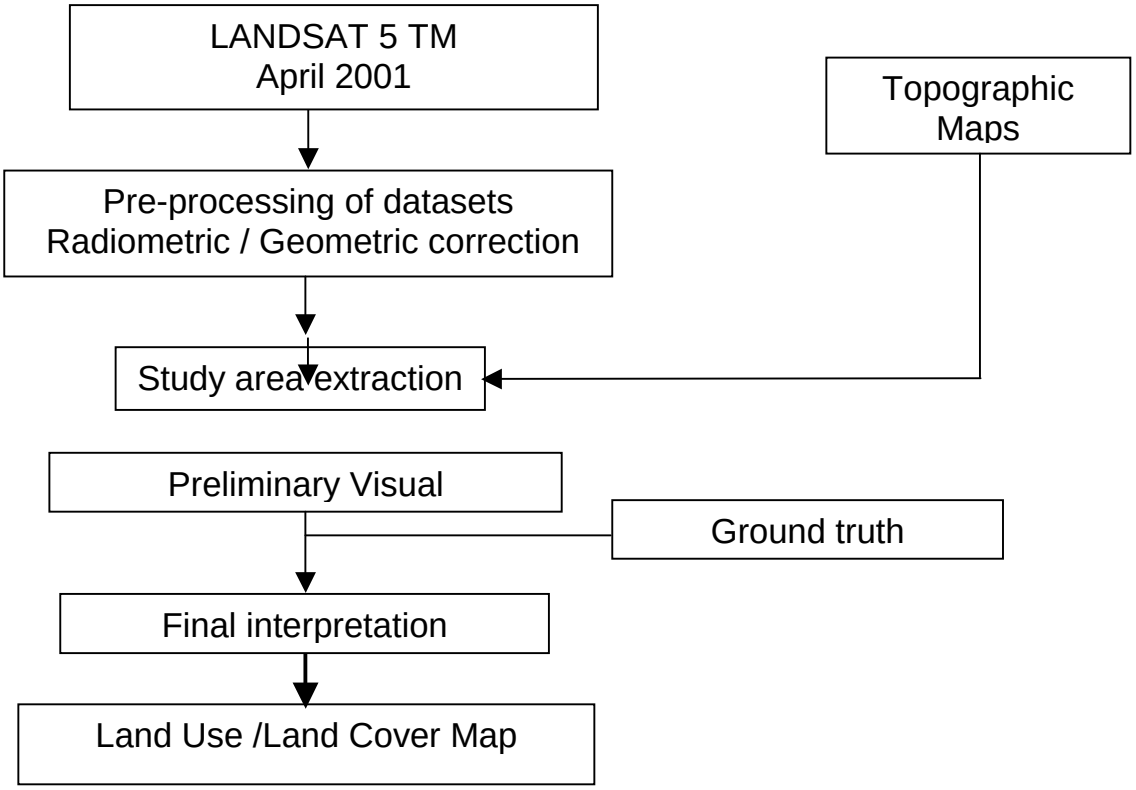

Figure 2 -Approach for Land Use/ Land Cover map

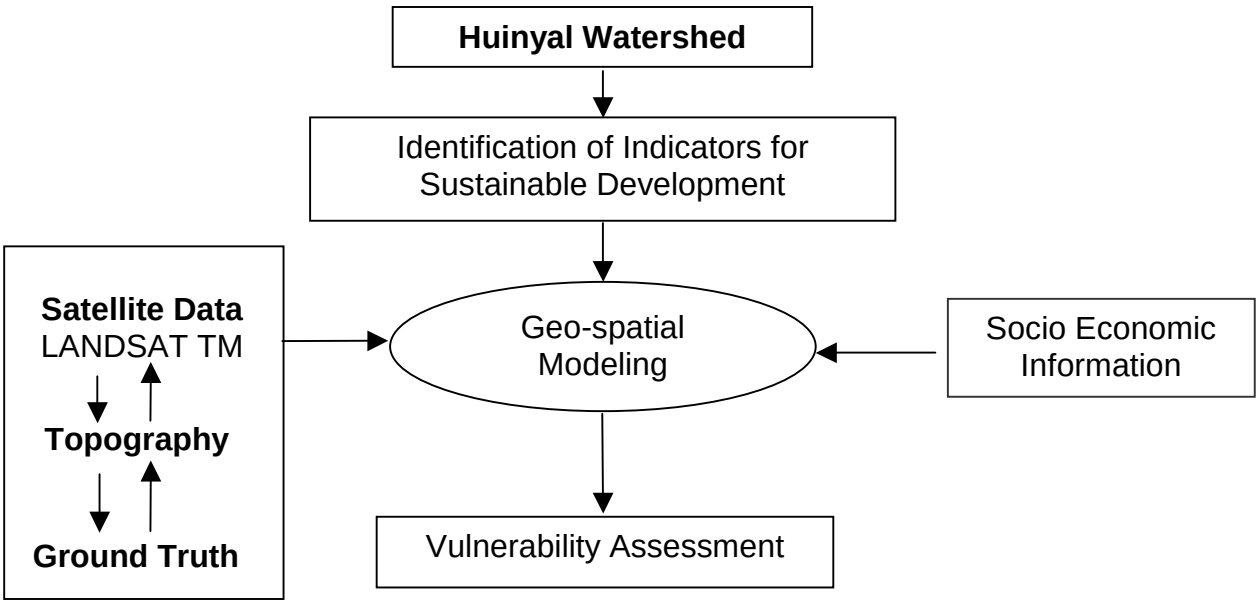

Figure 3 - Approach for Vulnerability Assessment

Questionnaires and field Performa

Field data being an important part of this study was collected by filling up the Performa specially designed for the required purpose. This Performa was carried to the field and was filled in every village visited. Before leaving for the fieldwork, detailed questionnaire was prepared considering the information related to resource utilization pattern, critical facilities, socio-economic status of the local villagers, total population, cattle population, quality and quantity of resources available, the distance to collect fuel-wood and fodder, etc. Field Performa was also prepared for making record of ground truth collection, which helps in post-field visual interpretation. The image elements were correlated with the ground truth realities and the interpretation key was developed. The tonal variation representing the different classes was marked on the hard copy image. The entries were made in the field Performa at each of the village visited.

Visual interpretation

In hilly areas, especially in Garhwal Himalaya, due to the terrain complexity, the spectral signature is influenced by the slope, aspect and altitude. The same objects might show different reflectance or the different objects might have same reflectance. In such a situation, intensive ground truthing is very important and based on that, on-screen visual interpretation was done.

Results & Discussion

GEO-SPATIAL ANALYSIS

Land Use/Land Cover Mapping: Landsat data of April 2001 was used as the source for the land use/land cover mapping. The interpretation key formulated during fieldwork has been used. The shadowed areas were put to corresponding classes on the basis of ground knowledge.

Resource Mapping: After the land use/ land cover is finalized, the classes were regrouped into various resources available. Following five classes are identified viz. agriculture, Plantation, forest, scrub/grassland and riverbed. Forest contains oak (dense and looped/open), deodar, pine (dense and open) and open mixed forest. Scrub and grassland include scrub/lowland grassland/pasture and highland grassland. Resource map is prepared as an input for resource distribution and resource utilization pattern.

Resource Utilization pattern: The present shows that resource utilization pattern in most of the villages is almost same. Most of the villages are highly dependent on forests for their daily requirements of fodder and fuel, including other secondary forest products like resins etc. The overall socio-economic condition of the villagers is heavily dependent on the nearby forest.

Infrastructure availability: Most of the villages have a poor accessibility and as a result they lack basic infrastructure like roads, schools, especially drinking water. The area is devoid of basic medical facilities almost of the villages lack a proper Dispensary.

Pressure on Forests: The high dependency of local villagers on the nearby forests for their daily requirements of fuel and fodder had left these villages prone to high anthropogenic pressure. Among the interviewed villagers, more than 80% of them agreed to have direct dependency on forest. All these practices emphasize the high risk of natural resource degradation, especially the key species of oak. These areas need special attention because activities like JFM is non-existent and people need motivation and public awareness is highly recommended in these areas to conserve the available resources in the whole watershed area.

Landslide hazard mapping: Landslide identification, which is a crucial parameter for any regional landslide hazard assessment, can be very well done particularly by visual interpretation. Coupled with satellite images, GIS is an excellent tool to display the spatial distribution of landslides along with their attributes. However, the landslide map so prepared should be validated with ground checks.

Forest risk zonation: Identification of fire risk zones was done taking into account various factors that are responsible for frequent forest fires in the watershed area due to which there is loss of Human life and property every year. The analysis made it clear that in almost all the cases human intervention

was the primary cause. Because the high-risk areas were all identified near the settlements or the areas where people frequently visit for their fodder or fuel wood requirements.

Critical area mapping: The purpose of mapping the critical area is to locate the areas, which are facing high pressure on natural resources, which are degrading at a faster rate. Critical areas were mapped by taking into consideration four important inputs viz., resource requirement index, resource importance index, physical accessibility index and also the disturbance index.

Vulnerability Map: By integrating the Critical area map, Landslide hazard zonation map, and Fire risk zonation map, the final output was generated giving proper weightages to each map. The highest weightage was given to Landslide hazard zonation map, then Critical area map and lowest weightage to Fire risk zonation map. In this way the vulnerability of the watershed was analyzed.

Conclusion

The present study has demonstrated that the area is vulnerable to various kinds of hazards. For sustainable development of the area we need to identify the hazards and make proper strategies so that there is a balance between development and destruction. Sustainable management of natural resources of land water and vegetation is essential in providing food and feed for human and livestock and also for environmental security. This type of study has significance in terms of natural resource management on a sustained basis. This study also emphasizes the role of Remote Sensing and GIS in sustainability studies. Geo-spatial technology is immensely helpful in the assessment of natural resources in the watershed and their effective management. For example, the digital terrain model (DTM) created in the GIS environment can be used for the identification of potential areas for the construction of water harvesting structures. The present study clearly shows that in Huinyal watershed the resource utilization and distribution pattern are responsible to the degradation of the natural resources available in the area. The vulnerability assessment is important because it is the indicator of the sustainability of the ecosystem and the socio economic status of a watershed. The identification of critical and vulnerable areas using geo-spatial techniques is strong inputs for the policy planning and proper management aimed at sustainable development of a watershed. The actual vulnerable area in the present study has been estimated to be 25%. Local villagers can play a very important role in preventing the degradation of their immediate environment. There is a need to make people aware of their negligence towards forest fires. They should be made aware of the deadly consequences of degradation of the forests. The deforestation of slopes impairs the water regime in the surface layers and thus contributes in slope failure and landslides

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