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Spatio-temporal analysis of Upper Tungabhadra Sub Basin, Karnataka, India

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ABSTRACT

An attempt has been made with an aim to document the land use and land cover changes in treated and untreated catchments in the Tungabhadra sub basin using geospatial data of the last three decades representing 1996, 2006 and 2016. The satellite data obtained from Landsat thematic mapper were used for land use and land cover classification. The data sets were processed for False Color Compositeby using ERDAS Imagine 9.3. Three decadal analysis results revealed that barren land is increased to 4.89% and waste land to 37.12%. Alarmingly, the built up area is increased from 143.83 Sq.km (1996) to 583.34 Sq.km (2016). Statistics reveal that, larger area of the catchment was treated with various engineering and biological measures by the authorities (26,350 Sq.km) and whereas a smaller portion of 2766.60 Sq.km is untreated. As it is an irrigated area,the more treatment activities need to be covered by the Watershed Development Department. Land cover analysis revealed that, there is no significant exponential change observed in untreated catchment compared to treated catchment. Hence, due to ineffectiveness or failure of treatment activities in the treated catchments leads to serious ramification on siltation of Tungabhadra reservoir. Thus, water storage capacity has reduced and the purpose of reservoir for which it was built could not be fulfilled.

Key words : *Land use/ Land cover, Treated/Untreated Catchments, RS and GIS, Upper Tungabhadra Sub Basin*

Introduction

Land use refers to purpose of land functions and land cover is defined as physical utilization for various human activities. Mapping of natural resources over a period of time provides significant insights with respect to land and water utilization trends. The spatial and temporal alterations in riverine catchments often results in hydrological changes and affects biotic community (Standford *et al.*, 1996 and Nied *et al.*, 2013). Anthropogenic activities pose threats for reduction in stream flow due to uncontrolled usage of water for irrigation and agriculture activities. Human induced alterations, construction of dams / obstructions across the rivers / streams and climate change variations led to a catchment disturbances and ecological settings (Richter *et al.*, 1998 and Vorosmarty, 2000). Changes in vegetation pattern in the river catchments has influenced over the spatial variability of soil moisture content in the river basins and hydrology (Korres *et al.*, 2015).

As part of Catchment area treatment (CAT) and to reduce soil erosion, many such activitieswere implemented in upper Tungabhadra sub-basin over a period of decades by the Watershed Development Department, Government of Karnataka. However, the rate of siltation of the reservoirs is considerably increasing every year. Thus, effectiveness of the CAT programs and their implications are unknown. Unscientific construction of check dams across streams to reduce soil erosion is temporarily and having short term effects causing downstream erosions. Wherever, protection of catchment with suitable plating of vegetation is possible, it has long term positive effects. Hence, land use changes are important and sustainable while treating the river catchments (Carolina *et al*., 2008). Similarly, land use / land cover change in the catchment are facing several changes over decades leads to lower water availability in the reservoirs. Hence, spatiotemporal analysis of treated and untreated catchments over different variability of land use and land cover is unknown.

Understanding catchment area changes with respect to human interactions spatially is important for policy makers for better catchment area management to avoid sedimentation of reservoirs. With the advancement and in combination with Remote Sensing (RS) data and geographical information system (GIS) spatial analysis of various land use systems over a period of decades becomes a practical tool for policy makers (Lo and Choi, 2004). Landsat-TM monitors earth surface continuously over three decades and provide useful information on changes in land use and cover for various geographic area. Quite a good number of studies were documented the methodology and data pre-processing techniques involved in RS and their importance towards obtaining accurate data (Scheidt *et al*., 2008 and El Bastawesy *et al*., 2013). Integration of remote sensing with spatial analysis plays a significant role during decision making processes for resources based planning for the issues/challenges presently faced by the Tungabhadra sub-basin. The present study aims to document the land use and land cover changes in treated and untreated catchments in the Tungabhadra sub basin using geospatial data of the last three decades representing 1996, 2006 and 2016.

Materials and Methods

Study Area

Tungabhadra sub basin is a part of Krishna basin spread across 29116Sq.km with 45 watersheds constituting 11.2% of the basin. The geographical coordinates of the sub basin extends between $13^{0}05^{|}$ N and $75^{0}15^{|}$ E and $15^{0}40^{|}$ N $76^{0}0^{|}$ E. The sub basin is drained with major rivers namely Tunga, Bhadra, Varada, Kumadvati, Karla Halla, DoddaHalla, Vadaghatte Halla and Hire Halla. These rivers are originating in the Western Ghats with its diverse array of biodiversity. The annual average rainfall in the forest catchment of the sub basin is 2300 mm and 800mm in the non-forest catchments. The basin has two major dams viz., Bhadra Dam is located at the foot hills of Bhadra Tiger Reserve with the gross water storage capacity of 71.50 TMC and Tungabhadra Dam is housed in non-forest catchment storing 132 TMC of water. A medium Dam of Tunga is also present foothills of the forest area with storage capacity of 12.24 TMC of waterand many barrages and lifts are being used for irrigation in the basin. The annual average yield of Tungabhadra sub basin is 580 TMC and out of which 338 TMC of water is used for in basin consumption. The soils of the basin are classified as Clay, loamy and clayey and loamy skeletal. Agriculture is the major occupation in Tungabhadra sub-basin with major crops includes maize, paddy, pulses, cotton, jowar, ragi and sugarcane.

Unlike other basins, Tungabhadra sub basin is also suffering with land use land cover changes due to deforestation, soil erosion, developmental and infrastructure activities leading to sedimentation of reservoirs. The tank irrigation in the Tungabhadra sub basin is drastically reduced from 53.4% in 1957-58 to 9.8% in 2003-04. This reduction is mainly attributed by changes in land use in the catchments and increased siltation in tank bed areas (Paranjape and Joy, 2015). Due to siltation, Bhadra and Tungabhadra reservoirs were reduce inwater storage capacity of 3.38 TMC and 32 TMC respectively (CWC, 2015). The study area map is given below.

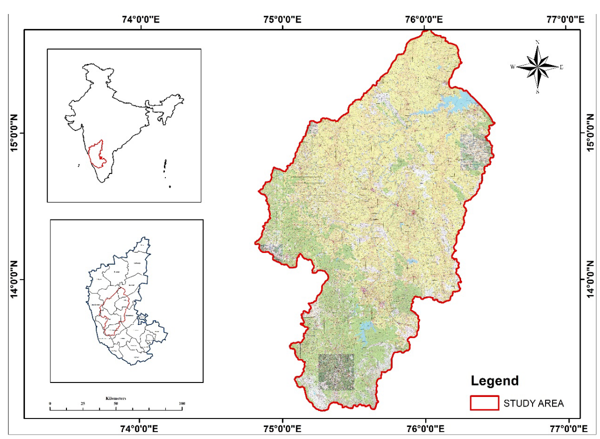

Fig. 1. Study Area Map

Methodology

The satellite data obtained from Landsat thematic mapped were used for land use and land cover classification (Table 1). The data sets were processed for False Color Composite by using ERDAS Imagine 9.3. Layer stacking and sub setting of images were done by using the delineated ground truthing, Normalized Differential indices for Vegetation and Water bodies and built up were used. Maximum Likelihood Algorithm in Supervised Classification method was used to identify the land use land cover classification and by ground truthing, uncertain areas were confirmed. The change detection and analysis were employed for collating qualitative and quantitative information from the satellite data (Rawat and Kumar, 2015; Arveti *et al*., 2016). Maximum likelihood classification was used for land use and land cover classification. By using ground truthing, the misclassified or unclassified areas were corrected using Kappa Khat Method. In the present study,twelve classes of land use types were identified in basin viz., barren land, built up, crop lands, deciduous forests, evergreen forests, fallow land, grass land, mixed forests, plantations, scrub land, waste land and water bodies. Details of CAT status implemented under various programs were obtained from Watershed Department, Government of Karnataka and delineated the boundaries to analyses land and land cover change in treated and untreated areas.

Results and Discussion

Status of land use cover and change

The studies show that over two decades (2006-2016), there is a significant change in land use land cover predominantly in terms of waste lands (17.54 sq. km. in 2006 to 873.29 sq. km. in 2016) with a change of 37.12%, barren lands (24.65 sq. km. in 2006 to 125.52 sq. km. in 2016) with a change of 4.89 %, built-up area (143.83 sq. km. in 2006 to 583.34 sq. km. in 2016) with a change of 1.06% and mixed forest (1227.86 sq. km in 2006 and 2428.07 sq. km. in 2016) by 1.03% (Table 2). The results are in agreement with the previous research studies (Venkatesh and Ramesh, 2018) Other observations includes that there is a decrease in the area of crop land by 0.03%, fallow land by 0.45%, plantation by 0.70% & scrub lands by 0.44% and that there is an increase in the area of deciduous forests by 0.04%, grasslands by 0.15% & water bodies by 0.16% (Fig. 2). This shows that the human anthropogenic activities such as ur-

Table 1. Data used for land use land cover analysis

Year	Sensor	Spatial Resolution
1996	Lands at 5 Thematic Mapper (TM), Enhanced Thematic Mapper (ETM+), Linear Imaging Self-Scanning Sensor – 1, LISS I	30 and 72 m(resampled to 56 m)
2006	Landsat 5 and Resources at ETM+, LISS III	30 and 23.5 m
2016	Resources at IRS-P6 LISS-III	23.5 m

Table 2. Land use and land cover (Sq.Km) in the study area

Sl.No	Type	1996	2006	%Change	2016	% Change
1	Barren Land	24.65	21.31	-0.14	125.52	4.89
2	Built-up	143.83	283.73	0.97	583.34	1.06
3	Cropland	19228.99	19140.45	0.00	18492.72	-0.03
4	Deciduous Forest	2521.96	2447.43	-0.03	2552.30	0.04
5	Evergreen Forest	858.40	859.63	0.00	920.02	0.07
6	Fallow Land	361.55	397.47	0.10	217.86	-0.45
7	Grassland	231.08	229.70	-0.01	265.09	0.15
8	Mixed Forest	1227.86	1198.63	-0.02	2428.07	1.03
9	Plantations	1778.87	1933.85	0.09	587.17	-0.70
10	Scrub Land	1569.39	1550.74	-0.01	876.03	-0.44
11	Waste Land	17.54	22.91	0.31	873.29	37.12
12	Water Bodies	1152.73	1031.03	-0.11	1195.45	0.16
	Total	29116.85	29116.85		29116.85	

banization, local encroachments, pressure on existing trees for fuel wood, improper management of forest land, tree felling activities, etc. have significantly affected the land use and land cover of the Tungabhadra sub basin especially built up area and waste lands.

During the first decade (1996-2006), there is a minimal decrease in the barren land by 0.14%, deciduous forest by 0.03%, grass land by 0.01%, mixed forest by 0.02%, scrub land by 0.01% and water bodies by 0.11%. During the second decade (2006-2016), there is a minimal decrease in the cropland by 0.03%, fallow land by 0.45%, plantations by 0.70% and scrub land by 0.44%. This is mainly due to human anthropogenic activities such as encroachment for developmental activities, pressure on existing tree species within the forest land and scrub lands for fuel wood by local people.

Similarly, during the first decade (1996-2006), there is a minimal increase in the built up land by 0.97%, waste land by 0.31% and there was no disturbance caused to the area of the evergreen forest. During the second decade (2006-2016), an increase in the barren land by 4.89%, built up by 1.06%, deciduous forest by 0.04%, evergreen forest by 0.07%, grassland by 0.15%, mixed forest by 1.03%, waste land by 37.12% and water bodies by 0.16%. This is mainly due to urbanization, local encroachments, pressure on existing trees for fuel wood, improper management of forest land, tree felling activities, etc.

Status of land cover change in treated and untreated catchments

In the treated catchment of the Tungabhadra sub-basin, there is a continual increase in the land use land cover percentage of built up area by 1.44% during 1996-2006 and 1.24% during 2006-2016, Evergreen forest by 0.07% during 2006-2016 and significant increase in the waste land by 0.31% during 1996-2006 and 35.31% during 2006-2016. Other significant observation was that there is increase in the barren land by 4.84% (Table 3) and mixed forest by 1.09% respectively during 2006-2016.

Similarly, in the untreated catchment of Tungabhadra sub-basin, there is a continual increase in the land use land cover percentage of built-up area by 0.31% during 1996-2006 and 0.56% during 2006-2016 and evergreen forest by 0.01% during 1996-2006 and 0.04% during 2006-2016. In addition to this, the barren land usage percentage has increased by 1.07% during 2006-2016 and fallow land by 3.02% during 2006-2016.

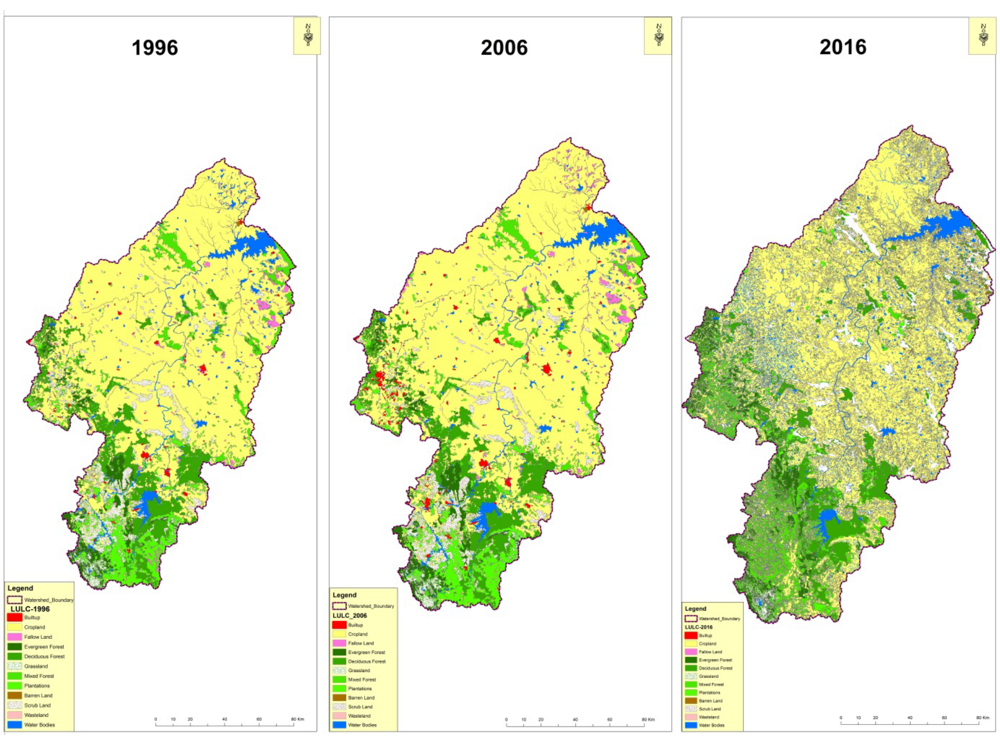

Fig. 2. Land use/ Land cover classification of Tungabhadra sub basin

Table 3. Land use and land cover change (%) in the untreated and treated catchments

Sl. No.	Type	Untreated Catchment		Treated Catchment	
		1996-2006	2006-2016	1996-2006	2006-2016
1	Barren Land	0.00	1.07	-0.14	4.84
2	Builtup	0.31	0.56	1.44	1.24
3	Cropland	-0.01	0.01	0.00	-0.04
4	Deciduous Forest	-0.01	-0.04	-0.03	0.06
5	Evergreen Forest	0.01	0.04	0.00	0.07
6	Fallow Land	-0.54	3.02	0.16	-0.58
7	Grass Land	0.00	0.00	-0.01	0.15
8	Mixed Forest	0.24	-0.22	-0.03	1.09
9	Plantations	0.21	-0.85	0.08	-0.68
10	Scrub Land	-0.27	-0.62	0.00	-0.43
11	Waste Land	0.00	0.00	0.31	35.31
12	Water Bodies	0.01	0.10	-0.13	0.17

Conclusion

The results indicated that, the human anthropogenic activities have increased in both treated and untreated catchments were observed with an increased percent of built up area and wastelands. In addition to this, only a minute increase in the evergreen forests is noticed. The percentage of the forest land is very low in both treated and non-treated catchments. The threat on the forest land/scrub lands in the region apart from the protected areas and its Eco-sensitive Zones is very high due to removal of vegetation for various purposes. This conveys the significant role played by the trees/vegetation in altering the micro-climatic change, soil conservation, ground water table and surface water in the catchment. This also questions the effectiveness of the implementation of the catchment area treatment plan in the Tungabhadra sub-basin. Maintenance of soil moisture contents in the catchment area especially in non-forest landscapes helpful in increasing water availability as well. The soil erosion occurrences were noticed significantly in the non-forest land compared to forest land. This leads to sedimentation and siltation of existing reservoirs thereby lead to downstream floods during the monsoon. Therefore, it is essential to ensure the effectiveness of the implementation of CAT plan in the study area irrespective of the area being treated by the existing/upcoming irrigation schemes or by the Watershed Department of the Government in the surrounding areas.

The land use and land cover changes of treated and untreated catchments in the Tungabhadra sub-basin over a period of time definitely plays a significant role in the understanding the impacts of developmental activities, negligible mindset towards conservation aspects, etc. The process of urbanization and human anthropogenic activities such as conversion of vegetation land into built up area, removal of trees for unscientific purposes, improper management of existing lands leads to the formation of wastelands making it unfit for any further greenery activities. It is also essential to ensure the effectiveness of the CAT plans being implemented in the Tungabhadra sub-basin and ensure the plantation activities being done along with its maintenance. Because in doing so, the impact of soil erosion/sedimentation/siltation lowers considerably and prevents flooding in the downstream areas thereby saving acres of agricultural yield and livelihood of people.

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References

Ankur Sharma, V. S. Arya, Shashikant, R.S. Hooda, and Sarvan Kumar, 2015. Monitoring Yumuna River Course along Haryana - A Spatio Temporal Change Analysis Study through Geoinformatics. *Intl. Jourl. of Scienc, Engg. and Technology Research*. 4 (11) : 3830-3834.

Arveti, N. Balaji Etikala and Padmanava Dash, 2016. Land Use/Land Cover Analysis Based on Various Comprehensive Geospatial Data Sets: A Case Study from Tirupati Area, South, India. *Advances in Remote Sens-*

ing. 5 : 73-82.

Bin Yong, Liliang Ren, Yang Hong, Jonathan J. Gourley, Xi Chen, Jinwei Dong, Weiguang Wang, Yan Shen and Jill Hardy, 2013. Spatial–Temporal Changes of Water Resources in a Typical Semiarid Basin of North China over the Past 50 Years and Assessment of Possible Natural and Socioeconomic Causes. *Journal of Hydrometeorology*. 14 : 1009-1034.

Brain D. Richter.Jeffrey V. Baumgartner., David P. Braun and Jennifer Powell, 1998. A Spatial Assessment of Hydrologic Alteration within a River Network. *Regulated Rivers: Research and Management*. 14 : 329 - 340.

Carolina Boix-Fayos, Joris de Vente, Maria Martiýnez-Mena, Gonzalo G. Barbera and Victor Castillo. 2008. The impact of land use change and check-dams on catchment sediment yield. *Hydrol. Process*. 22 : 4922 - 4935.

Compendium of Silting of Reservoirs in India, 2015. *Central Water Commission, Government of India.* 3rd Edition. New Delhi. 1- 219.

El Bastawesy, M., Ramadan Ali, R., Faid, A. and El Osta, M. 2013. Assessment of water logging in agricultural megaprojects in the closed drainage basins of the Western Desert of Egypt.*J. Hydro. Earth Sys. Sci.* 17 : 1493 - 1501.

Fei Yuan. Kali E. Sawaya. Brian C. Loeffelholz and Marvin E Bauer. 2005. Land cover classification and change analysis of the Twin Cities (Minnesota) Metropolitan Area by multitemporal Landsat remote sensing. *Remote Sensing of Environment.* 98 (2) : 317-328.

Korres, W., Reichenau, T.G., Fiener, P., Koyama, C.N., Bogena, H.R., Cornelissen, T., Baatz, R., Herbst, M., Diekkrüger, B., Vereecken, H. and Schneider, K. 2015. Spatio-temporal soil moisture patterns – A meta-analysis using plot to catchment scale data. *Journal of Hydrology*. 520 : 326-341.

Lo, C.P. and Choi, J., 2004. A hybrid approach to urban land use/cover mapping using Landsat enhanced thematic mapper plus (ETM+) images. *Inter. J. Rem. Sen*. 25 (14) : 2687-2700.

Nied, M., Hundecha, Y. and Merz, B. 2013. Flood-initiating catchment conditions: a spatio-temporal analysis of large-scale soil moisture patterns in the Elbe River basin. *Hydrol. Earth Syst. Sci*. 17 : 1401–1414.

Rawat, J.S. and Manish Kumar. 2015. Monitoring land use/cover change using remote sensing and GIS techniques: A case study of Hawalbagh block, district Almora, Uttarakhand, India. *The Egyptian Journal of Remote Sensing and Space Sciences.* 18 : 77- 84.

Kukal, S.S. and Bawa, S.S. 2013. Temporal variations in runoff and soil loss in relation to soilconservation practices in catchments in Shiwaliksof lower Himalayas. *International Soil and Water Conservation Research*. 1(2) : 19-25.

Scheidt, S., Ramsey, M. and Lancaster, N. 2008. Radiometric normalization and image mosaic generation of ASTER thermal infrared data: an application to extensive sand sheets and dune fields. *Rem. Sen. Envi*. 112 (3) : 920-933.

Standford, J.A., Ward, J.V., Liss, W.J., Frissel, C.A., Williams, R.N., Lichatowich, J.A. and Countant, C.C. 1996. A General Protocol for restoration of regulated rivers. *Regul. Rivers: Res. Management*. 12 : 391-413.

Suhas Paranjape and Joy, K.J. 2015. Tanks in the Tungabhadra Sub basin and an IWRM Strategy for Tanks: The long and the short view. www.sawasjournal.org. 2 (1) : 1-15.

Venkatesh, K. and Ramesh, H. 2018. Impact of Land use land cover change on run off generation in Tungabhadra River Basin. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume IV-5, ISPRS TC V Mid-term Symposium "Geospatial Technology – Pixel to People", 20–23 November 2018, Dehradun, India. 367-374.

Vorosmarty, C.J. 2000. Anthropogenic disturbance of the terrestrial water cycle. *Bioscience*. 50(9) : 753 -765.

Wang Fang, Ge Quansheng, Yu Qibiao, Wang Huaxin, Xu Xinliang, 2017. Impacts of land-use and land-cover changes onriver runoff in Yellow River Basin for period of 1956–2012. *Chinese Geographical Science*. 27(1) : 13–24. doi: 10.1007/s11769-017-0843-4.