Land use change mapping and its impact on storm water runoff using Remote sensing and GIS: a case study of Mumbai, India

Darshan A. Sansare¹, Sumedh Y. Mhaske¹

Civil and Environmental Engineering Department, V.J.T.I Matunga Mumbai, India
e-mail: darshansansare@gmail.com

Abstract. The rapid increase in urbanization worldwide has induced a change in land use–land cover (LULC) over the years. In Mumbai, India, this has further altered the hydrological processes like infiltration, evapotranspiration, interception and erosion and also caused loss of current drainage capacity and flooding in urban areas. This paper mainly assesses the changes in land-use land-cover types and its impact on storm water discharge from 1973 to 2018 in Mumbai using ArcGIS software. The image was classified into five LULC categories after superimposing in Arc-GIS, such as forest, open land, wetland, water and built-up area. The analysis of LULC pattern for the area under study over a period of 45 years showed that there was 66% rise in the built-up area whereas the Forest, open land and Wetland and water body together had reduced by 21%, 36% and 28%, respectively with respect to overall catchment area of Mumbai. Also, the analysis results gave a rise in peak discharge of storm water by 36% because of the changes in LULC over the given time period. On the whole, the land area affected by water logging has significantly increased over the time. The study therefore indicates that the integration of GIS and remote sensing was an effective way of approach for assessing the process of land-use land-cover change.

1. Introduction

The worldwide population growth is increasing with high rate, industrialization and urbanization has been increased drastically, which has resulted in rapid and large scale of alterations in land cover [1]. As the boundaries of the coastal cities like Mumbai are surrounded by sea, this city faces land scarcity. Change in LULC has great impact on the hydrological process with the increasing urbanization. The present drainage system becomes ineffective to carry the storm water when condition like high intensity of downpour along with high tide occurs which creates the situation of flooding [4]. In managing natural resources and monitoring environmental changes the current status of Land-use and land-cover (LULC) changes plays an important role, also it is key factor that affects human and physical conditions [7, 14, 20].

[6] used supervised (MLA) and unsupervised (ISODATA) classification method for analysis of LULC change for the period of 1985 to 2010 and also develop future LULC map for Talkha of Egypt. [2] used Maximum likelihood classification (MLC) method for finding transformation of land cover for the period of fifty years in Avellino Italy. From this study it reveals that, land use of urban areas increases in fast pace it significantly affects the agricultural land compare to land covered by forest for the Year 1954 to 2004. [8] used hybrid, parametric (MLA and ISODATA), and nonparametric (DT) methods for evaluating LULC changes. Accuracy assessment and Kappa statistic of the study was 93% and 0.92 respectively.

[9] used ERDAS imagine software for LULC change detection for the year 1984 to 2015. For classification of LULC in Six categories, Unsupervised ISODATA method was used. Considering period of three decades, this study reveals that settlement and agricultural land continuously increased, while area under open land and grassland reduced over the study period.
LULC alteration has a direct impact on the generation of runoff [10]. As per Sansare et al (2018), study is to carry out analyze the LULC change by comparing 1973 and 2018 LULC data for catchment area Mumbai, India along with the impact of LULC change spatially and temporally on the peak flood discharge and runoff generation for the catchment area, Mumbai.

Remote sensing and GIS are useful tools for LULC change detection and data analysis [11, 12, 18, 21]. There is a great potential of GIS and remote sensing techniques in measuring the change pattern of land use cover in town area [15]. As per Sansare et al (2019), used remote sensing and GIS tools for thematic mapping for F-North ward, Mumbai.

This study objected in generating map for Mumbai city which shows change in land cover for the period 1973 to 2018 by using Arc-GIS software.

2. Study Area
Mumbai, the financial capital of India and capital of Maharashtra is the main trading and economic center and is developing rapidly. Mumbai city extends between 18.00–19.20N and 72.00–73.00E covering a total area of 437.79 km² with an average population density of 27209/km² [3]. It experiences a humid climate, being located on the southwest monsoon belt, with an average annual rainfall of 2500 mm, of which 70% occurs in July and August [5].

3. Methodology
Satellite images were obtained from USGS website, toposheet numbers 47A were scanned and geo referenced in Arc-GIS 10.4 software. After geo-referencing, ISO cluster unsupervised classification method is used for LULC change detection.

i) Calculate LULC change detection in percentage over the period by using the formula

\[
\text{Change in land cover (\%) = } \frac{(\text{Initial time land cover} - \text{Final time land cover}) \times 100}{\text{Initial time land cover}}
\]

\[
\text{Change in land cover (\%) = } \frac{[\ (\text{AT-1}) - (\text{AT-2}) \ ] \times 100}{(\text{AT-1})}
\]

If, CL (\%) = + Decreases, CL (\%) = - Increases
AT-1 = Area (sq.km) of LULC @ Initial Time, AT-2 = Area (sq.km) of LULC @ Final Time

Classification accuracies for the years 1973 and 2018 were evaluated using Error matrices. From the analysis, the total accuracy of the LULC transformation for 1973 Landsat MSS image was 86.7 %, with Kappa statistic of 0.803 and for 2018 Landsat ETM+ image was 90 %, with Kappa statistic of 0.87.

Limitations – There is a limitation in the accuracy analysis for the year 1973. Since Google Earth was introduced in the year 2003. Ground thruthing of the year 1973 was done with the help of toposheet number 47A of Mumbai and it was done using Google Earth for the year 2018.

ii) Calculate impact of LULC change spatially and temporally on the peak flood discharge and runoff generation for the catchment area by using Rational Method as per reference book, Engineering Hydrology By K Subramanya:

\[
Q=C*I*A /3.6
\]

where:
Q =Discharge (m³/sec), C = Runoff Coefficient, I = Intensity of Rainfall (mm/hr)
A = catchment area (sq.km)
Figure 1. Methodology of LULC change detection and peak discharge calculation.
4. Results and Discussion

Figure 2. The map showing satellite image (SRTM Data) obtained from USGS website, for the year 1973.

![Figure 2](image-url)

Figure 3. Unsupervised classification of Land-use and land-cover of Mumbai for Year 1973.

![Figure 3](image-url)

The above map (Fig.3) depicts that ISO cluster unsupervised classifications were generated from the USGS data, starting with 10 classes for the year 1973 to gain better classification accuracy due to its lower resolution.
Figure 4. The Image showing results in count of unsupervised classification of image in five classes.

Figure 5. The Image showing result of correct classification of Land in five classes with area in sq/km after recoding is done.

The above map (fig. 4 & fig. 5) depicts that ISO cluster unsupervised classifications were generated from the USGS data in five classes for the year 1973.
Figure 6. Land-use and land-cover of Mumbai for the year 1973.
The above map (fig.6) shows the LULC distribution of the Mumbai in 1973. This map is made in ArcGIS software which is simple, reliable and less time consuming.

Figure 7. The Map showing Satellite image (SRTM Data) obtained from USGS website, for the year 2018.
Figure 8. Unsupervised classification of Land-use and land-cover of Mumbai for Year 2018. The above map (fig.8) depicts that ISO cluster unsupervised classifications were generated from the USGS data, starting with 10 classes for the year 2018.

Figure 9. The Image showing results in count of unsupervised classification of image in five classes year.
Figure 10. The Image showing result of correct classification of Land in five classes with area in sq/km after recoding is done for the year 2018.
The above map (fig.10) depicts that ISO cluster unsupervised classifications were generated from the USGS data in five classes for the year 2018.

Figure 11. Land-use and land-cover of Mumbai for the year 2018.
The above map (fig.11) shows the LULC distribution of the Mumbai in 1973. This map is made in Arc-GIS software which is simple, reliable and less time consuming.
Figure 12. Land-use and land-cover of Mumbai for Year-1973 and Year-2018.

Figure 13. The above Pie chart indicates the changes in the land use-land cover area in (sq.km) for Different geographical features.

Table 1. Land use–land cover changes for the study area with changes from 1973 to 2018

| Sr. No | Land Use Type     | 1973 | % Total | 2018 | % Total | % Change in LULC |
|--------|-------------------|------|---------|------|---------|------------------|
| 1      | Built-up          | 139.26 | 30      | 231.307 | 49      | +66.09           |
| 2      | Forest            | 114.55 | 24      | 90.32  | 19      | -21.15           |
| 3      | Bare land         | 84.55  | 18      | 54.02  | 11      | -36.10           |
| 4      | Water and wetland | 132.78 | 28      | 95.48  | 20      | -28.09           |
| Total  |                   | 471.14 | 100     | 471.12 | 100     |                  |
Figure 14. The above column chart indicates the changes in the land use-land cover w.r.t Total Catchment for different geographical features over the period considered.

Table 2. Change in discharge for the study area with changes from 1973 to 2018

| Return Period | Colaba Raingauge | Discharge for Year-1973 | Discharge for Year-2018 | Increase % Discharge |
|---------------|------------------|-------------------------|-------------------------|----------------------|
| In Years | Rainfall mm/hr | Built-up | Open land | Forest | Total Q (m³/sec) | Built-up | Open land | Forest | Total Q (m³/sec) |                   |
| 2 | 53.4 | 1962 | 501 | 425 | 2889 | 3259 | 321 | 335 | 3915 | +35.52 |
| 10 | 81.4 | 2991 | 765 | 648 | 4404 | 4969 | 489 | 511 | 5968 | +35.52 |
| 25 | 95.5 | 3509 | 897 | 760 | 5166 | 5829 | 573 | 599 | 7001 | +35.52 |
| 50 | 105.9 | 3891 | 995 | 842 | 5729 | 6464 | 636 | 664 | 7764 | +35.52 |
| 100 | 116.3 | 4274 | 1093 | 925 | 6292 | 7099 | 698 | 730 | 8526 | +35.52 |

Figure 15. The above column chart indicates the changes in the discharge from run off for (Rainfall=53.4mm/hr) different geographical features over the period considered.
5. Conclusions
As Mumbai being a coastal city surrounded by sea and creek, LULC change rapidly alters the hydrologic process with an increase in urbanization. The reasons for the LULC changes were evaluated systematically. The LULC analysis of Mumbai showed that in 2018, the built-up area has been increased drastically by 66% in comparison to 1973, as a result of open spaces, Forest, Wetland and water body had diminished by 36%, 21% and 28%, respectively with reference to total catchment area, due to an uncontrolled increase in urbanization. The need for plantation of trees, wetland protection, and forest protection can be clearly seen from the result of this study. Also, due to urbanization, industrialization and the enormous growth of population, most of the city had gotten embedded in concrete and due to this impervious nature of concrete there is no scope for the infiltration of water. The analysis of the LULC data also suggests a similar point of view. There is an increase in peak discharge by 36 % for LULC change between the years 1973 and 2018. Significant change in LULC, increase in peak discharge and the drains are clogged due to wastes has resulted in there is a frequent occurrence of floods or water logging in Mumbai.

6. Acknowledgement
The authors are grateful for the data and the co-operation from the Municipal Corporation of Greater Mumbai and VJTI, Mumbai for this study. Also, thankful to Dr. Babasaheb Ambedkar Research and Training Institute (BARTI) for awarding fellowship for Ph.D. research purpose.

7. References
[1] Dewan A M and Yamaguchi Y 2009 Land use and land cover change in Greater Dhaka, Bangladesh: using remote sensing to promote sustainable urbanization Appl Geogr. 29 pp 390–401
[2] Fichera, C. R, Modica G, Pollino M 2012 Land cover classification and change-detection analysis using multi-temporal remote sensed imagery and landscape metrics European Journal of Remote Sensing 45(1) pp 1–18
[3] FFC (Fact Finding Committee) 2006 Maharashtra State Govt. Committee Report 31–130 (unpublished).
[4] Gupta K 2007 Urban flood resilience planning and management and lessons for the future: a case study of Mumbai, India Urban Water J. 4(3) pp 183–194
[5] Hallegatte S et al. 2010 Flood risks, climate change impacts and adaptation benefits in Mumbai: An initial assessment of socio-economic consequences of present and climate change induced flood risks and of possible adaptation options; Environment Working Papers, No. 27. Technical Report. OECD Publishing.
[6] Hegazy I R and Kaloop M R 2015 Monitoring urban growth and land use change detection with GIS and remote sensing techniques in Daqahlia governorate Egypt International Journal of Sustainable Built Environment 4(1) pp 117-124
[7] Kamarudin M K A, Gidado K A, Toriman M E, Juahir H, Umar R, Abd Wahab N, Ibrahim S, Awang S and Maulud K N A 2018 Classification of land use/land cover changes using GIS and remote sensing technique in Lake Kenyir Basin, Terengganu, Malaysia International Journal of Engineering and Technology 7(3.14 Special Issue 14) pp 12-15
[8] Kantakumar L N and Neelamsetti P 2015 Multi-temporal land use classification using hybrid approach. Egyptian Journal of Remote Sensing and Space Science 18(2) pp 289–295
[9] Meshesha T W, Tripathi S K and Khare D 2016 Analyses of land use and land cover change dynamics using GIS and remote sensing during 1984 and 2015 in the Beressa Watershed Northern Central Highland of Ethiopia Modeling Earth Systems and Environment 2(4) pp 1-12
[10] Melesse A M and Shih S F 2002 Spatially distributed storm runoff depth estimation using Landsat images and GIS Comput Electron Agric. 37 pp 173–183
[11] Miller S N , Kepner W G, Mehaffey M H, Hernandez M, Miller R C, Goodrich D C, Devonald K K, Heggem D T, Miller W P 2002 Integrating landscape assessment and hydrologic modeling for land cover change analysis J Am Water Resour As. 38 pp 915–929
[12] Prakasam C 2010 Land use and land cover change detection through remote sensing approach: a case study of Kodaikanal taluk, Tamil nadu Int J Geomat Geosci. 1(2):150
[13] Quentin F B, Jim C, Julia C, Carole H, Andrew S 2006 Drivers of land use change, final report: matching opportunities to motivations, ESAI project 05116, Department of Sustainability and Environment and primary industries, Royal Melbourne Institute of Technology.
[14] Rimal B 2011 Application of remote sensing and GIS, land use / land cover change in Kathmandu Metropolitan City, Nepal Journal of Theoretical and Applied Information Technology 23(2) pp 80–86
[15] Rawat J S, Biswas V, Kumar M 2013 Changes in land use/cover using geospatial techniques: a case study of Ramnagar town area, district Nainital, Uttarakhand, India Egypt. J. Remote Sens. Space Sci. 16 pp 111–117
[16] Sansare D A and Mhaske S Y 2018 Analysis of Land Use Land Cover Change and its Impact on Peak Discharge of Storm Water Using GIS and Remote Sensing: A Case Study of Mumbai City, India. International Journal of Civil Engineering and Technology (IJCIET) 9(11) pp 1753–1762
[17] Sansare D A, Mhaske S Y 2019 Natural Disaster Analysis and Mapping using Remote Sensing and QGIS Tools for F-North ward, Mumbai City, India Disaster Advances 12 (1) pp 40-50.
[18] Seeber C, Hartmann H, Xiang W, King L 2010 Land use change and causes in the Xiangxi catchment, Three Gorges Area derived from multispectral data J Earth Sci. 21 pp 846–855
[19] Shiferaw A 2011 Evaluating the land use and land cover dynamics in Borena Woreda of South Wollo highlands, Ethiopia J Sustain Dev Afr. 13(1) pp 87–107
[20] Verburg P H, Neumann K and Nol L 2011 Challenges in using land use and land cover data for global change studies Global Change Biology 17(2) pp 974-989
[21] Wagner P D, Kumar S, Schneider K 2013 An assessment of land use change impacts on the water resources of the Mula and Mutha Rivers catchment upstream of Pune, India Hydrol Earth Syst Sci. 17 pp 2233–2246