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Estimation of Effective Impervious Surface Area of Cochin using Satellite Images

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Abstract

Urbanization refers to the process in which an increasing proportion of a population lives in cities and suburbs. Urbanization fuels the alteration of the Land use/Land cover pattern of the region including increase in built-up area, leading to imperviousness of the ground surface. With increasing urbanization and population pressures; the impervious areas in the cities are increasing fast. An impervious surface refers to an anthropogenic ally modified surface that prevents water from infiltrating into the soil. Surface imperviousness mapping is important for the studies related to water cycling, water quality, soil erosion, flood water drainage, non-point source pollution, urban heat island effect and urban hydrology. The present study estimates the Total Impervious Area (TIA) of the city of Kochi using high resolution satellite image (LISS IV, 5m. resolution). Additionally the study maps the Effective Impervious Area (EIA) by coupling the capabilities of GIS and Remote Sensing. Land use/Land cover map of the study area was prepared from the LISS IV image acquired for the year 2012. The classes were merged to prepare a map showing pervious and impervious area. Supervised Maximum Likelihood Classification (Supervised MLC),which is a simple but accurate method for image classification, is used in calculating TIA and an overall classification accuracy of 86.33% was obtained. Water bodies are 100% pervious, whereas urban built up area are 100% impervious. Further based on percentage of imperviousness, the Total Impervious Area is categorized into various classes.

Keywords: Urbanization, Impervious surface, Remote Sensing and GIS.

Introduction

With increasing urbanization and pressure of population, the impervious areas in the cities are increasing. An impervious surface refers to an anthropogenic surface modification that prevents water from infiltrating into the soil[1]. Impervious surfaces are defined in watershed management as surfaces that prohibit the movement of water from the land surface into the underlying soil. Buildings and paved surfaces (e.g., asphalt, concrete), roads, parking lots etc. are considered impervious covers. Natural conditions such as bedrock close to the surface, very dense soil layers such as hard pan that restrict water movement etc. are not considered "impervious cover". Major driving force towards the increase in impervious cover is the Land use/ Land cover changes occurred as a result of urbanization[2]. As the area of impervious surface increases, the time of concentration and runoff travel time are decreased and the degree of hydraulic connection is increased[3].

In watershed management, the term "impervious cover" refers to the conditions that are created by human action. Natural conditions are addressed in other ways, such as through theassessment of ground water recharge, soil and rock analysis etc. One major benefit to the focus on humanstructures is that buildings and pavements are fairly easy to identify using satellite imagery/aerial photographs while subsurface or natural conditions are not obvious. The common types of impervious surfaces can be categorized into two primary categories: the rooftops and the transport system (roads, sidewalks, and parking lots)[4]. The environmental impacts of impervious surfaces have been discussed in many previous studies[4-6] which include impacts on water cycling, water quality and erosion of construction sites, non-point source pollution, stream health, and the urban heat island effect. Satellite remote sensing images integrated with GIS have massively been applied for studying various spatial aspects due to their relatively low cost and suitability for large area mapping which can be used for impervious surface identification and estimation .[7-10]

Various GIS methods had been applied successfully for impervious surface extraction in previous research, including spectral mixture analysis, regression tree, artificial neural network, multiple regression and sub-pixel classification[6, 11-22]. The present study aims at extracting impervious surface data from satellite imagery with 5 meter resolution using supervised Land use classification method. The negative impacts of increased impervious cover (IC) on receiving water bodies as increased runoff and pollution load have been well documented[22-24]. Due to the acceptance of this inverse relationship, IC has frequently been used in watershed and site design efforts as a chief indicator of environmental degradation. Impacts of urbanization on the environment can be well established by an Impervious Surface map. But not much effort has been done in India, to map impervious cover.

Reasons for concern about impervious cover: Environmental Impact of Impervious cover lies in the fact that increased impervious cover degrades the environment. Impervious Cover

is used as an indicator of Environmental degradation. The hydrologic changes and non-point source pollutant loading from impervious land cover cause most of the environmental degradation than the environmental cover itself. High levels of impervious cover are associated with dense development.

The distribution of impervious surfaces influence urban climate by altering sensible and latent heat fluxes within the urban surface and boundary layers; it increases the temperature of urban regions by causing heat island effect. Strong correlation between imperviousness of a drainage basin and the quality of its receiving streams has been reported. For example, stream quality usually starts to degrade if more than ten percent of the area of a watershed is impervious.

Material and Methods

Materials used: IRS LISS IV image for the year 2012, with spatial resolution of 5 m was used for the study. The image was processed using Erdas Imagine 9.3 software. GIS Analysis and map composition was carried out in ArcGIS 9.3.

Study area: Cochin City is one among the fast growing urban centers in the southern states of India. It is located between 76° 10' 30" and 76° 25' 29.30" East latitude and 10° 6' and 9° 49' 30" North longitude. Physiographically, this area is unique as the entire area is a product of fluvial-estuarine agencies modified by human activities in terms of reclamation. Due to uncontrolled reclamation and urbanization, the impervious cover of the city is increasing. The area experiences a humid climate. In general, four seasons are identified; (i) Summer season from March to May (ii) South-west monsoon season from June to September (iii) North- east monsoon season from October to December and (iv) Winter during January and February. Mean annual rainfall is about 3500 mm.

Methodology: The methods depict the degree of imperviousness from 0 to 100% at the pixel level. Land use/ Land cover map of the study area was prepared using LISS IV imagery acquired for the year 2012, in an Erdas Imagine environment. The map was prepared with supervised classification technique using mean distance to minimum classifier. Supervised classification yields the best results when proper ground information is available. Classification accuracy was determined by preparing error matrix.

The classified image has five classes- built-up, open / exposed area, plantation, vegetation and water body. These classes were merged to prepare the Total Impervious Area (TIA) layer. A map was composed from this layer to show the total pervious and impervious area under the city.

The TIA layer was gridded with 1000 m grid. The TIA layer was then transferred to a GIS environment and the area under previous surface, impervious surface and water bodies were calculated. As there is no confined water bodies in the study area, water bodies does not add to the infiltration, but only increase in the runoff. Hence water bodies were excluded from the area calculations. Percentage imperviousness of the area under each grid was calculated as;

Percentage imperviousness = {Impervious Area/ (Impervious area+ pervious area)} ×100

Percentage imperviousness of each grid is expressed as the Effective Impervious Area (EIA) of the study area

Results and Discussion

The land cover map of Kochi is prepared from the LISS IV. An overall classification accuracy of 86.33% was obtained. The classified map is given in figure 1.

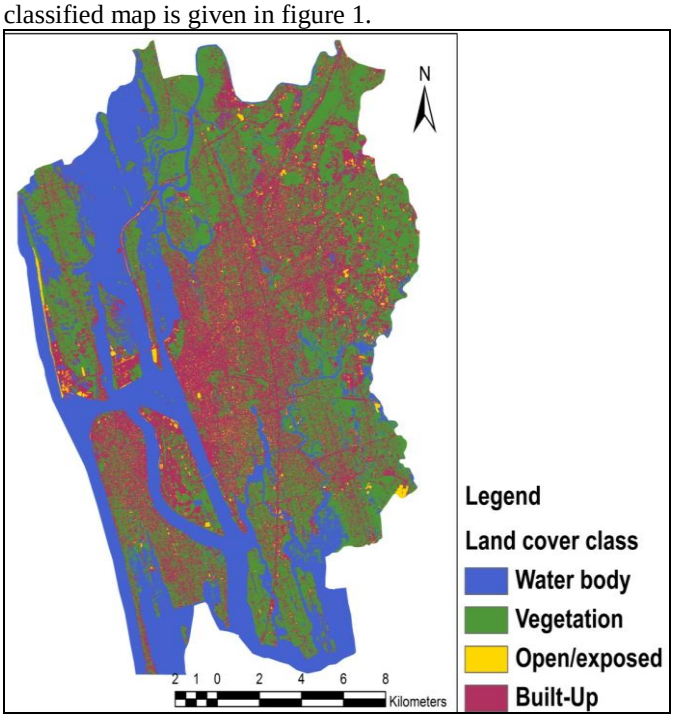

Figure-1
Land cover map of Kochi

An anthropogenic impervious surface map was prepared for Kochi by merging the above classes.

The results show that 114.44 square kilometers of the total area of the city is under impervious cover. The raster representation of percentage imperviousness is given in figure 3.

From the map, it can be seen that the maximum imperviousness in the grid (one square kilometer area) is 88%.

Conclusion

Supervised classification proved to be a good method in mapping impervious surfaces provided the number of land use classes in the region is less and proper ground knowledge is

available. Total Impervious Area and Effective Impervious Area of the city are mapped and it is observed that 114.44 square kilometers of the total area (330 sq.kms) of the city is under impervious cover. Maximum percentage imperviousness observed is 88% per square kilometer.

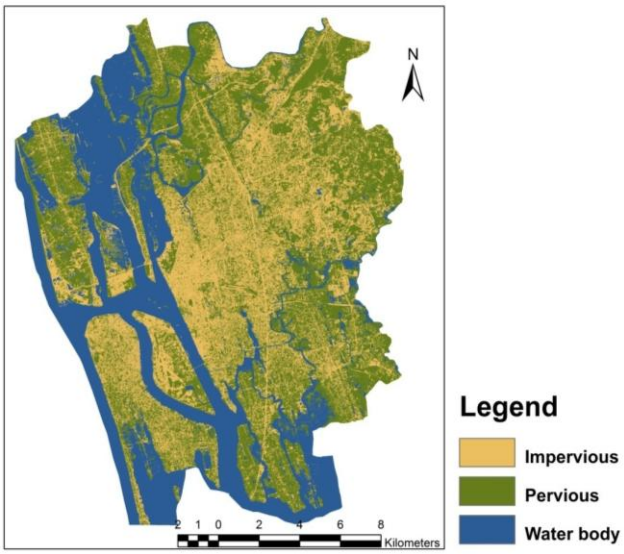

Figure-2
Map showing total impervious area of Kochi

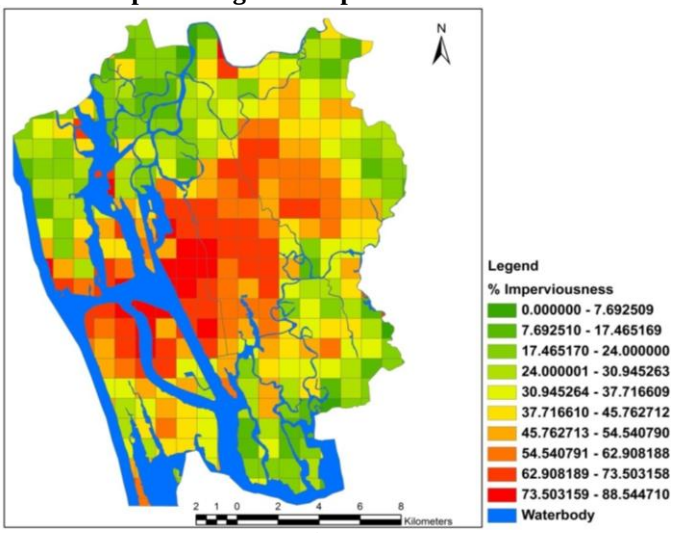

Figure-3
Map showing effective impervious area

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