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Land-Use Land-Cover Change and Its Impact on Surface Runoff using Remote Sensing and GIS

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Abstract Due to urbanization, the incessant growth and development occurring in the peri-urban region, has led to a significant transformations of land-use/ land-cover pattern especially in built-up areas. As a result, there has been an expansion of impervious land (concretization) which has significantly affected the surface runoff behavior in the urban realm. Scenarios like urban floods, water pollution and soil degradation are some of the major consequences of changes in runoff pattern. It calls for an objective assessment and the study temporal behavior of surface runoff pattern for taking up any preventive and/or curative measures. Timely and reliable information on surface runoff in spatial domain is a pre-requisite in this endeavor. Space-borne multispectral and multi-temporal measurements hold a great promise in analyzing land-use/land cover patterns and their temporal behavior, and its impact on the runoff in a timely and cost-effective manner. A study was taken up in Serilingampally Mandal of Rangareddy district, a peri-urban area of Hyderabad city, Telangana state for assessment and monitoring of surface runoff patterns using Landsat-MSS data and Resourcesat 2 LISS-IV data collected in 1975 and 2016, respectively through heads-up/on-screen visual interpretation approach. Initially, the information on land use/cover pattern was generated to assess the growth of the urban settlements. Subsequently the corresponding increase in surface runoff during the monsoon seasons (June-October) 1975 and 2016 were computed using SCS (Soil Conservation Service) curve number method. Results indicate a sharp increase in built up land from 0.91% to 69.36%. During the period 1975-2016 with consequent higher runoff to the tune of 27.5% as compared 1975 period.
Keywords *spectral measurements; landsat-MSS; resourcesat 2 LISS-IV; urbanization; surface runoff; soil conservation service curve number*

1. Introduction

Land is becoming a scarce resource due to population growth and industrialization. Due to this reason there is rapid change in land-use land cover in general and in urban areas in particular. The irregular growth in urban sprawl has caused a great impact on the fertile lands as well as it became a vital reason for many environmental problems, waste disposal and water pollution as specified by the U.N. Conference on Human settlement. Land-use and land-cover changes may have four major direct impacts on the hydrological cycle and water quality: they can cause floods, droughts, and changes in river and groundwater regimes, and they can affect water quality (Rogers, 1994).

The process of urbanization has a considerable hydrological impact in terms of influencing the nature of runoff and other hydrological characteristics, delivering pollutants to rivers, and controlling rates of erosion (Goudie, 1990). The development of residential and commercial buildings increases imperviousness which reduces the time of runoff concentration so that peak discharges are higher and occur sooner after rainfall starts in catchments. The volume of runoff and flood damage potential will greatly increase. Moreover, the installation of sewers and storm drains accelerates runoff (Goudie, 1990). Therefore, the rainfall–runoff phenomenon in an urban area intends to be fairly dissimilar from that in natural conditions depicted in conventional hydrological cycles. Integration of urbanization with hydrological studies is made possible because both utilize land-use and land-cover data.

2. Background

The land-use and land-cover pattern of a region is an outcome of natural and socio-economic factors and their utilization by man in time and space. Hence, information on land-use and land-cover is essential for selection, planning and implantation of land-use and can be used to meet the increasing demands for basic human needs and welfare. This information also assists in monitoring the dynamic of land-use resulting out the changing demands of increasing population (Zubair, 2008).

There has been a significant change in land-use and land-cover for the past decade. For sustainability of the sprawl there needs to be a harmonic interaction with the nature. This can be possible by a proper monitoring and management of natural resources that are water and land. Alteration of the land-use and land-cover impacts the surface runoff behavior and leads to the scenarios like urban floods, water pollution, soil degradation and ground water.

3. Role of Remote Sensing and GIS

With multi-temporal analysis, remote sensing gives a unique perspective of how rural area evolves. “Remote sensing methods can be employed to classify types of Land- Use in a practical, economical and repetitive fashion, over large areas” (Natural Resource, Canada). The collection of remotely sensed data facilities the synoptic analysis of earth-system function, patterning and change at local, regional and global scales over time, such data also provide an important link between intensive localized ecological research and regional, national and international conversation and management of biological diversity.

Remotely sensed data and geographic information systems (GIS) have been identified as a powerful and effective tool in detecting urban growth (Harris & Ventura, 1995; Yeh & Li 1996, 1997). Digital as well as visual interpretation of the satellite based multi-resolution and multi-temporal data proves to be pivotal for understanding and monitoring urban transformation. GIS provides a multi-dimensional environment for visualization, manipulation and analyzing digital data from various inputs required for urban feature identification, change detection, and spatial database development. In hydrological and watershed modeling, remotely sensed data and GIS are found to be valuable for providing cost-effective data input and for estimating model parameters (Engman & Gurney, 1991; Drayton et al., 1992; Mattikalli et al., 1996). Thomas (2015) used RINSPE model implemented in ArcView GIS 3.3 environment to model for estimating runoff in the Olifants river catchment area in north eastern South Africa as surface runoff and entering into the subsurface as infiltration. In another study, Hong Quang Nguyen and Martin Kappas (2015) used Soil and Water Assessment Tool (SWAT) and Bridging Event and Continuous Hydrological (BEACH) models for estimating surface runoff and evapotranspiration in a tropical watershed in North Vietnam. While estimating the runoff in Vindhyachal region, part of Mirzapur district, Uttar Pradesh, northern India, Topno et al. (2015) observed an improvement in estimated runoff accuracies by using a curve number (CN) model developed by the United States Department of Agriculture (USDA).

4. Study Area

The area of concern of the present study, Serilingampally, is a municipality and Mandal in Ranga Reddy district, Telangana, is bound by geo co-ordinates 17.414 to 17.517^{0}N and 78.283 to 78.414^{0}E and covers an area of approximately 101 sq. km (Figure 1). Due to its close proximity to Hitech City, Gachibowli, Nanakramguda, Manikonda and Kondapur, there has been a heavy influx of IT companies. As a result, it has witnessed an unprecedented growth and development in the infrastructure in the recent times. Lithologically, the test site consists of granite-gneiss complex. Hills, pediment, pediplain and valleys the physiographic units encountered in the test site. Coarse-textured red soils predominantly occur with inclusions of black soils in local depressions and low lying areas. The area enjoys semi-arid sub-tropical climate with average daytime temperature ranging from 25-30^{o}C during November to February and 40-45^{o}C during April-June. Annual precipitation ranges between 700-1000 mm yr^{-1} which is received mostly during July to October.

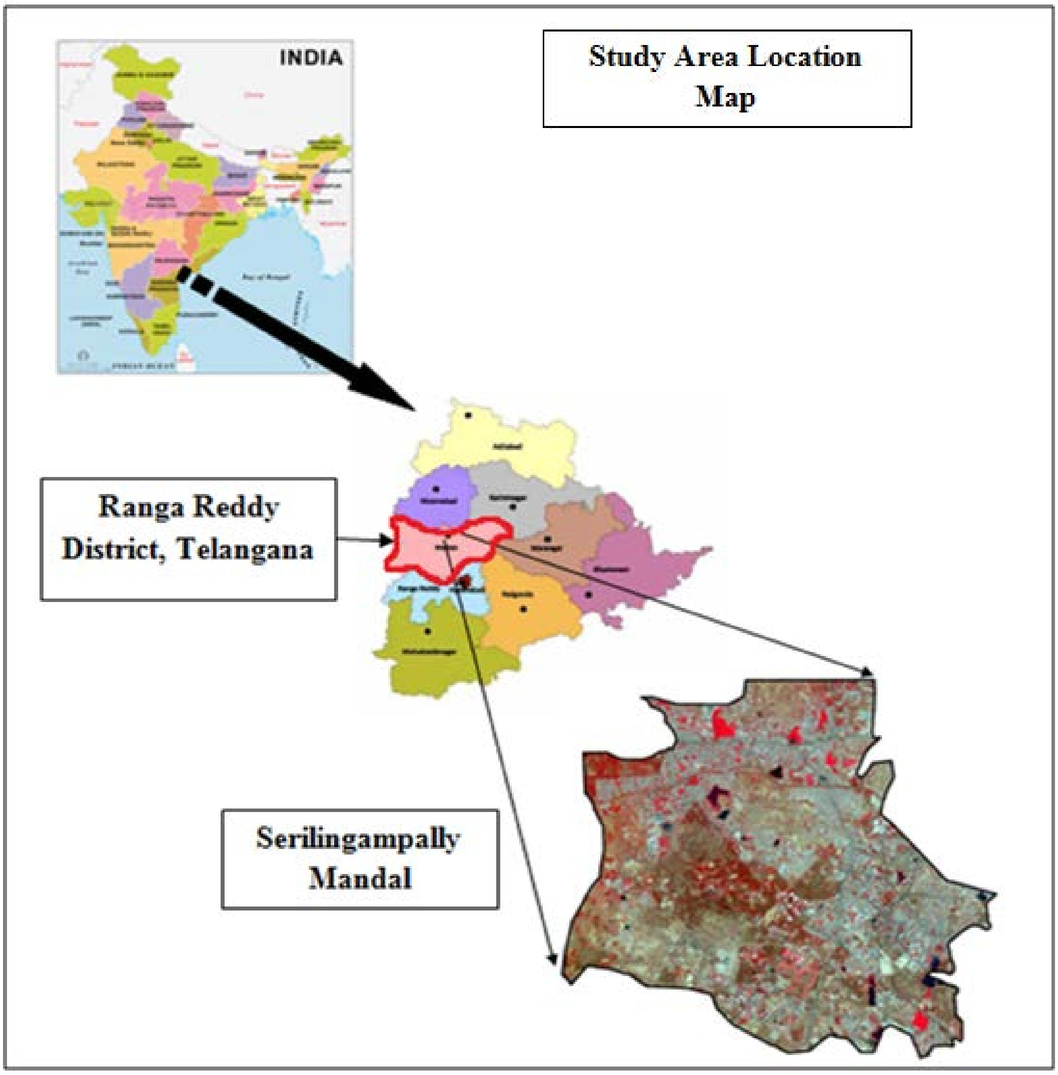

Figure 1: *Location map of the test site*

5. Database

The Landsat MSS and Resourcesat-LISS IV digital data with 80m and 5.8m spatial resolution, respectively were used for developing land use/ land cover maps of the test site. The specifications of the satellite sensor data used `are given in Table 1 and 2 respectively. Whereas Landsat MSS digital data was downloaded from United States Geological Survey (USGS) Database, Resourcesat LISS-IV data was procured from National Remote Sensing Center, Hyderabad. Survey of India topographical map at 1:25,000 scale was used for developing base map as well for data analysis. The information on relief was extracted from Carto-DEM. Hydrological Soil Group (HSG) map was derived from soil texture available in soil resources map collected from Telangana State Remote Sensing Center, Hyderabad. Mandal-wise precipitation data was obtained from Directorate of Economics and Statistics, Telangana. Ancillary information consists of cadastral maps and socio-economic data collected from Serilingampally Mandal office.

Table 1: *Specifications of Resourcesat-2 LISS IV sensor*

Specifications	LISS IV
No. of bands	1 (mono), 3 (MX)
Spectral bands (µm)	B2 0.52-0.59 B3 0.62-0.68 B4 0.77-0.86 B3-default band for mono
Resolution (m)	5.8
Swath (km)	70/23
Revisit (days)	5
Quantization	10-bit

Source:http://lps16.esa.int/posterfiles/paper1213/[RD13]_Resourcesat-2_Handbook.pdf

Table 2: *Specifications of MSS of Landsat-1*

Specifications	MSS
No. of bands	4
Spectral bands (µm)	B4 0.5-0.6 B5 0.6-0.7 B6 0.7-0.8 B7 0.8-1.1
Resolution (m)	80
Swath (km)	185
Revisit (days)	18
Quantization	6-bit

Source: http://gisgeography.com/usgs-earth-explorer-download-free-landsat-imagery/

6. Methodology

The methodology involves geo-referencing of digital temporal satellite data, generation of land use/ land cover map, derivation of hydrological soil groups from available soil map and integration the information on land use/land cover, hydrological soil group to estimate run off following USDA-Soil Conservation Service curve number approach (Figure 2).

To begin with, Landsat-MSS data was georeferenced to Survey of India (SOI) topographical maps at 1:50,000 scales on a Silicon Graphics (Octane)-based system by identifying adequate ground control points by using ERDAS/IMAGINE software by identifying well distributed ground control points identifiable on Landsat-MSS digital image and topographic maps. Similar exercise was done for geo-referencing Resourcesat-2 LISS-IV data with 6m spatial resolution using ground control points from

1:25,000 scale topographic maps. The digital output, thus generated, was used for land use/ cover mapping.

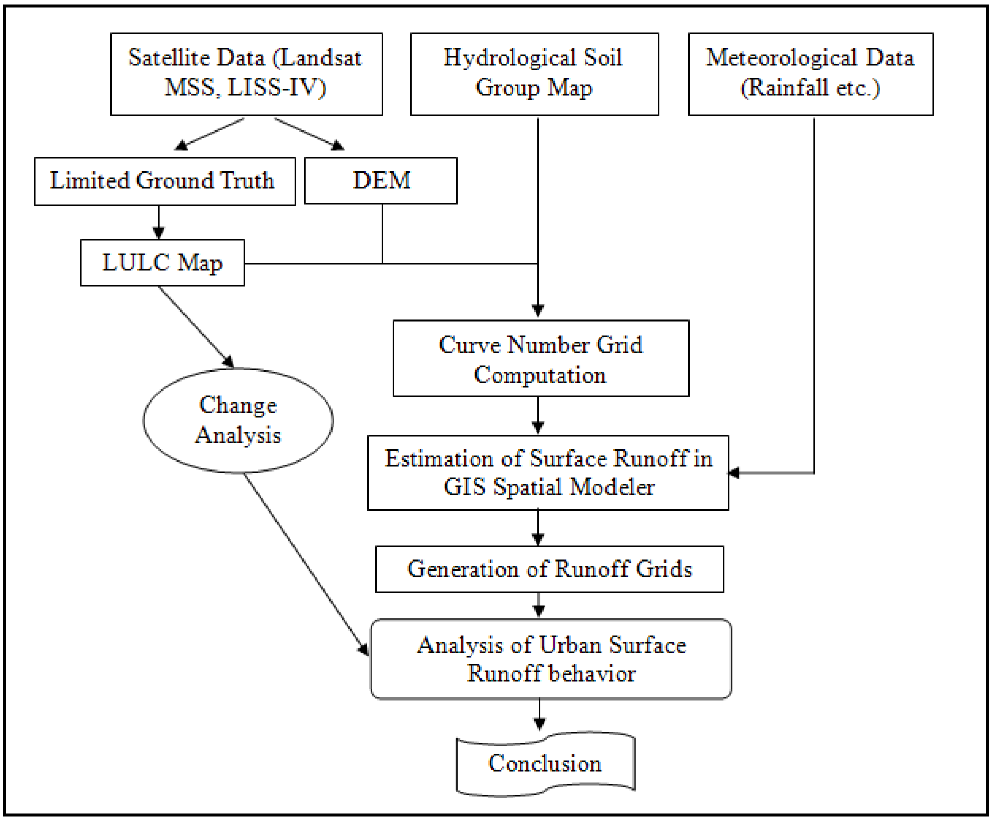

Figure 2: *Schematic diagram of the methodology*

6.1. Preliminary Visual Interpretation

Due to coarse resolution of Landsat-1 MSS data for the period land use/land cover mapping for 1975 was confined to 8 aggregate classes while high resolution LISS IV data could afford delineation of 14 distinct land-use/ land cover categories.

6.2. Ground Truth Collection

The parcels of land representing various land use/land cover classes as delineated during preliminary visual interpretation in each sample strip and located onto topographical maps, were physically located on the ground. Subsequently observations on various land use categories in each sample strip were made to correlate the image elements and their correspondence with land use/ cover categories. The location of each observation was recorded with help of a GPS receiver.

6.3. Map Finalization

To begin with, the digital Resourcesat-2 LISS-IV data was displayed onto colour monitor of the Silicon Graphics (Octane) - based system using ERDAS IMAGINE software and a blank vector layer was overlaid onto the image. The areas which were delineated as having land use/ land cover categories during preliminary visual interpretation were then located in the image and the boundaries were modified *vis-a-vis* ground truth collected during field visit. The vector coverage was generated for and use/land cover categories delineated from Landsat MSS and LISS-IV data delineated on the colour monitor of the Silicon Graphics (Octane) system using ERDAS/ IMAGINE software and its topology built. The area statistics for each land use/ land cover categories was generated.

6.4. Land Use/ Land Cover Change Analysis

A change analysis for the corresponding years was performed in the geo-spatial environment to prepare a change detection map. The vector coverage of use/land cover categories delineated from Landsat MSS and LISS-IV data were overlay and the transformation of land-use and land-cover classes from one to another was observed. The spatial extent of various land /land cover statistics of the changes in land use/ land cover categories over the period of time from 1975 to 2016 was generated.

6.5. Computation of Surface Runoff

There are numerous rainfall-runoff algorithms for simulating the hydrological cycle. We have used a Curve Number algorithm, a simplified and most applicable rainfall loss method, for runoff estimation. As mentioned earlier, the SCS (Soil Conservation Service) curve number method was developed by the Soil Conservation Service of United States Department of Agriculture (USDA).The primary reasons for its wide applicability and acceptability lies in the fact that it accounts for most runoff producing watershed characteristics (e.g. soil type, land use/treatment, surface condition and antecedent moisture condition (AMC). The amount of total direct runoff is estimated as follows:

$$Q = \frac{(P-0.2S)^2}{P+0.8S} \; (Q = 0 \; IF \; P \leq 0.2S) \ldots\ldots\ldots (1)$$

$$S = \frac{25400}{CN} - 254 \quad \ldots\ldots\ldots\ldots\ldots (2)$$

Where, Q is the precipitation excess (runoff) in mm (millimeters), S is the potential maximum retention in mm (millimeters) and CN is the SCS curve number.

It is amply clear from equations (1) and (2) that two main inputs that are required for computation of the surface runoff are: precipitation and curve number. The CN values are normally estimated using field survey data with reference to CN (under AMC II condition) tables published by USDA's SCS. The SCS has evolved the hydrological soil group code A, B, C, or D based on permeability and infiltration characteristics of soils. Group A soils are coarse, sandy, well-drained, with the highest rate of infiltration and the lowest potential for runoff. Group D soils, on the other hand, are heavy-textured, clayey, poorly drained soils, with the lowest rate of infiltration and highest potential for runoff. Group B and C soils are intermediate between groups A and D. We have prepared daily rainfall grids for the monsoon season (June-October) using IDW (Inverse Distance Weight) GIS tool for the years 1975 and 2016 and have resampled to suitable scale for a better spatial representation. The curve number grids were generated through an integrated GIS analysis of land-use, soil textural information (Figure 3) and hydro-DEM (Figure 4) under AMC II (normal condition).

A spatial model for simulating the rainfall-runoff phenomenon was developed using advanced map algebra functions in a GIS environment for preparing monthly surface runoff grids from which the total runoff during the monsoon period of the corresponding years was computed.

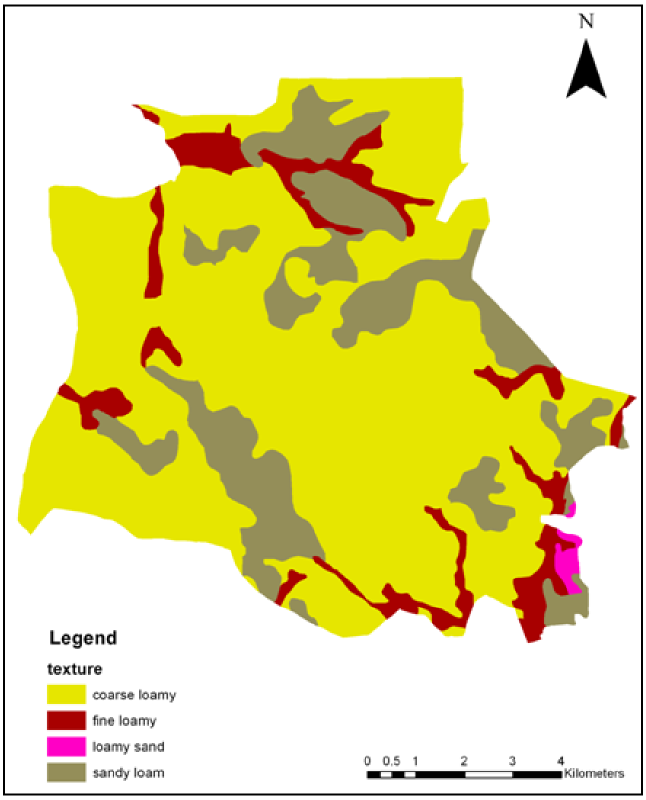

Figure 3: *Soil texture map of the test site*

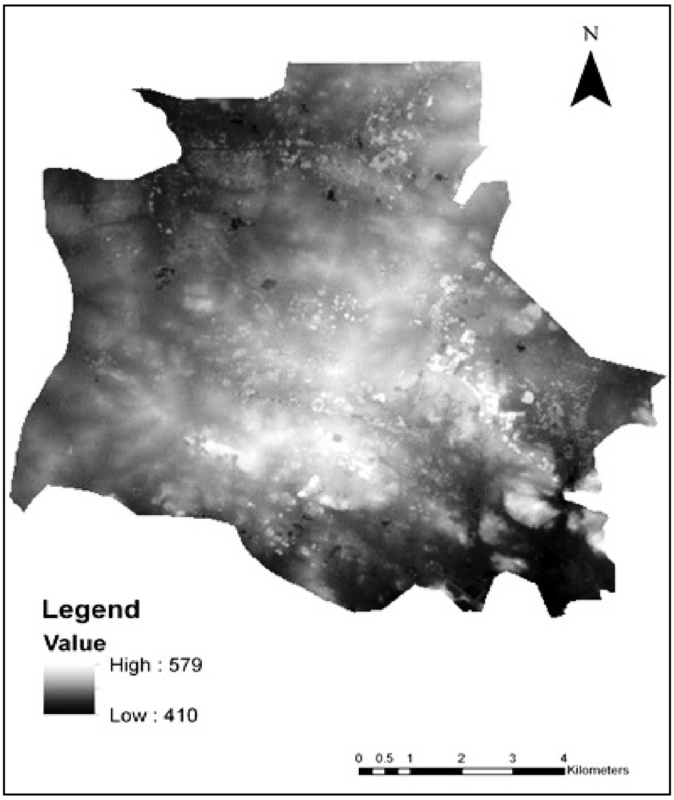

Figure 4: *DEM of the test site (values are in metres)*

7. Results and Discussion

Land use/land cover pattern as delineated from Landsat-MSS and Resourcesat-2 LISS-IV data were used to study its temporal behavior and the urban sprawl that has occurred in the test site. The corresponding increase in surface runoff due to development of impervious land (concretization) due to urbanization was assessed to provide the information to planners and decision makers for utilizing the land and water resources with a sustainable approach.

7.1. Land Use/Land Cover Scenario and Change Analysis

Landsat-MSS data could afford delineation of broad land use/land cover categories, namely agriculture, forest, scrubs, layouts recreational and water bodies (Figure 5). The land use/land cover map derived from LISS-IV data is appended as Figure 6. As evident from the map several sub-divisions within each land use/ land cover category delineated from Landsat_MSS data could be made. For example, within settlements medium dense settlements, dense settlements, apartments, and villas could be identified on LISS-IV image with 6m spatial resolution.

During the period 1975 to 2016 spanning over four decades, there have been remarkable changes in built-up land, cropland and scrubs. The built up land has expanded from 0.91% in 1975 to 69.36% in the year 2016. Conversely, the cropland has shrunken from (1.18% in 1975 to 4.22% in 2016). Similar trend has been observed in scrub which has decreased from 22.84% in 1975 to 5.67% in 2016 (Table 3 & 4).

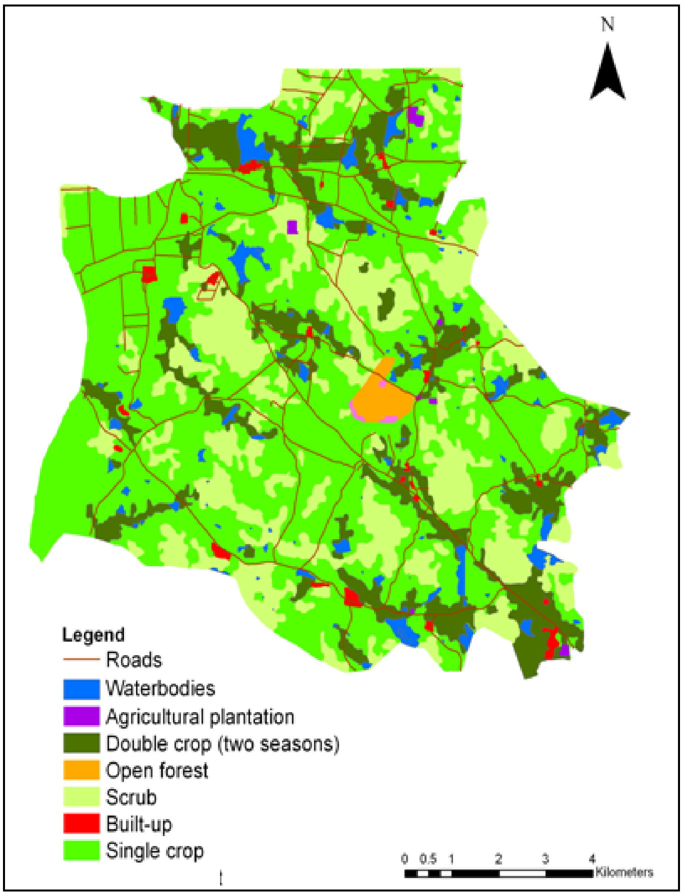

Figure 5: *LULC map of the study area derived from Landsat-MSS imagery*

Table 3: *Spatial extent of various land-use and land cover categories during 1975*

Land-use	Area (sq-km)	Percent Area (%)
Agricultural Plantation	0.25	0.26
Double Crop (two seasons)	13.09	13.52
Open Forest	1.02	1.05
Scrub	22.12	22.84
Built-up	0.89	0.92
Single crop	55.82	57.65
Water bodies	3.63	3.75

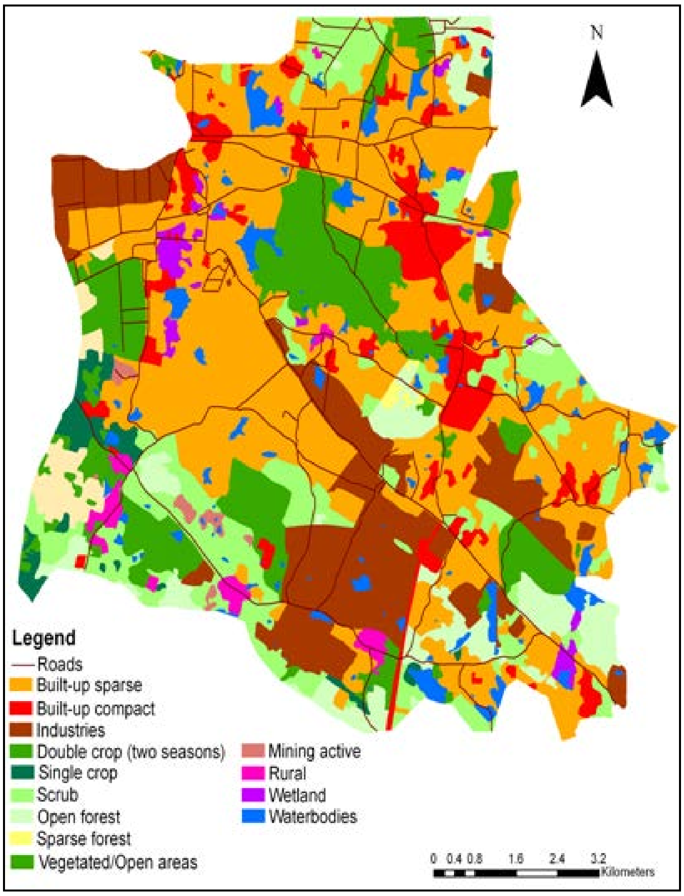

Figure 6: *LULC map derived from 2016 LISS-IV data*

Table 4: *Spatial extent of various land-use and land cover categories during 2016*

Land-use	Area(sq-km)	Percent Area (%)
Built-up compact	6.23	6.44
Built-up sparse	37.27	38.49
Double crop (two seasons)	0.89	0.91
Industries	12.86	13.29
Single crop	3.2	3.31
Mining active	0.44	0.45
Open forest	0.94	0.97
Rural	1.09	1.13
Scrubs	16.27	16.81
Vegetated/open areas	12.56	12.96

Water bodies	3.63	3.82
Wetlands	1.11	1.15

7.2. Urbanization and Runoff

As pointed out in section 7.1, the land use/land cover area statistics indicates an increase in built-up land from 0.91% in 1975 to 69.36% in 2016. Conversely, there has been a sharp decrease in cropland (71.18% in 1975 to 2.63% in 2016). Urban growth has led to increase in area under impervious cover which tends to increase surface flow. Runoff map for the month of June for the corresponding years are portrayed in Figure 7.

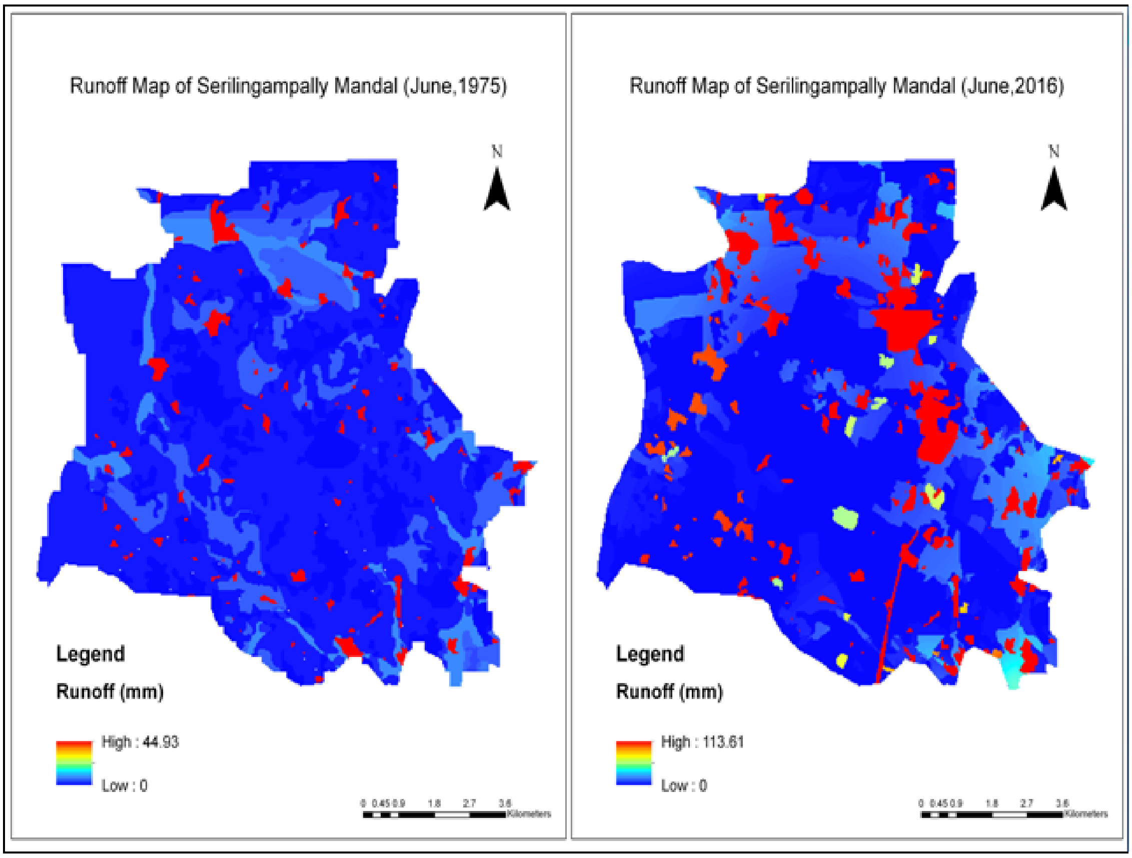

Figure 7: *Runoff map of Serilingampally Mandal for the month of June (1975, 2016)*

It is evident from the figure that there has been a significant increase in the built-up area over a period of four decades resulting in to corresponding increase in potential to overland flow represented in red patches for the built-up and water bodies in an integrated way. The runoff value is as high as 113.61 mm for the month of June in 2016 compared to 44.93 mm in 1975. It is observed that a total precipitation of 869.15 mm in 1975 monsoon has yielded a runoff of 312.30 mm while a precipitation of 870.73 mm in 2016 monsoon has contributed a runoff amounting to 398.26 mm. An overall increase in runoff of to the tune of 27.5% has been observed.

8. Conclusions

Alteration of the land-use and land-cover impacts the surface runoff behavior and leads to the scenarios like urban floods, water pollution, soil degradation and ground water. In order to assess the magnitude of the impact of land cover change on overland flow, a novel approach utilizing remote sensing, GIS and curve number model was used. The approach involves generation of information on land use/land cover pattern and integrating it with soil texture, relief and precipitation using USDA-SCS curve model. The advantage of *a priori* knowledge of the area coupled with the ease of access to detailed ground truth enabled the visual interpretation of satellite data to study the land-use / land cover dynamics and generation of hydrological soil groups. The study demonstrates the role of urban growth on over land flows by way appreciable increase impervious cover with attendant decrease in infiltration. However, the role of quantum and intensity of rainfall pattern in the process cannot be overlooked.

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References

Drayton, R.S., Wilde, B.M., & Harris, J.H.K. (1992). Geographic information system approach to distributed modeling. *Hydrological Processes, 6*, 36-368.

Engman, E.T., & Gurney, R.J. (1991). *Remote sensing in hydrology*. London: Chapman and Hall, London.

Goudie, A. (1990). *The human impact on the natural environment*, 3rd ed. Massachusetts: The MIT Press, Cambridge.

Harris, P.M., & Ventura, S.J. (1995). The integration of geographic data with remotely sensed imagery to improve classification in an urban area. *Photogrammetric Engineering and Remote Sensing, 61*(8), 993-998.

Mattikalli, N.M., Devereux, B.J., Richards, K.S. (1996). Prediction of river discharge and surface water quality using an integrated geographic information system approach. *International Journal of Remote Sensing, 17*(4), 683-701.

Nguyen, Hong Quang, & Martin Kappas. (2015). Modeling Surface Runoff and Evapotranspiration using SWAT and BEACH for a Tropical Watershed in North Vietnam, Compared to MODIS Products. *International Journal of Advanced Remote Sensing and GIS, 4*, 1367-1384.

Rogers, P. (1994). Hydrology and water quality. In W.B. Meyer, & B.L. Turner II (Eds.), *Changes in land use and land cover: A global perspective* (pp. 231-258). Cambridge: Cambridge University Press.

Thomas, A. (2015). Modelling of Spatially Distributed Surface Runoff and Infiltration in the Olifants River Catchment/Water Management Area Using GIS. *International Journal of Advanced Remote Sensing and GIS, 4*, 828-862.

Topno, A., Singh, A.K., & Vaishya, R.C. (2015). SCS CN Runoff Estimation for Vindhyachal Region using Remote Sensing and GIS. *International Journal of Advanced Remote Sensing and GIS, 4*, 1214-1223.

Yeh, A.G.O., & Li., X. (1997). An integrated remote sensing- GIS approach in the monitoring and evaluation of rapid urban growth for sustainable development in the Pearl River Delta, China. *International Planning Studies, 2*(2), 193-210.

Zubair, A.O. (2006). Change detection in land use and land cover using remote sensing data and GIS (A case study of Ilorin and its environs in Kwara state.), Department of Geography, University of Ibadan.