Analysis and Delineation of Krishna Watershed using Remote Sensing Data and GIS

Jahnavi Puppala
Department of Civil Engineering
Rajiv Gandhi University of Knowledge Technologies
Srikakulam, India

Jeevan Madapala
Assistant Professor, Department of Civil Engineering
Rajiv Gandhi University of Knowledge Technologies
Srikakulam, India

Abstract— **The software ArcGIS 10.2 was used to delineate and analyze the Krishna Watershed in India. Parameters like area, shape, length of drainage, drainage density, stream order, elevation and slope of the watershed were derived and presented. ASTER GDEM tiles lying in the study area were downloaded, mosaicked, clipped to the basin extents and processed to derive basin properties. For the years 1995 and 2005, LULC maps were prepared with LANDSAT data and available data in NASA's ORNL DAAC portal. The results showed that in the period 1995-2005, a large proportion of land was converted to developed land or built-up area, with an increase of almost 50% with respect to the initial area in 1995 and a 3% increase in agricultural land was observed. The maps offer quantifiable LULC change detection and would be invaluable as input for other applications such as hydrological modelling and LULC change prediction.**

Keywords—LULC mapping; ArcGIS; Watershed Delineation; LANDSAT data; Watershed characteristics.

I. Introduction

The influence of widespread LULC change on the intrinsic environment are multi-faceted, including alteration of hydrological cycle, climate change, increased water extraction, degradation of water quality, threatened biodiversity, imbalance of soil nutrients and aggravated erosion of soil [1]. In this context, it is essential that we study how anthropogenic activity is affecting the LULC.

Quantification of these LULC changes is quite useful at the level of a watershed, an independent geographical area with a complete hydrological cycle. The equilibrium of a watershed is a delicate balance that is easily upset by various factors. Among these, anthropogenic changes are the most noticeable, owing to the current trend of urbanization and socio-economic development, causing undesirable changes on a large scale in the context of a watershed.

Urbanization leads to increase in impervious surface, decreasing the total area available for infiltration of the rainwater received by the catchment, thus altering natural terrain properties, vegetation and soil characteristics. It causes a multitude of problems like increased frequent floods with spiked peak flow, increased sediment loadings, droughts, decreased base flow, changing stream morphology, fluctuating stream temperatures causing thermal shocks, and loss of aquatic and riparian habitat.

Having comprehension of LULC and its change is essential for effective management and planning of natural resources [2]. The most efficient method to map the dynamic LULC changes is to use Remotely Sensed data and a Geographic Information System. It is almost impossible for manual surveys alone to be made on a scale large enough to be of any value to the current scope of planning and development. Progress in the research of RS tools with the aid of Geographic Information System (GIS) makes this technique a success and enables a wider scope of research including LULC change detection, building LULC models and prediction of LULC [3].

The aim of this study is to analyze the LULC changes in the Krishna Watershed in India by quantifying the economic growth and development of the watershed with land use as a gauge of reference. LULC change over the years of 1990, 2000, 2010 and 2020 is compiled and maps are documented as part of this study.

II. Literature Review

The terms "land use" and "land cover" are used interchangeably. Land use is "the total of all arrangements, activities and inputs that people undertake in a certain land cover type". By contrast, Land cover "is the observed physical and biological cover of the earth's land as vegetation, rocks, water body or man-made features" [4]. Environmental factors such as soil characteristics, climate, topography, vegetation, water body, etc. determine land use. Therefore, knowledge of past changes in land use and projecting future trends need understanding the interaction of the basic human motives that drive production and consumption [5].

Land-cover characterization, mapping and monitoring are the most important and typical application of remotely sensed data. Remote Sensing and Geographical Information System (GIS) provides a modern foray into the various issues of ecosystem and watershed management [6]. The technique has been used extensively in the tropics for generating valuable information on the forest cover, vegetation type and land use changes [7]. The availability of accurate and timely land cover datasets plays an important role in many global change studies

[8]. But there still exist data gaps, especially in developing countries. They seem to sometimes lack consistent data collection and sharing frameworks, despite there being extensive change evident in land systems [9].

But new opportunities are arising to fill the existing data gaps and to derive new land use intensity indicators. Data availability is rapidly improving, and new algorithms and computer processing capacities allow for better use of these datasets [9]. Multispectral and multitemporal continuous scanning of earth surface by Landsat satellite facilitates applications in forestry, urban sprawl, agriculture, vegetation [10]. Hence, Landsat imageries are extensively used in LU/LC studies for image classification processes and mapping. Landsat data acquired for different periods encompass consistent geometry throughout the region. The Landsat database is collected and the images are mosaiced to cover the study area or region [11]. This allows for students and civilians to access the open-source data and generate maps expressing LULC parameters for educational and research purposes.

III. MATERIAL AND METHODOLOGY

A. Study Area

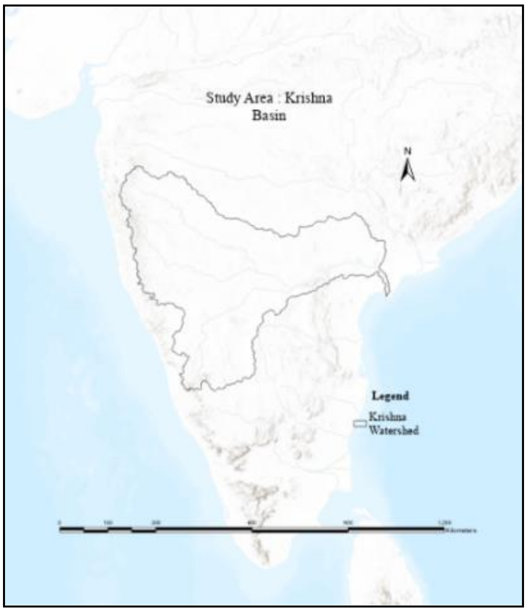


Fig. 1. Study Area: Krishna Watershed

The Krishna basin or watershed lies between the latitudes 13° 07’ N and 19° 20’ N and longitudes 73° 22’ E and 81° 10’ E. On the north, the basin is bound by the range separating it from the Godavari basin, on the south and east by the Eastern Ghats and on the west by the Western Ghats. The total drainage area of the basin is around 258,948 km^2 [12].

B. Data

Remote Sensing Data was used. Landsat 8 OLI (Operational Land Imager) and TIRS (Thermal Infrared Sensor), Landsat 7 and Landsat 4/5 TM data was used in this study. The Landsat images were downloaded from ‘EarthExplorer’ in the USGS official website, ‘earthexplorer.usgs.gov’. There is also readily available decadal LULC mas for India in NASA’s ORNL DAAC portal. The map is available as a raster with each LULC class being assigned a different value.

C. Methods

The Digital Elevation Model data was fed into the software and a multitude of tools were used to determine the characteristics of the watershed. ArcGIS 10.2.2 was used for mosaicking DEM data of the entire study area. Processing and sub-basin delineation. An overview of a basin properties derivation process is represented in a schematic diagram in “Fig.2.” Each of the tools shown is used in succession to derive parameters like slope, stream network and stream order for each sub-basin.

The Landsat data was used for the generation of LULC maps in Arc-map, part of ArcGis.10.2. After mosaicking the Landsat images, the resultant was clipped to the study area for 1991, 2001, 2013 and 2021. The method followed for LULC map creation:

- Band Composition was done for multi spectral bands from band 1 to band 7.
- A Supervised classification method was carried out using training areas and test data for accuracy assessment.
- Maximum Likelihood Algorithm was employed to detect the land cover types as described in Table 1.
- The changes in the LULC maps of consecutive years were analyzed using appropriate GIS tools.
- The quantified change in LULC between the years was tabulated for easy interpretation.

There is also readily available decadal LULC maps for India in NASA’s ORNL DAAC portal. The map is available as a raster with each LULC class being assigned a different value. The raster was first clipped to the extent of the study area. There were 19 classes in total, which are described in Table 1.

TABLE 1 PIXEL VALUE AND CORRESPONDING CLASS

Pixel Value	Class	Pixel Value	Class
1	Deciduous Broadleaf Forest	11	Aquaculture
2	Cropland	12	Mangrove Forest
3	Built-up Land	13	Salt Pan
4	Mixed Forest	14	Grassland
5	Shrubland	15	Evergreen Broadleaf Forest
6	Barren Land	16	Deciduous Needleleaf Forest
7	Fallow Land	17	Permanent Wetlands
8	Wasteland	18	Snow & Ice
9	Water Bodies	19	Evergreen Needleleaf Forest
10	Plantations		

It is difficult and not feasible to work with so many LULC classes. The raster was therefore reclassified into fewer classes for easier handling of the data.

Reclassified Classes:

TABLE 2 RECLASSIFIED PIXEL VALUE AND CORRESPONDING CLASS

Pixel Value	Class	Pixel Value	Class
1	Water Bodies	4	Forest >60%
2	Developed Land	5	Forest 60% to 10%
3	Agriculture	6	Degraded Forest

The reclassified raster was then geo-processed and the LULC change between the years of 1995 and 2005 was the methods used are briefly described in "Fig.5."

IV. RESULTS AND DISCUSSIONS

A. Watershed Properties

Before the LULC changes over the years were analyzed, the basic physical properties of the Krishna Watershed were derived. The entire watershed was divided into 7 sub-watersheds and the properties such as area, slope and drainage density were found using ArcGIS 10.2.2 Desktop Application. The results are tabulated in "Table. 3" for easier comprehension.

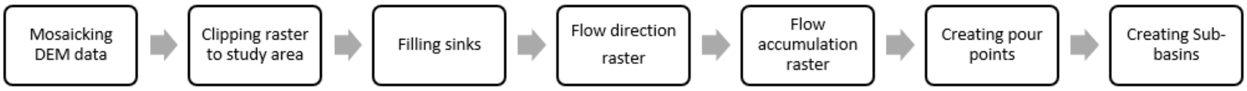


Fig. 2. Terrain Processing

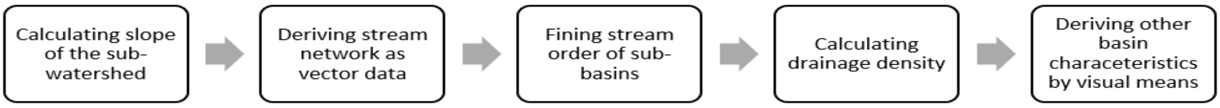


Fig. 3. Watershed and sub-watershed characteristics derivation

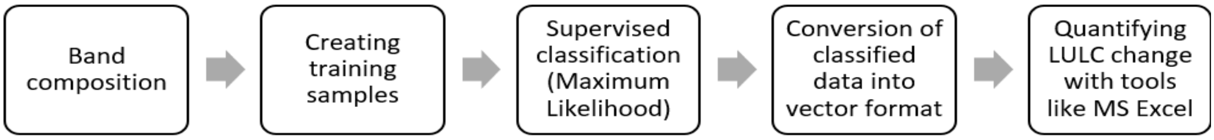


Fig. 4. Analysis of land use and land cover changes

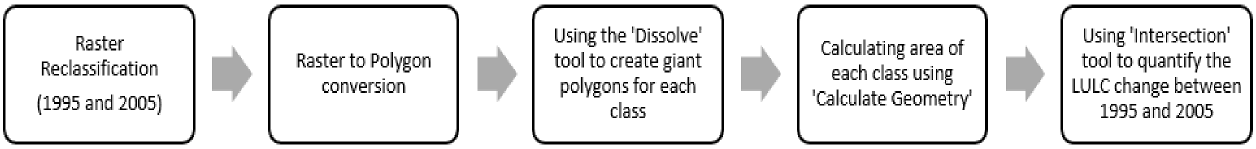


Fig. 5. Quantifying land use and land cover changes between two different years

B. LULC Change ove the years

The LULC maps for reclassified classes was done in ArcGIS Pro using the Layout option. The maps for the Krishna Watershed in 1995 and 2005 are shown in "Fig.6" and "Fig.7."

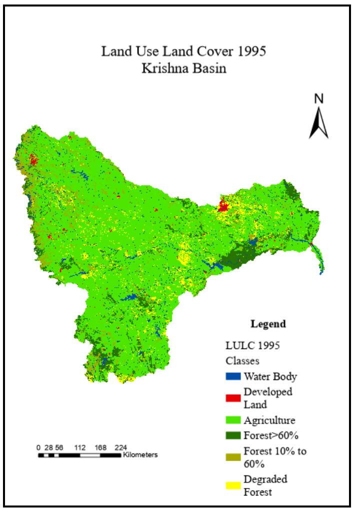


Fig. 6. Land use and land cover map for 1995

The area occupied by each class for the Krishna Watershed was found out and tabulated as shown in "Table. 4." Each class was also expressed as a percentage of the total area.

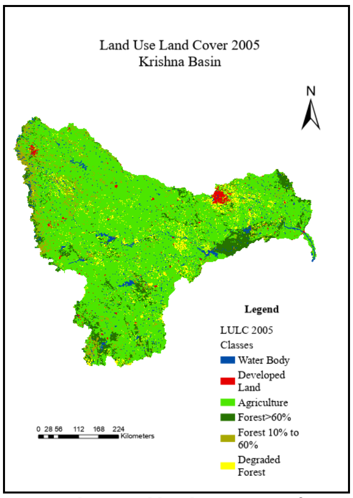


Fig.7. Land use and land cover map for 2005

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 03, March-2022

Table 3 Characteristics of Krishna Watershed

Basin name	Image	Basin Property	Value
Krishna watershed		Area in Square Kilometers	258784.5
		Shape	Short-narrow
		Length of Drainage	44365.987 Km
		Drainage Density	0.171025
		Highest Stream Order	7
		Elevation (Meters above mean sea level)	High:1888
		Slope legend: Very Gentle slope Gentle Slope Moderate Slope Strong slope Extreme Slope Steep Slope Very Steep	
Sub watershed 1		Area in Square Kilometers	50152.3
		Shape	Long basin
		Length of Drainage	8585.2 Km
		Drainage Density	0.171266
		Highest Stream Order	6
		Elevation (Meters above mean sea level)	Low:348 High:1479
		Slope legend: Very Gentle slope Gentle Slope Moderate Slope Strong slope Extreme Slope Steep Slope Very Steep	
Sub watershed 2		Area in Square Kilometers	20365
		Shape	Fan- shaped
		Drainage Length	3377.1 Km
		Drainage Density	0.166466
		Highest stream order	6
		Elevation (Meters above mean sea level)	Low:300 High:724

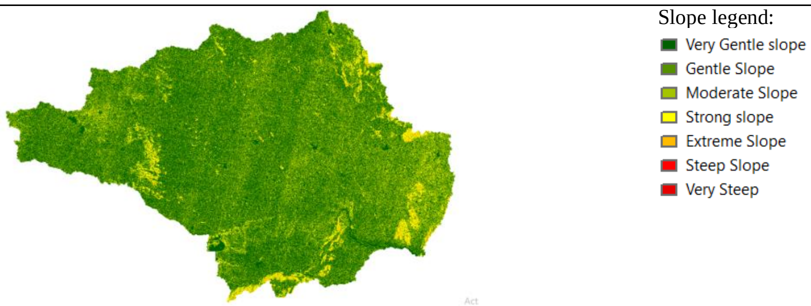
International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 03, March-2022

<table>
<tr><td></td><td></td><td colspan="2">Slope legend:</td></tr>
<tr><td rowspan="7">Sub watershed 3</td><td rowspan="6"></td><td>Area in Square Kilometers</td><td>55821</td></tr>
<tr><td>Shape</td><td>Short- narrow</td></tr>
<tr><td>Drainage Length</td><td>9103 Km</td></tr>
<tr><td>Drainage Density</td><td>0.163122</td></tr>
<tr><td>Highest stream order</td><td>5</td></tr>
<tr><td>Elevation (Meters above mean sea level)</td><td>Low:308
High:1435</td></tr>
<tr><td></td><td colspan="2">Slope legend:</td></tr>
<tr><td rowspan="7">Sub watershed 4</td><td rowspan="6"></td><td>Area in Square Kilometers</td><td>33288.1</td></tr>
<tr><td>Shape</td><td>Long-narrow</td></tr>
<tr><td>Drainage Length</td><td>5764.2 Km</td></tr>
<tr><td>Drainage Density</td><td>0.173405</td></tr>
<tr><td>Highest stream order</td><td>5</td></tr>
<tr><td>Elevation (Meters above mean sea level)</td><td>Low:343
High:1888</td></tr>
<tr><td></td><td colspan="2">Slope legend:</td></tr>
</table>

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 03, March-2022

Sub watershed 5		Area in Square Kilometers	48583.8
		Shape	Long-narrow
		Drainage Length	8767.6 Km
		Drainage Density	0.181079
		Highest Stream Order	6
		Elevation (Meters above mean sea level)	Low:219 High:1881
		Slope legend: Very Gentle slope Gentle Slope Moderate Slope Strong slope Extreme Slope Steep Slope Very Steep	
Sub watershed 6		Area in Square Kilometers	10974.8
		Shape	Short basin
		Drainage Length	1899.6 Km
		Drainage Density	0.173979
		Highest Stream Order	5
		Elevation (Meters above mean sea level)	Low:127 High:892
		Slope legend: Very Gentle slope Gentle Slope Moderate Slope Strong slope Extreme Slope Steep Slope Very Steep	
Sub watershed 7		Area in Square Kilometers	36479
		Shape	Long basin
		Drainage Length	6478.3 Km
		Drainage Density	0.177595
		Highest stream order	6
		Elevation (Meters above mean sea level)	Low:3 High:785

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 03, March-2022



The LULC change over the years was obtained and the positive (increase of area in that specific class) and negative change is calculated for each class. The change was expressed as a percentage of the total area of the watershed and as a percentage of the initial area of the specific class in "Table. 5."

Table 4. Result of LULC Classification for 1995 and 2005

Year	1995		2005	
LULC Class	**Area in Square Kilometers**	**Percentage of Total area**	**Area in Square Kilometers**	**Percentage of Total area**
Water Body	8760.6	3.3	8971.95	34.58
Developed	2218.3	0.855	3317.73	12.789
Agriculture	196388.3	75.7	197397.1	760.95
60% Forest	20023.7	7.719	20015.1	77.157
10-60% Forest	17049.7	6.57	16878.59	65.06
Degraded Forest	14966	5.769	12826.2	49.44
Total	259406.6	99.9= 100%	259406.6	999.9=100%

Table 5. Land use and land cover change between 1995 and 200 for Krishna Basin

Year	1995 to 2005		
LULC Class	Change in square Kilometers	Change with respect to Initial area in 1995	Change with respect to total area of watershed
Water Body	211.28	2.41 %	0.814 %
Developed	1099.497	49.566 %	4.238 %
Agriculture	1008.75	0.51 %	3.8886 %
60% Forest	-8.622	-0.043 %	-0.0332 %
10-60% Forest	-171.087	-1.0034 %	-0.659 %
Degraded Forest	2139.76	-14.297 %	-8.2487 %

C. Discussions

It can be observed from Table. 4 that Developed land increased the most between 1995 and 2005, displaying a growth of almost 50% with respect to the initial area in 1995. The most noticeable decrease was observed in degraded forest or barren land, with a decrease of 14%. It is safe to assume that of all the classes, urban expansion occurred the most in barren land and degraded forest areas.

The increase in water bodies in 2005 could be due to the data being gathered in the monsoon season as opposed to the drier months as was done for the data for 1995. Noticeable increase in agricultural land (3.8%) was also observed in the decade. Thick forest (>60%) saw the least variation between 1995 and 2005.

V. Conclusion

A change analysis based on remote sensing imagery from different sensors, and readily available data from portals like ORNL DAAC made it possible to quantify and map the changing pattern in LULC in the Krishna River Watershed between 1995 and 2005. With a time-series of maps, change analysis can reveal the overall development of land distribution, including the detection of sites of different types of changes. Analyzing and mapping the trends of LULC changes in the Krishna Watershed provides a basis for strategic planning, managing, and protection decision-making. It also serves as the basic input of variety of other applications such as rainfall-runoff modelling, mapping artificial groundwater points, and the likes. However, the use of multispectral satellite imagery with finer resolution may offer more details of changes in the area.

Based on the analysis of ORNL DAAC Decadal Land Use and Land Cover Classification data available for the years 1995 and 2005, it was found that the LULC change trends varied significantly in certain classes in the mentioned duration. The results showed that in the period 1995-2005, most LULC were converted to developed land or built-up area, with an increase of almost 50% with respect to the initial area in 1995. This expansion could most likely be owed to the increasing population and migration of certain demographics to urban areas for a plethora of reasons. Noticeable decrease was felt in barren land between 1995 and 2005. There was also an increase of 3% in agricultural land of with respect to the total area. This increase can also be attributed to farmers expanding crop land to accommodate the requirements of a growing population. Although it is not possible to derive deterministic cause and effect of the LULC variation between a single decade from the present analysis, it would fairly easy to deduce the trend of LULC change with analysis done over a longer time period. The quantified results and maps generated here would definitely prove useful for further application and obtaining a broad sense of LULC change in the specific decade.

Acknowledgment

The authors would like to express their sincere gratitude to the IIIT Srikakulam Administration for their unwavering support in this endeavor. They are also grateful to NASA's

'EarthExplorer' and ORNL DAAC portals for making available the necessary data. They would also like to use this opportunity to express their gratitude to all their peers and colleagues who helped complete the paper by providing insight and much needed perspective.

REFERENCES

[1] Turner, B. L. (2007). The emergence of land change science for global environmental change and sustainability. *Proceedings of the National*, 104.

[2] N.SN, L. (2008). Methodologies for Mapping Land Cover/Land Use and its Change. In L. S, *Advances in Land Remote Sensing.* Dordrecht: Springer, Dordrecht. doi:https://doi.org/10.1007/978-1-4020-6450-0_13

[3] Araya, Y. H. (2009). URBAN LAND USE CHANGE ANALYSIS AND MODELING: A CASE STUDY OF SETÚBAL AND SESIMBRA, PORTUGAL. Institute for Geoinformatics , Münster.

[4] U.N.F.A.O. (1997). *United Nation Food and Agricultural Organization, Online Journals*. Retrieved from United Nation Food and Agricultural Organization: http://www.npc/gov.ng.com

[5] I.I. Abbas, K. M. (2010). Mapping Land Use-land Cover and Change Detection in Kafur Local Government,Katsina, Nigeria (1995-2008) Using Remote Sensing and Gis. *Research Journal of Environmental and Earth Sciences* , 7.

[6] P. K. Yadav, M. K. (2012). Land Use Land Cover Mapping, Change Detection and Conflict Analysis of Nagzira-Navegaon Corridor, Central India Using Geospatial Technology. *International Journal of Remote Sensing and GIS, Volume 1, Issue 2,* , 9.

[7] Forman, R. (1995). *Land mosaics: The ecology of landscape and region.* Cambridge UK.: Cambridge university press.

[8] P.Giri, C. (2012). Remote Sensing of Land Use and Land Cover: Principles and Applications. CRC Press.

[9] Tobias Kuemmerle, K. E. (2013). Challenges and opportunities in mapping land use intensity globally. *Current Opinion in Environmental Sustainability*, 10. doi:http://dx.doi.org/10.1016/j.cosust.2013.06.002

[10] McCallum, I. O. (2006). A spatial comparison of four satellite derived 1 km global land. *International Journal of Applied Earth Observation and Geoinformation*, 8.

[11] Vidhee Avashia, S. P. (2020). Evaluation of Classification Techniques for Land Use Change Mapping of Indian Cities. *Journal of the Indian Society of Remote Sensing*, 32. doi:https://doi.org/10.1007/s12524-020-01122-7

[12] *Krishna*. (2021, August 24). Retrieved from India WRIS: https://indiawris.gov.in/wiki/doku.php?id=krishna