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GIS: an effective tool to develop resilience to climate change

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ABSTRACT

Average temperature of our planet has risen by 1.4°F over the past century. This rise in global temperatures have been accompanied by changes in weather and climate in the form of changes in rainfall, floods, droughts, or intense rain, as well as more frequent and severe heat waves. The greenhouse gases are essential for living but its content in atmosphere is being altered by human activities which results in Global Warming. Researchers, approach creators, designers, engineers, and numerous others have utilized Geographic Information System (GIS) innovation to better comprehend this intricate circumstance. Various GIS applications are being adopted for floodplain mapping, warning response and preparedness, damage computations and ecosystem restoration, prediction of time based loss of glacial covers and resultant rise in sea level. Satellite remote sensing used with GIS has provided major advances in understanding the climate system and its changes, by quantifying processes and spatio-temporal states of the atmosphere, land and oceans. The paper shall focus on outlining the various GIS applications which can be put to various uses. Evaluation of large data at global and regional levels through GIS can readily help the decision makers to visually understand the consequences of climate change and work towards developing a resilient system. The strategy involved in adaptation and resilience can prove to be essential in counteracting against climate change.

Keywords: Climate Change, GIS, Resilience, Mapping Vulnerability, Data Control

1. INTRODUCTION

Climate change can be defined as a long-term shift in weather conditions which can be recognise by changes in temperature, winds, precipitation, and other indicators. Climate change can involve both changes in average conditions as well as in, extreme events**.** The earth's climate depends on its long-terrm state and average temperature which is regulated by the balance between incoming and outgoing energy,to which, if there is any sustained change leads to climate change.

Earth's average temperature has risen by 1.4°F over the past century, and is projected to rise by a much faster rate. Small changes in the average temperature of the planet can leads to potentially dangerous shifts in climate and weather**.** Glaciers have shrunk, ice on rivers and lakes are breaking up earlier, plant and animal ranges have shifted and trees are flowering sooner are some of the evidences of the various effects triggered by global climate change.

Because there are so many impacts of climate change, scientists have broadly categorized them into three areas:-

I. ***Variable climate and weather extremes*****:** Emissions of heat-trapping gases from human activities causes our atmosphere to heat up. These heating further changes the way weather systems functions on our planet.
II. ***Altered ecosystems and habitats*****:** As climatic patterns rapidly shift, habitats on land and in the sea are changing, making them inhospitable for some species. In some cases, entire ecosystems are at risk of collapsing.
III. ***Risks to human health and society*****:** The imbalance caused in the human life is perhaps one of the biggest impacts. More extreme weather directly or indiretly increased pressure on health, infrastructure, and economy.

Since the abrupt climate change is the consequence of human choices, we need spatial modeling tools that represent the world as seem and modified by the human beings. This is where the role of geographic information science comes into play. In order to create such climate change models that include humans, we need geographic information system (GIS). Basically, GIS can be thought of as having triple roles in climate change studies that is measurement, modeling and visualization.

Measuring Climate Change

In this stage the process of data assimilation is done in order to measure the climate change. The data assimilation basically concerns collecting climate data for the derivation of baseline climatology and interpolation of climate data for obtaining comprehensive climate data sets. Digital Elevation Molels (DEM) can be used as an example for providing baseline climatology. The high resolution DTMs allow studying impacts of terrain on climate at micro scales. All database which are captured with satellites, airplanes or other flying platforms are orginally DEMs (like SRTM-Shuttle Radar Topography Mission or the ASTER GDEM- Advanced Spaceborne Thermal Emission and Reflection Radiometer)

Modelling of Climate Change

There are several methods that can be used in the assessment of climate change impacts, which include quantitative and predictive models, empirical studies, expert judgment, and experimentation. Quantitative models are those models which can be represented or expressed in quantitative approach with very precise results.

Visualization of Climate Change

The best way to stimulate climate change awareness in society is by visual imagery or animated video clips such as model-driven visualization of climate change. In this regard, geovisualization of landscapes which is a visual simulation or a landscape medelling, representing places of interest and on-ground conditions in 3D prespective. It plays a very important role as it is capable of showing past, present and future on the real scenerios. These are being used for visionings, education, research,, decision making and policy formulation upto a great extent.

Climate Change- Adaptation and Resilience

Scientists and policy makers recognize that both adaptation and resilience measures are required to reduce the impacts of climate changes. Adaptation means suspecting the adverse effects of climate change and taking sufficient steps to prevent or minimize the harm they can bring about. Examples of adaptation measures incorporate utilizing rare water assets more productively; adjusting building bye-laws to future atmosphere conditions and extreme weather events; building flood defenses; creating drought-tolerant crops; picking tree species and forestry practices less vulnerable to storms and fires; and putting land corridors to help species migrate.

Climate resilience can be characterized as the limit for a socio-natural framework to maintain function in the face of external stresses caused up by climate change and to adjust, redesign, and develop into a more desirable configuration that enhances the maintainability of the framework, abandoning it better arranged for future climate change impacts**.**

The global climate change has been attributed to two major factors: natural which includes climate and environmental variability, for example, in ocean currents, volcanic eruption, solar output, Earth's orbit around the Sun, etc and anthropogenic activities. In recent times the increase in anthropogenic pressure is leading to the emission of greenhouse gases (GHGs) which, in turn, are increasing the rate of global warming and therefore escalating the frequency and intensity of natural disasters like cyclone, flood, drought etc. Climate change can have adverse effects on humans, which can be observed in the form of increased regularity of natural disasters, reduced environmental and societal resilience, and thus increases vulnerability.

2. MAPPING VULNERABILITY

A vulnerability map gives the accurate area where people, the natural environment or property are at risk in view of a possible tragic circumstance that could bring about death, harm, pollution or other demolition. These maps are most often created with the assistance of GIS and digital land survey designed for utilization in the field. These can be used in various phases of disaster management such as Prevention, mitigation, preparedness, operations, relief, recovery and lessons-learned.

Planners and specialized experts can utilize these maps in the prevention stage to avoid high risk zones while developing areas for different infrastructure use. For example, Fire divisions can plan for rescue operations before any dangerous event could occur. The salvage groups may use these guide maps to make sense of where to respond first either to spare human lives or the environment or property. Various risk objects can be created on such maps; the mapmaker then allocates the precise directions for the article and gives them an ID-number and gathering them into classes with respective symbols. For Example:

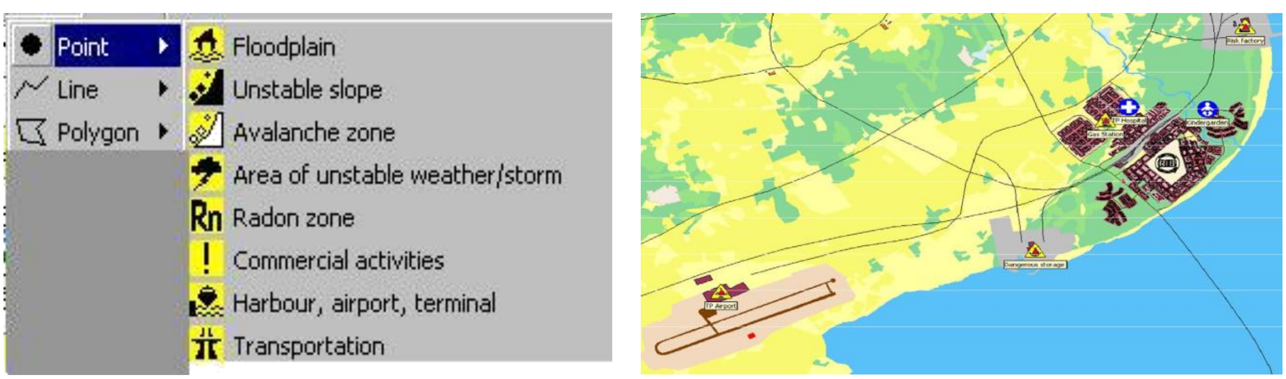


Figure Symbols to representing risk object classes. Risk objects are shown as yellow triangles. Threatened objects are blue circles

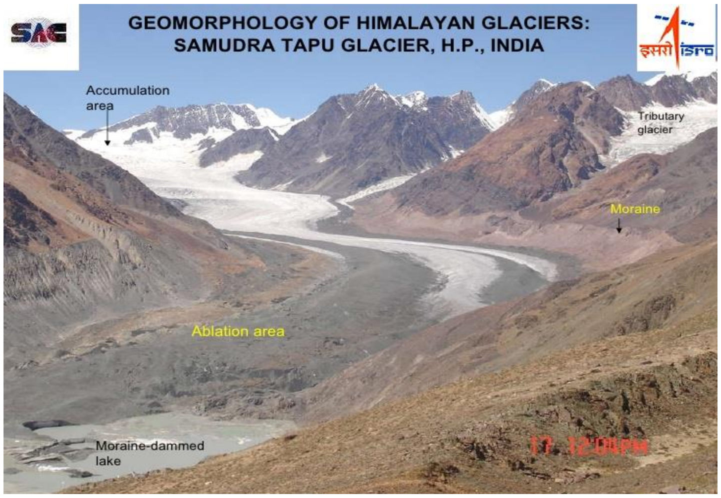
To utilize the vulnerability map in a helpful manner, assess the zone in meters or hectares that would be influenced by the specific risk and the number and kind of objects within the zone that need protection. Estimate the total number of buildings and population assosiated with it that need to be executed.

GIS In Action: Some Application

The advantage of spatial climate data sets is that they can be compared in a GIS with dissimilar data sourced from many sources. Hence, GIS has enabled the study of the environmental impact of the variation of climate for many applications at a variety of scales.

Glaciers

Glacierized territories right now cover around 10% of the world's territory and around 75% of the freshwater assets of the world.Since ice sheets reacts to local atmosphere, glacier monitoring gives vital data on atmosphere variability and change. The most ideal approach to infer environmental change from ice sheets is through observing mass balance. Changes in icy mass zone and terminus positions, which can be effortlessly, extrcated utilizing geoinformatics, given an idea of glacier reaction to environmental change. The checking of ice sheet is made conceivable through multi-temporal satellite imagery analysis. Recognizable proof of icy mass changes is conceivable only when ice sheet stock is accessible for correlation. In territories where important stock is not accessible, remote sensing turns out to be an exceptionally helping hand. For vast regions like the Himalayas, assessment of glacial cover is crucial in serving as a model for deriving baseline inventory. Satellite-derived glacier inventory also aids in building future monitoring strategies.



In the above image, Multi temporal IRS satellite pictures were utilized as confirmation of the retreat of Parbati glacier in the Himalayas. Snow line & future change in areal degree of glacier was assessed utilizing mass balance, response time and rate of melting at terminus and for lasting snow spread IRS 1D LISS III pictures were utilized.

Salient Features

Retreat of 1317 glaciers 11 basins proposes 16 % misfortune in zone from 1962. Mean of glacial degree lessened from 1.4 to 0.32 sq km. Number of glaciers expanded because of fracture yet extent is reduced. Snow line toward the end of summer transformed from 4900 m to 5300 m from 1970. Numerous icy masses are without accumulation area range and may encounter terminal retreat because of absence of formation of new glaciers. Large scale dissolving and retreat of regular snow was seen in basins like Ravi all through the winter.

Future atmosphere situations may be taken up from GIS-based displaying, for example, determination of surface vitality equalizations of melting glaciers. GPS information, utilized alongside ASTER (Advanced Space-borne Thermal Emission and Reflection Radiometer) DEMs (Digital Elevation Models) and aerial photos, has been observed to be exceedingly viable in checking glacier height changes and its diminishing.

Flood Mapping

GIS can be used to make, enlarge and print a topographical map of the area prone to flooding in an effective and a precise way. Digitizing floods in map using GIS may not be a true representation of real flood behaviour but rather they have turned out to be a useful guide during the planning phase when utilized with other available flood infromation. Using the tools available in GIS, flood extents at certain intervals are overlaid on a 3 dimensional Digital Elevation Model (DEM) and used to create an animation of potential flood immersion. Anticipating a map, with a rich arrangement of basic information, onto a screen and being able to control different parts of the map during flood planning has enormously enhanced correspondence between crisis managers and has prompted a more definite understanding of the issues to be tended to.

There are numerous softwares involved in GIS like ARC-GIS, QUANTUM-GIS, MAP INFO, etc. The model is firstly processed in these, then river and reservoir are digitized.

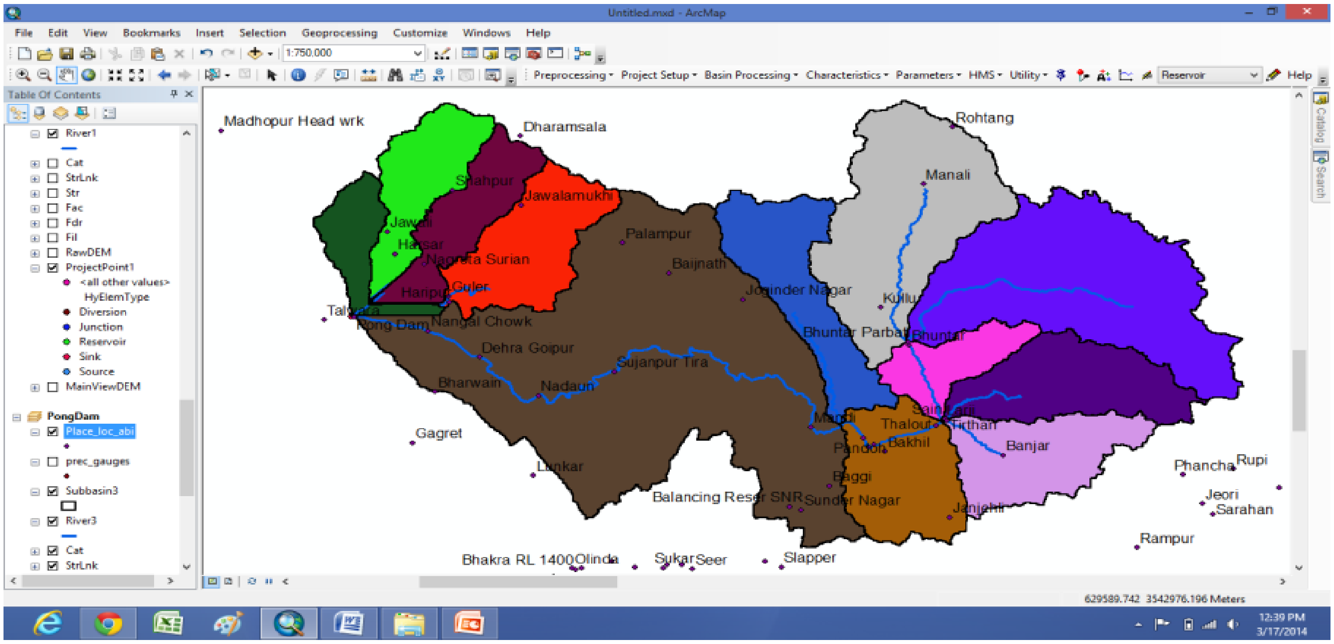


Figure Processing a state map for flood mapping

The river modeling software are further linked to work in coordination with GIS. The software used here is HEC-HMS which converts rainfall (precipitation) into runoff (river flow). The real time data of previous years are added in the software and it is calibrated. Rainfall hydrographs are generated as resultant. After it has been calibrated, real time values can be incorporated in the process by meteorological data to give present and future conditions of rainfall. HEC RAS is rainfall simulation software and contains several hydraulic design features that can be invoked once the basic water surface profiles are computed The river banks are digitized and cross-sections are created. An artificial reservoir is created to counter the flood level. Further, the precipitation data is exported to HEC RAS.

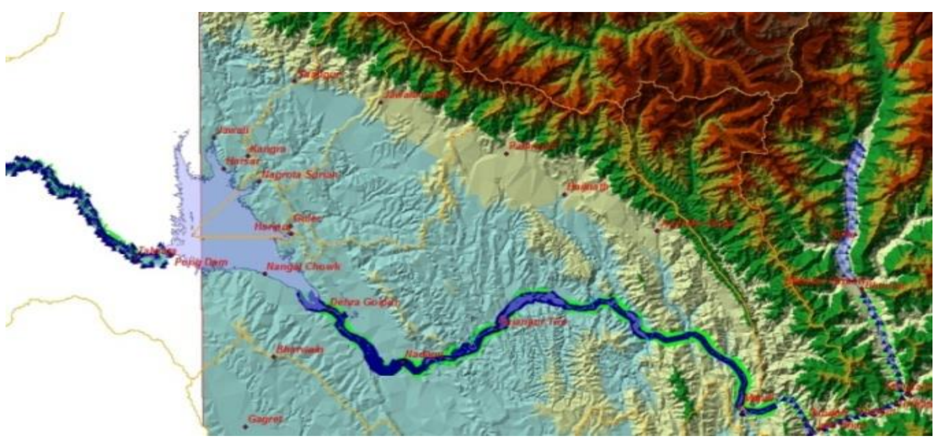


Figure Digitizing river, making cross-sections and creating an artificial resevoir

In every profile we have to run animation which will show water levels at various locations. From that we can conclude if there is any flood possibility or not.

Forestry

The forests affects climate because of its capability to absorb solar radiation, and maintain water and nutrients cycles, alongside surface harshness. In forestry, deforestation and environmental change are interrelated. One of the most widely recognized global warming mitigation strategies includes afforestation programs. GIS can be utilized to create atmosphere zone to choose site suitability for afforestation. GIS has been broadly used to model and monitor the spread of forest fire by associating climate change with remote sensing imagery.

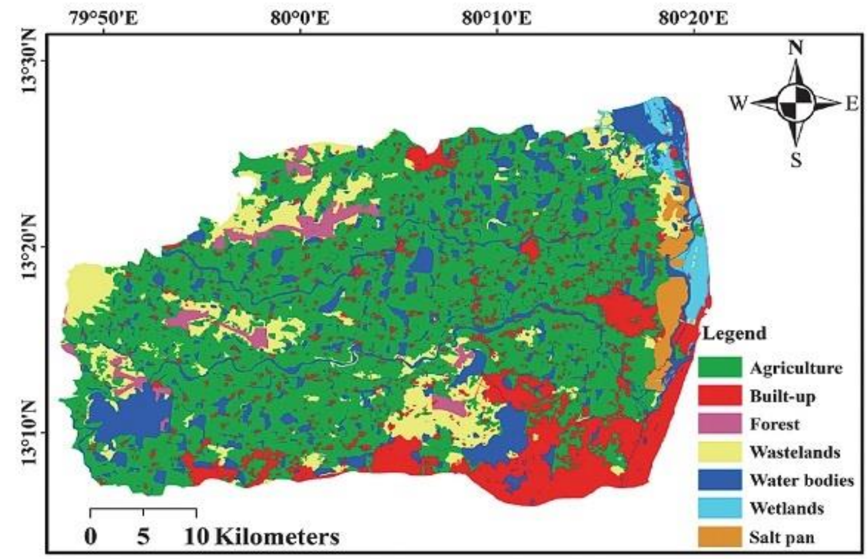


Figure Map showing the different distribution

Human Health

Health is defined by the constitution of the World Health Organization as "a state of complete physical, mental and social well-being, and not merely the absence of disaster or infirmity. Health problems that have special connection to the locality can be effectively analysed using mapping and modelling techniques. This involves mapping of current boundaries of a health problem. Vector-borne diseases have a geographical control and also restricted by climate and land characteristics. These can be modelled effectively using remotely sensed climate data sets with GIS and GPS inputs.

Typical example of such applications:-

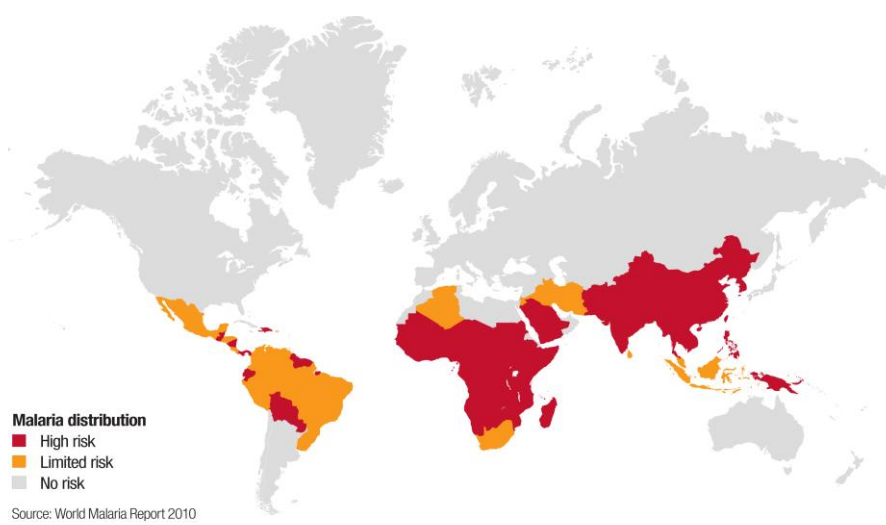


Figure Showing the distribution of Malaria Diseases

3. CONCLUSION

Climate change is influencing our future. Considering the multitude of issues surrounding climate change science from its root causes to resultant impacts, geography is clearly an elemental factor, affecting and being affected by every aspect of climate change, be it on a local, regional of at a global level. Hence Geoinformatics appears to be the only solution as it holds the key to bring all the actors from past, present and expected future on a common ground. Be it the climate change studies, disaster management, or providing resilience to any damage. The holistic approach of GIS will proves to be an important asset to the problem in the long term perspective. Continued monitoring with GIS using data from the satellite earth observation will ultimately confirm perceptions in climate change research. Several applications have been discussed in the paper so that it can be used to understand the potential of Geographical Information System.

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