

A STUDY ON TEMPORAL CHANGES OF LAND USE/LAND COVER IN ARKAVATHY RIVER BASIN USING RS & GIS TECHNIQUES

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ABSTRACT

The changing footprints of land use/land cover within a river basin have an impact on the hydrological processes of river basins. Urbanization can affect infiltration whereas increase in forest cover can decrease runoff. The study of such impact on hydrological processes due to the dynamic nature of land use/land cover over a period of time will therefore help in unraveling the causes of water scarcity and drought like conditions occurring in any river basin. Arkavathy river basin, a sub-basin of Cauvery river basin, suffers from severe water shortages every year. Hence, there is a need to assess the temporal changes of land use/land cover to understand the impact on hydrological processes and then identify the causes of water scarcity within the basin. From such analysis, suitable water management solutions can be found to overcome the water scarcity and thwart aggravation of the water crisis.

Therefore, an attempt has been made in this study to analyze the land use/land cover changes in the Arkavathy river basin using Remote Sensing and Geographic Information System (RS and GIS) techniques and its impact on the water availability in the past 25-30 years. Appropriate strategies within the river basin for droughts and water scarcity are then suggested.

Key words: Remote Sensing, Geographic Information System, river basin, hydrology, water scarcity

INTRODUCTION

Land use/land cover of any region on the earth is dynamic due to rapid changes in the socio-economic activities and natural phenomena (Cheruto et al., 2016). In the context of water management within a river basin, the information about the changing footprint of land use/land cover is necessary, because it impacts the hydrological processes such as infiltration and runoff. For example: Increase in urbanization decreases infiltration thereby aggravating groundwater scarcity (Subramanya, 2013). Similarly, increase in forest cover can increase infiltration (Hamilton, 2008). The status of water bodies and cropped land provide vital clues in the pursuit of finding causes and solutions to the issues connected with water scarcity and drought. Hence, the temporal study of land use/land cover changes in a river basin helps in gaining vital knowledge on the impact over the hydrological processes over a period of time. Such knowledge will help in identifying appropriate strategies to overcome situations such as droughts and water scarcity and thwart further aggravation of the water crisis.

STUDY AREA

Arkavathy river basin, a sub-basin of Cauvery river basin, located in South India, has been chosen for the present study. Arkavathy river basin faces the problem of chronic water scarcity amidst widespread groundwater exploitation (Raja Rao, 2009; Srinivasan et al, 2015). According to Rekha (2016), cultivation of water intensive crops such as paddy, sugarcane, cash crops is witnessed in the tank, well and bore-well commands of the basin. This river basin is

experiencing increased economic activities due to the growing metropolitan city of Bengaluru (the capital city of the south Indian state of Karnataka) and other adjoining area, thereby affecting the land use/land cover classes such as water bodies, cropped area, built-up area, etc., over a period of time. Therefore, temporal analysis of land use/land cover changes in Arkavathy river basin provides vital clues about the influence of change in land use/land cover on hydrological processes and the consequent impact on water availability over a period of time. Plate 1 shows the Arkavathy river basin and its location.

The present study quantifies the temporal changes in the land use/land cover for the basin using RS and GIS techniques for the years 1988, 1995, 2002 and 2014 spanning four decades. To overcome the drought and chronic water scarcity in the basin, it is imperative to devise appropriate water management solutions which require the assessment of the impact of temporal changes in land use/land cover on water availability. Keeping the above discussion in view following objectives were formulated for this study.

- i) To study the changes in land use/land cover in the Arkavathy river basin for the period 1987 - 2014.
- ii) Assessing the impact on water availability, causes for water scarcity and solutions for better management of water resources in the Arkavathy river basin.

Data Products

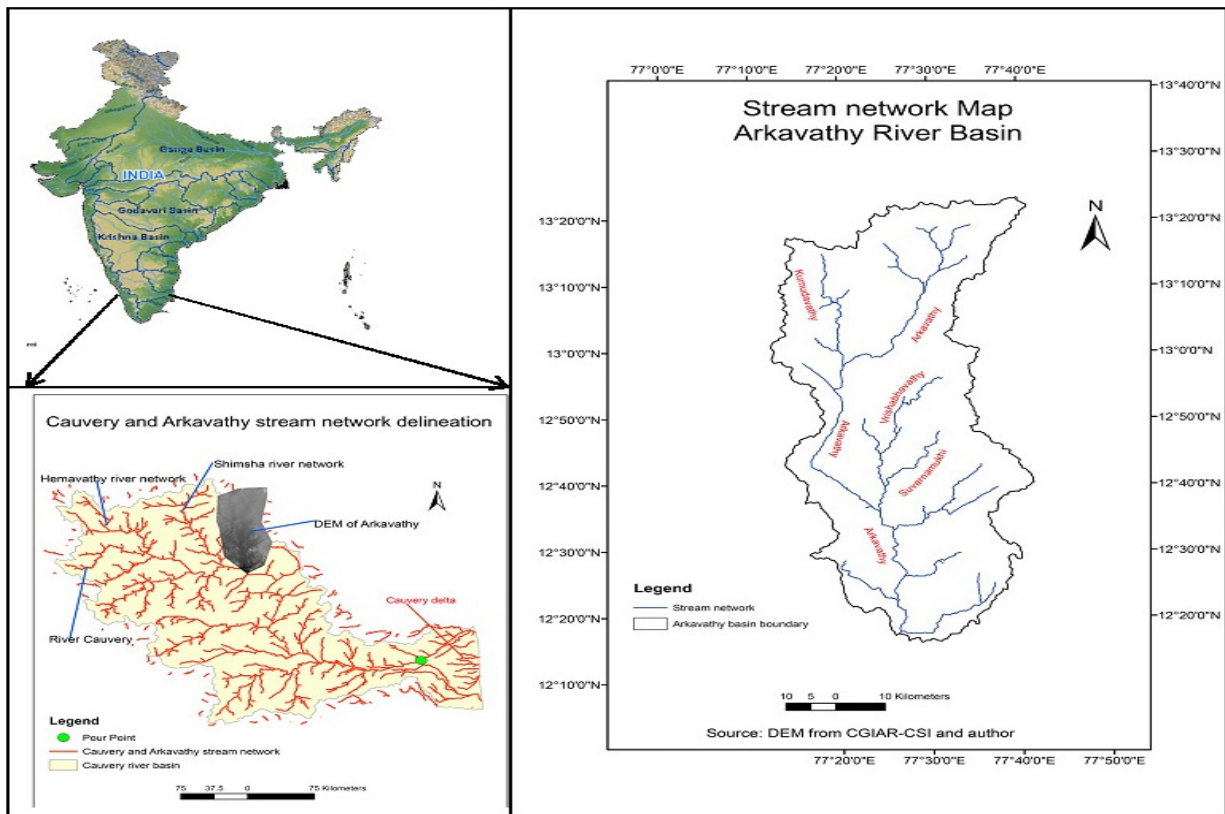
The data products used for the study are,

- i. Landsat satellite images

Multi-temporal Landsat satellite images representing four different decades of 1980s, 1990s, 2000s and after 2010 have been chosen for the study period 1987 – 2014 (27 years). Landsat ETM, Landsat TM and Landsat-8 satellite images are downloaded from USGS earth explorer site for the years 1988, 1995, 2002, 2014. The details of sensors are shown in Table 1.

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(Source: India-WRIS, CGIAR-CSI and authors)

Plate 1 Location of Cauvery river basin and Arkavathy river basin**Table 1. Details of sensors and date of pass**

Satellite	Sensor	Path	Row	Date of Pass	Map Projection/Datum
Landsat 5	TM multi-spectral	144	51	19.01.1988	UTM 43N/WGS 84
Landsat 5	TM thermal	144	51	08.12.1995	UTM 43N/WGS 84
Landsat 7	ETM+ multi-spectral	144	51	03.12.2002	UTM 43N/WGS 84
Landsat 8	ETM+ thermal	144	51	26.11.2014	UTM 43N/WGS 84

ii. Digital Elevation Model (DEM)

The NASA's Shuttle Radar Topography Mission (SRTM) DEM with a resolution of 90 m at the equator pertaining to South India covering the study area of Arkavathy river basin has been downloaded from CGIAR Consortium for Spatial Information site (CGIAR-CSI, 2016).

From the results, the impact of temporal changes on the water availability and the underlying causes of water scarcity in Arkavathy river basin are assessed and appropriate water management solutions are suggested to overcome the drought and chronic water scarcity in the basin. The extracted DEM of Arkavathy river basin is shown in Plate 1.

METHODOLOGY

Arc GIS and ERDAS Imagine software have been used for digital image processing, creation of false colour composite (FCC) layers and classification of information classes for

the quantification of land use/land cover changes in Arkavathy river basin. The methodology is shown in Fig.1.

About 5 land use/land cover classes namely forest, rangeland, agriculture, water, settlements have been used by Torahi and Rai (2011) for evaluation of the changes in land cover for a span of 16 years (1990 – 2006). In the current study, eight land use/land cover classes up to level II classification have been adopted for evaluation of the changes in land use/land cover in accordance with NRSC (2006) and Anderson et al., (1976) for a span of 27 years (1987 – 2014). The standard classification system has three descriptions: Level I, Level II and Level III that depends on quality of satellite images, type of sensor, and level of information required. Level II land use/land cover classes require higher resolution than Level I classes and similarly Level III require higher resolution satellite imagery than Level II as Level III is a more detailed land use/land cover data that require sensor with higher spatial, temporal and

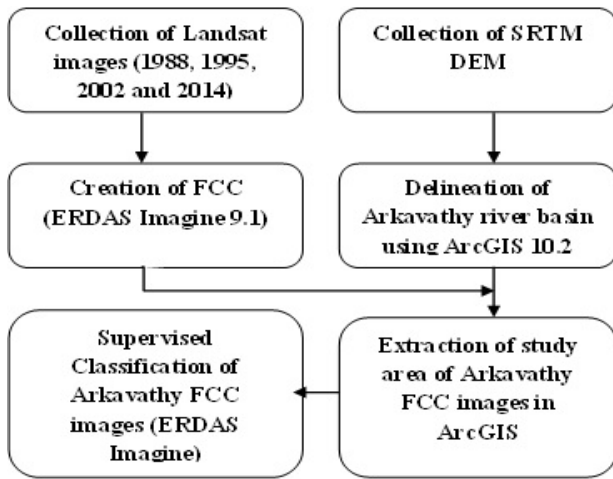


Fig.1: Methodology of temporal analysis using RS & GIS

radiometric resolution. Level I and Level II classes have been chosen for the current study and the same have been extracted using Landsat imagery. The eight land use/land cover classes are shown in Table 2.

Landsat satellite images for the years 1988, 1995, 2002 and 2014 have been classified using supervised classification techniques in ERDAS Imagine. Image classification is a process in which pixels are sorted into a finite number of individual classes or categories of data based on “Digital number” (DN) values of the pixels. Using the algorithm of ERDAS Imagine software, the information from the specified areas of the information class is created which are called as “class signatures”. The process is called “Signature training”. Field visits are conducted to various

parts of the Arkavathy river basin for ground truth verification of the information classes selected for this temporal study (water bodies, vegetation, agriculture crop lands, barren rocky regions, etc.). The supervised classification has been carried out by first creating class signatures pertaining to the information classes like forests, water bodies, built-up area, agriculture using AOI (Area of Interest) tools. At least 10-15 class signatures for each information class are created using the signature tool of ERDAS Imagine to ensure homogeneity of a particular class. Parametric rule maximum likelihood method has been adopted for supervised classification to obtain mean, variance and covariance, and applies probability theory to the classification task which is a superior classification method than others (Bhatta, 2013).

Ground truth verification has been conducted across the basin to verify the classes of land use/land cover identified for the supervised classification.

Table 2.: Land use/land cover classification

Level I	Level II
Built up	Built-up, Urban
	Built-up, Mining
Agriculture	Agriculture, Crop Land
	Agriculture, Fallow
Forest	
Barren/unculturable/wastelands	Scrub Land
	Barren, Rocky
Water bodies/wetlands	Water bodies

(Source: NRSC, 2006)

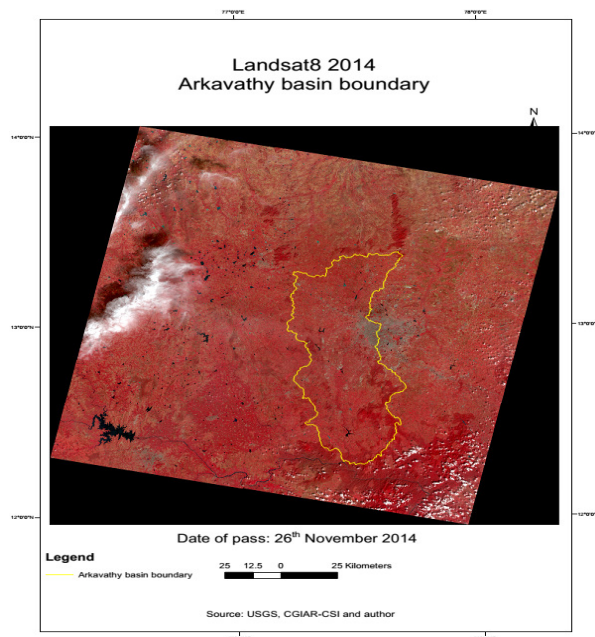
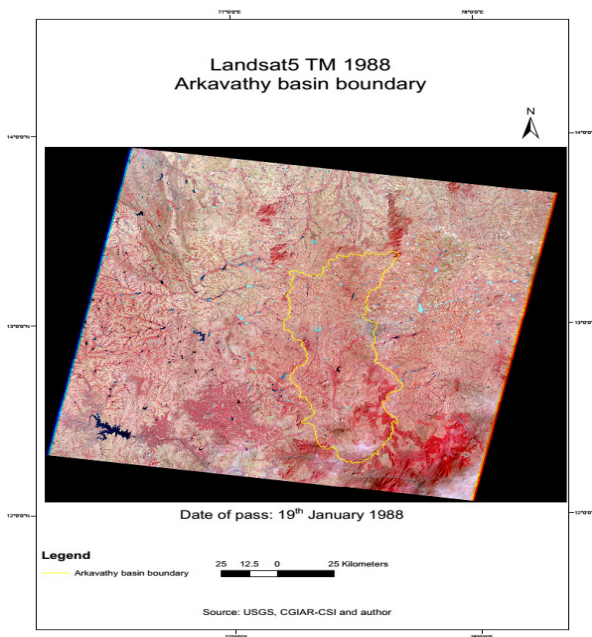


Fig 2: Landsat scene (False Colour Composite): Arkavathy basin boundary
Source: USGS Earth Explorer. (2016)

RESULTS AND DISCUSSIONS

The results of FCC of Landsat satellite scenes for the years 1988 and 2014 are shown in Fig.2. The supervised classification of extracted images of Arkavathy river basin for the years 1988, 1995, 2002 and 2014 is shown in Fig.3.

The area of the eight land use/land cover classes for the four years are compiled in Table 3 and the quantification of the change in land use/land cover during the period 1987 – 2014 are shown in Table 4 and the variation of the same in Fig 4.

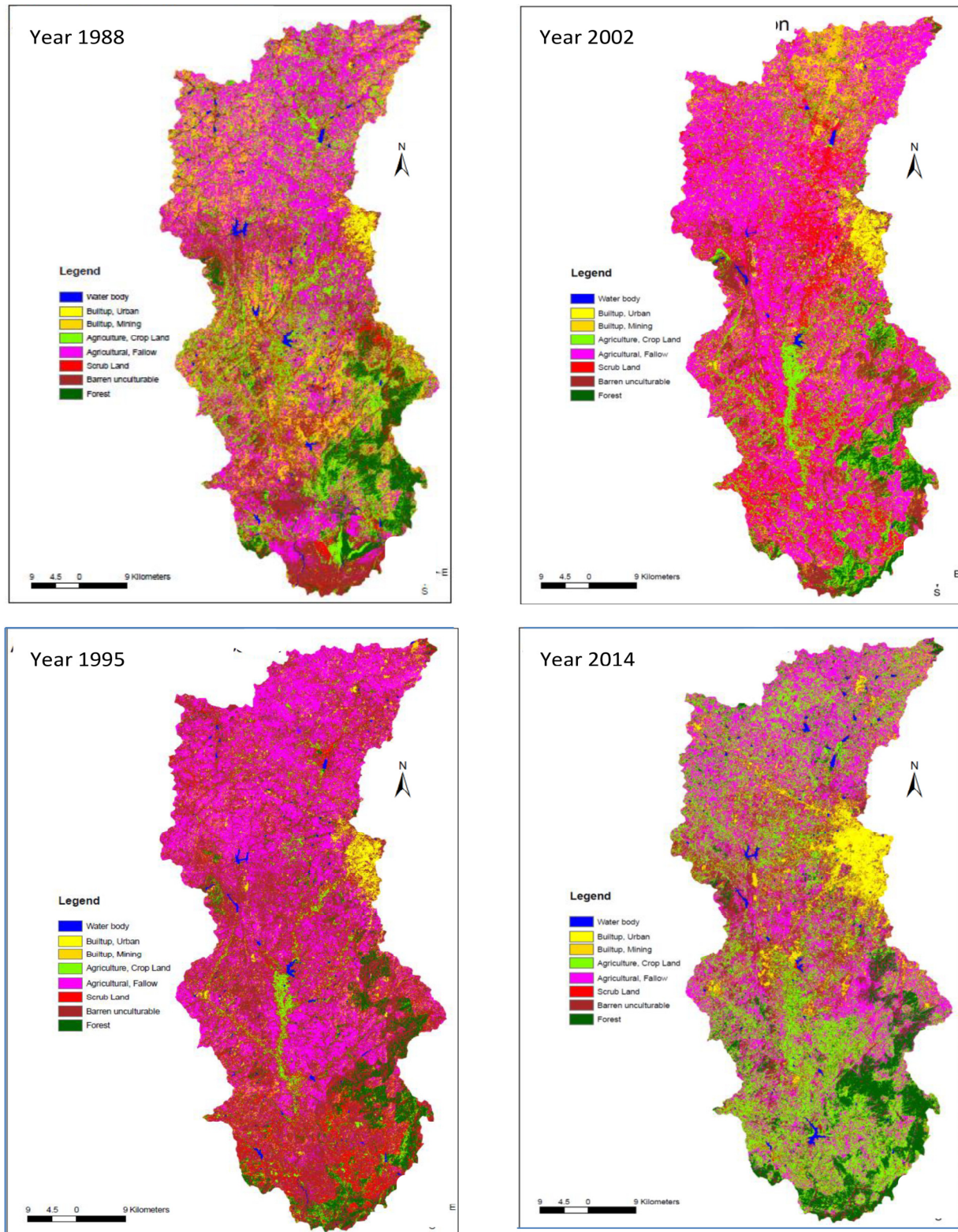


Fig 3: Results of Supervised Classification

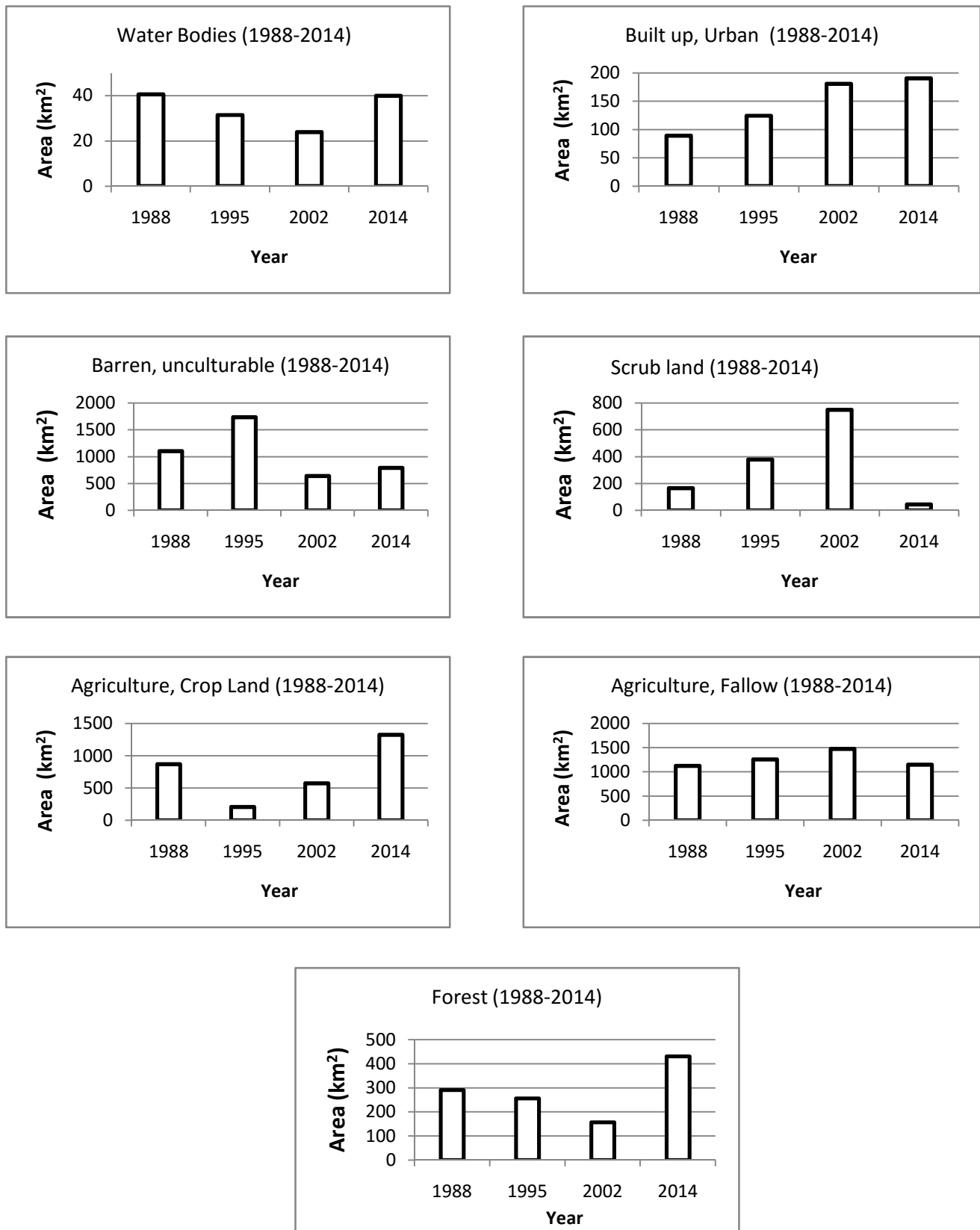


Fig 4 : Temporal variations of land use/land cover in Arkavathy river basin

Table 3: Spatial distribution (km²) of land use/land cover changes in Arkavathy river basin (1988 – 2014)

Level I Classification	Level II Classification	1988		1995		2002		2014	
		Area (km ²)	Area (%)	Area (km ²)	Area (%)	Area (km ²)	Area (%)	Area (km ²)	Area (%)
Built up Area	Built up, Urban	89.33	2.16	124.61	3.01	181.06	4.37	190.69	4.60
	Built up, Mining	451.56	10.90	147.9	3.57	340.46	8.22	169.48	4.09
Agriculture Land	Agriculture, Crop Land	872.9	21.07	206.75	4.99	573.6	13.84	1326.17	32.00
	Agriculture, Fallow	1126.71	27.19	1260.07	30.41	1476.76	35.64	1149.76	27.75
Forest Land		290.87	7.02	256.9	6.20	157.67	3.80	430.89	10.40
Barren/ unculturable/ wasteland	Scrub Land	166.08	4.01	379.44	9.16	751.65	18.14	44.21	1.07
	Barren, Rocky	1105.79	26.69	1736.7	41.91	638.74	15.41	792.65	19.13
Water bodies/ wetlands	Water bodies	40.59	0.98	31.47	0.76	23.89	0.58	39.96	0.96

Table 4 : Percentage variation of land use/land cover changes in Arkavathy river basin (Change in area in km²)

Level 1 Classification	Level 2 Classification	Change (1988-1995)	Change (%)	Change (1995-2002)	Change (%)	Change (2002-2014)	Change (%)	Change (1988-2014)	Change (%)
Built up Area	Built-up, Urban	35.28	39.49	56.45	45.30	9.63	5.32	101.36	113.47
	Built-up, Mining	-303.66	-67.25	192.56	130.20	-170.98	-50.22	-282.08	-62.47
Agriculture Land	Agriculture, Crop Land	-666.15	-76.31	366.85	177.44	752.57	131.20	453.27	51.93
	Agriculture, Fallow	133.36	11.84	216.69	17.20	-327.00	-22.14	23.05	2.05
Forest Land		-33.97	-11.68	-99.23	-38.63	273.22	173.29	140.02	48.14
Barren/ unculturable/ wasteland	Scrub Land	213.36	128.47	372.21	98.09	-707.44	-94.12	-121.87	-73.38
	Barren, Rocky	630.91	57.06	-1097.96	-63.22	153.91	24.10	-313.14	-28.32
Water bodies/ wetlands	Water bodies	-9.12	-22.47	-7.58	-24.09	16.07	67.27	-0.63	-1.55
Negative value signifies decline in area and Positive value signifies increase in area									

Table 5 : Variation of land use/land cover classes with rainfall quantity and drought status in Arkavathy river basin

Date of pass of Landsat image	Rainfall (mm)	Drought Status	Land use/land cover classes (km ²)				
			Water bodies	Agriculture , Crop land	Agriculture, Fallow land	Forest land	Built-up, Urban
19th January 1988	1038.92 (Annual rainfall for 1987-88)	No drought in 1987-88	40.59	872.9	1126.71	290.87	89.33
8th December 1995	757.73 (Annual rainfall for 1995-96)	Moderate drought in 1994-95 and Mild drought in 1995-96	31.47	206.75	1260.07	256.9	124.61
3rd December 2002	458.92 (Annual rainfall for 2002-03)	Mild drought in 2001-02 and Moderate drought in 2002-03	23.89	573.6	1476.76	157.67	181.06
26th November 2014	620.93* (Seasonal rainfall for 2014)	No drought in 2013-14	39.96	1326.17	1149.76	430.89	190.69
* Data is available up to 2014 December. Hence seasonal rainfall is considered.							

The results of the temporal study of the Arkavathy river basin for the study period 1987 - 2014 reveal consistent increase in the built-up urban area. It is observed that the Bengaluru metropolitan area has witnessed tremendous expansion in the basin along with the smaller cities such as Doddaballapura, Nelamangala, and Kanakapura. Table 3, Table 4 and Fig 4 show that there has been an increase of urban area by 113 % between 1988 and 2014. According to Subramanya (2013), the implication of increase of the urban area is felt on the hydrology of the basin in the form of higher surface runoff and lesser infiltration into the ground lead to lower groundwater recharge. Therefore, it can be inferred that urbanization of the basin is one of the causes for water scarcity as the basin is gradually shifting towards a lower groundwater recharge regime with concomitant increase in urban areas. Further, urbanization accompanied with increase in population and industrialization will further increase stress on both surface and groundwater.

Table 3, Table 4 and Fig 4 show that the overall area under agriculture (both under cropped area and fallow) has increased during the period 1987 - 2014. The total area under agriculture has increased from 1999 km² in 1987 to about 2475 km² in 2014. There is a drop in the agriculture area in 1995 and 2002 which is attributed primarily due to less than average precipitation in the Arkavathy river basin of about 653.59 mm in 1994-95, 757.73 mm in 1995-96 and 458.92 mm in 2002-03 (Table 4). The average rainfall for the time series 1987 – 2014 is 874.87 mm as per rainfall analysis conducted in the basin. The implication of increase of cultivated land is the phenomenal rise in demand for fresh water in Arkavathy river basin as agriculture is the largest consumer of freshwater. This trend, if sustained, will aggravate the water crisis in future.

Further it is noticed that the area under cropped land has increased from 872.9 km² in 1988 to 1326 km² in year 2014 an increase of 51.93 % and constituting 32 % of the area of the basin. The increase in agricultural land is at the expense of conversion of the scrub land and barren lands. Barren lands covered an area of 1105.79 km² in 1988 whereas the increase in area of built up urban areas is 101.36 km². The decline in barren lands and scrub land over the period 1988 - 2014 stands at 28.32 % and 73.38 % respectively. The results reveal no conversion of forest lands into agricultural land because there is hardly any expansion in the area of forests in the Arkavathy river basin beyond the geomorphic region of denudational/structural hills in the South and North-Eastern part of the basin. The implication of increase in agricultural land at the expense of the area of scrub land does not alter the hydrology of the basin considerably as infiltration levels of both scrub land and crop lands does not differ much. It is noticed that the fallow agricultural lands in the basin varies depending on the quantity of rainfall occurring in the particular year. For example: There is increase in agriculture fallow lands in year 1995 and year 2002 which is attributed to the below average rainfall in years 1995 and 2002 causing a decrease in crop land and concomitantly, there is a decline in fallow land in 2014 when the rainfall is 914.86 mm i.e. above average rainfall of

874.87 mm in Arkavathy basin. The significance of the increase in cropped land in comparison to fallow lands is that it increases infiltration where decrease in fallow lands decrease infiltration and increase the surface runoff in the basin. Raja Rao, (2009) and Srinivasan et al, (2015) have clearly found that the basin is subjected to groundwater over-exploitation and water scarcity. Table 5 shows that the basin suffers from droughts. Further authors while conducting the rainfall study has found that Arkavathy river basin has suffered 11 drought years (about 40% of the period) during the study period of 1987 – 2014. Against this background, the notable finding of the temporal study has been the stagnation of water bodies for the last 27 years. This is worrisome because without harvesting the rain water, the scope of managing water scarcity and drought in the Arkavathy river basin reduces drastically. The study shows there has been no overall increase in the status of water bodies between 1987 and 2014. The area under water bodies in 1987 was 40.59 km² whereas the area in 2014 is 39.96 km². The percentage change is merely 1.55 %. This shows that the status of water harvesting in the basin has not increased in the past 27 years concomitant with the rise in water demand due to expansion of urban areas and agriculture. The status of water bodies shows that the status of water harvesting in Arkavathy basin is stagnant – a pointer to the poor water management in the basin. The area under water bodies also varies with the availability of the rainfall in the basin. For example: The total area under water bodies in 1987 was 40.59 km² when the rainfall in 1987-88 was 1038.92 mm (which is above the average rainfall of 874.87 mm). The area of water bodies then plummets to 31.47 km² in 1995 and halves to 23.89 km² in 2002 when there was rainfall of 458.92 mm that is deficient by 47.54 % of the average annual rainfall of 874.74 mm which is mild drought (IMD, 2018).

Forests are important land cover that influences the hydrological process. A decrease in forest area increases the runoff and reduction in forest area causes decrease in runoff, though the influence also depends on the area of the basin (Hamilton, 2008). Forests in Arkavathy river basin are not widespread, but they are largely confined to the geomorphic units of denudational and structural hills in the southern Arkavathy river basin in Kanakapura taluk, parts of the western Arkavathy river basin in Ramanagara taluk and north-eastern tip of the basin at Nandi Hills. The total forest lands in Arkavathy river basin of 430.89 km² is observed in 2014 are just 10% of the total area of Arkavathy river basin. The vast geomorphic unit of pediment-pediplain complex that constitutes nearly 83% of the basin continues to lack forested land. Although the area under forest land fluctuates in accordance with the quantity of rainfall, there is hardly any increase of forest land beyond that of the geomorphic region of denudation/structural hills. The relatively low forested lands of 10%, witnessed in Arkavathy river basin, influence the infiltration of rainfall and recharging capacity of the groundwater. The presence of few forests explains the cause of low groundwater potential in the basin. Against the backdrop of over-

exploitation of groundwater, this will accelerate the groundwater scarcity in the basin.

LIMITATIONS

The findings of the current study have been limited to the period 1987-2014 because the integrated study in Arkavathy river basin was commenced from 2014-15 onwards and accordingly rainfall data in Arkavathy river basin was limited for the period 1987-2014. The satellite images are again limited by the availability of minimum cloud cover/cloud free data over the study area for *Rabi* (November-December) season.

The Landsat satellite images used in the current study has a spatial resolution of 30 m which was found to be coarse for distinguishing information classes such as built-up mining areas from built-up urban; forested lands from scrub land; and agricultural fallow lands from barren rocky/unculturable lands. Unsupervised classification was not chosen because of low spectral reflectivity of the satellite images.

CONCLUSIONS

- The temporal study results show the lack of integrated land and water management in Arkavathy river basin.
- The land use/land cover changes for the period 1987-2014 show that the rapid expansion of urban areas, particularly, the Bengaluru metropolitan area and cities such as Doddaballapur, Nelamangala, and Kanakapura etc. This scenario if continued unabated will accentuate the worsening groundwater crisis.
- The study finds that there is no increase in area under water bodies between 1988 and 2014. The change observed is merely 1.55 %. Therefore, any continuation of the status quo will lead to catastrophic water shortages in the basin and low resilience to overcome water scarcity and droughts in the future.
- Between 1988 and 2014, forest land has shown a modest increase of 48.14%. The pediment-pediplain area that constitutes nearly 83% of the area of the basin is devoid of forests.
- The implication of increase in cultivated land is the phenomenal rise in demand for fresh water as agriculture is the largest consumer of freshwater. This will increase the stress on the existing water resources of the basin.
- The study demonstrates no links between land and water management in the basin. The lack of coordinated management of land and water resources reflects disintegrated water management prevailing in the basin thus leading to frequent water scarcity and drought like conditions.

RECOMMENDATIONS

- Groundwater has to be recharged in Arkavathy river basin.

- Considering the fact that the basin has large areas of pediment-pediplain complex to the extent of 83.42 %, there is tremendous scope for afforestation in the non-urban areas to increase the infiltration of rainfall into the grounds the present area under forest land is merely 10%.
- The development paradigm being imposed in the basin due to the Bengaluru metropolitan area (that has accentuated water stress) has to be modified.
- Unplanned and unchecked urbanization in the basin has to be halted and the same has to be diversified outside the Arkavathy river basin. This will reduce demand for water and increase the scope for infiltration of water into ground.
- Resilience of the Arkavathy river basin to overcome water stress has to be increased by increasing the area under surface water bodies.
- Farmers need to be educated and incentivized for enabling change in the mindset for less water intensive cropping patterns as agriculture consumes 80 % of freshwater. More water conservation and water harvesting activities are recommended for the Arkavathy river basin.
- The temporal study of land use/land cover shall be conducted using high resolution satellite images that can identify information classes up to Level III so as to identify crop types and forest types that specifically evaluate the crop water requirement. As agriculture is the largest consumer of freshwater, this information assists in evaluation of the cropping pattern more precisely and measures to reduce water demand.
- Finally, in order to achieve optimum results in the basin, water management should be coordinated with land management in accordance with the temporal study of land use/land cover pattern identified in the study.

DECLARATION

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- ii) Conflict of interest: There is no conflict of interest with this research work.

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