CURRENT WORLD ENVIRONMENT

ISSN: 0973-4929, Vol. 16, No. (3) 2021, Pg. 665-678

Current World Environment

www.cwejournal.org

Land Use/Land Cover (LU/LC) Changes and its impact on Soil Organic Carbon Stock in Killiar River Basin, Kerala, India: A Geospatial Approach

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Abstract

The changes in pattern of land use and land cover (LU/LC) have remarkable consequences on ecosystem functioning and natural resources dynamics. The present study analyzes spatial pattern of LU/LC change detection along the Killiar River Basin (KRB), a major tributary of Karamana river in Thiruvananthapuram district, Kerala (India), over a period of 54 years (1967-2021) through Remote Sensing and GIS approach. The rationale of study is to identify and classify LU/LC changes in KRB using Survey of India (SOI) to posheet (1:50,000) of 1967, LISS-III imagery of 2005, Landsat 8 OLI & TIRS imagery of 2021 and further to scrutinize impact of LU/LC conversion on Soil Organic Carbon stock in the study area. Five major LU/LC classes, viz., agriculture land, built-up, forest, waste land and water bodies were characterized from available data. Within the study period, built-up area and wastelands showed substantial increase of 51.51% and 15.67% respectively. Thus, the general trend followed is the increase in built-up and wastelands area which results in the decrease of all other LU/LC classes. Based on IPCC guidelines, total soil organic carbon (SOC) stock of different land use types were estimated, and was 1292.72 Mt C in 1967, 562.65 Mt C in 2005 and it reduced to 152.86 Mt C in 2021. This decrease is mainly due to various anthropogenic activities, mainly built-up activities. This conversion for built-up is at par with rise in population, and over-exploitation of natural and agricultural resources, is increasing every year.

Article History
Received: 12 December 2020
Accepted: 29 November 2021

Keywords
Geospatial Technology;
Kerala;
Killiar River Basin;
Land Use/Land Cover;
Soil Organic Carbon.

Introduction

Land use/land cover (LU/LC) change has been identified as one of the most potent anthropogenically driven repercussions on environment. The latter half of the 20th century witnessed land use changes emerging as a widespread phenomenon all over the world.[1] Monitoring LU/LC changes is one of the most important components to evolve strategies for managing natural resources and monitoring environmental changes.[2,3,4] Urban development

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Doi: http://dx.doi.org/10.12944/CWE.16.3.2

leads the LU/LC changes in many areas in the world, mostly in developing countries.[5,6,7]

Information on LU/LC changes helps to understand changes of environment and assist decision-makers to plan suitable projects for sustainable development.[8,9] Landsat data provides longest record with large-scale medium spatial resolution earth observation data.[10,6,11] Urban expansion settings in many parts of the world pose a vital impact on a wide range of sectors viz., ecology, climate, hydrological systems, land use, energy flow etc., all of which can be tracked through LU/LC change detection analysis.[12,13,14]

Majority of the land use induced changes on soil carbon storage are reflected as atmospheric CO^2 release or removal,[15,16,17] eventually leading to the perturbation of global carbon cycle.[12]

There is a net flux of carbon from land use change resulting from conversion of natural ecosystems.[15,18,19] For instance, as forests hold tremendous amount of carbon stocks, the conversion of forest into plantations create an imbalance of Soil Organic Carbon (SOC) during land use conversion.[20,21,22] The sensitivity of Soil Organic Carbon to anthropogenic disturbances makes it a potential determinant of terrestrial carbon cycle and climate change.[16,22] Thus, Soil Organic Carbon assessment can help stakeholders to make better initiatives regarding LU/LC in which sustainability can be achieved.

This paper analyzes the spatial pattern of LU/LC change detection along the Killiar River Basin (KRB) - a major tributary of Karamana river in Kerala - over a period of 64 years (1967-2021) through remote sensing and GIS approach. Also, a preliminary attempt has been made to appraise the land use change impacts on soil carbon stock, which is first of its kind in the study area. Thus the research aims to contribute as a baseline data for policy-makers for the formulation of sustainable land management strategies leading to the improved carbon sequestration.

Study Area

The study was carried out in the Killiar river basin (KRB), one of the prominent tributaries of Karamana River in Thiruvananthapuram district, Kerala (India). The Karamana river starts from southern tip of the Western Ghats at Chemmunji Mottai and Aathiramala (1600 m amsl), flows 68 km westward and merges with the Arabian Sea at Panathura, south of Thiruvananthapuram. The largest tributary of Karamana river is Killiar, which originates at Panavur (8°38'30.7" N and 76°59'19.4" E) in Nedumangad taluk of Thiruvananthapuram district and flows for a distance of 24 km. The drainage area is 102 km^2 and is a 6th order river (Figure 1). Killiar drains Nedumangad forest and its basin is rich in avian fauna. The Killiar merges with the Karamana River at Pallathukadavu (08º27'23.4" N and 76º57'32" E). In its final lap, the river runs parallel to sea and the river course here is known as the Edayar.

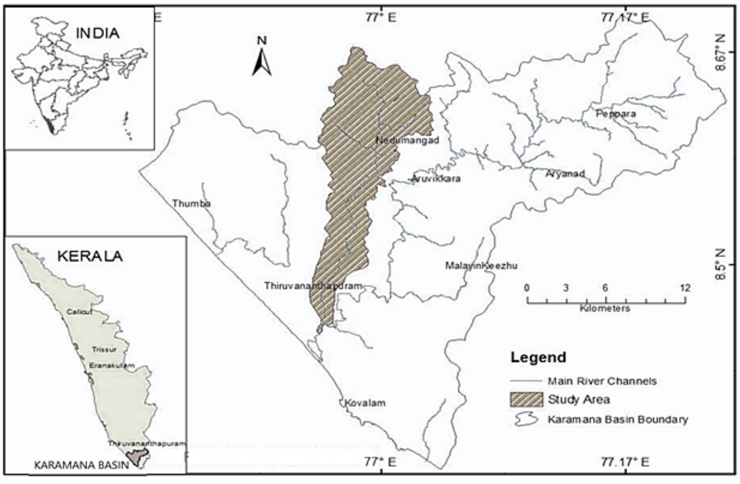


Fig.1: Location Map of the Study Area

Methodology

The land use map of KRB for the period 1967, 2005 and 2021 has been prepared using the SOI toposheet of 1967 (1:50,000), IRS LISS-III data of 2005 (geo-referenced, 1:50,000) and Landsat 8 OLI & TIRS imagery of 2021 (supervised classification) respectively. Land use data was visually interpreted using ArcGIS v.10.0 software (for processing, analysis and integration of spatial data) and layer stacked for the convenience of selection of the study area. Supervised classification was performed and the image was delineated to Level – I. It is further divided into Level–II and Level-III. The LU/LC thematic map was prepared from this for 1967, 2005 and 2021. Area of each category was calculated and analyzed for change detection by comparative change analysis.

Soil Carbon Stock Calculation Based on Land Use Changes

The Soil Organic Carbon (SOC) stock was calculated for soil to a depth of 30 cm using Intergovernmental Panel on Climate Change (IPCC) based guidelines (2003).[23] The computation of carbon pool (Mt C) in all land use categories were done by multiplying the carbon stock in each unit area (t/ha) with the total area covered by that particular land use. The SOC stock for the study period i.e., 1967, 2005 and 2021 were assessed using by applying the equation provided by IPCC 2003.[23]

$$\Delta C_{CCsoil} = [(SOC_0 - SOC_{(0-T)}) \times A] / T \quad ...(1)$$

$$SOC = SOC_{REF} \times FLU \times FMG \times FI \quad ...(2)$$

ΔC_{CCsoil} = annual change in carbon stocks in mineral soils, tonnes C yr^{-1}

SOC_0 = soil organic carbon stock in the inventory year, tonnes C ha^{-1}

$SOC_{(0-T)}$ = soil organic carbon stock T years prior to the inventory, tonnes C ha^{-1}

T = inventory time period, yr

A = land area of each parcel, ha

SOC_{REF} = default reference carbon stock (t/ha) (Table S1)

FLU = stock change factor for each land use pattern (dimensionless), FMG = stock change factor for management practice (dimensionless), FI = stock change factor for organic matter input (dimensionless) based on IPCC Good Practice Guidance for LULUCF guidelines.[23]

The SOC stock change factors (FLU, FMG, and FI) were used from IPCC[23] (Table S1), depending on land use management practices. The SOC stock change factors (FLU, FMG, and FI) were adopted from IPCC[23] based on land use management strategies reported by local people during field visits in addition to the data provided by Kerala State Remote Sensing and Environment Centre (KSREC). For calculating change in SOC stock (Mt C i.e., million tonnes of carbon) change in area (ha) was multiplied with the change in SOC stock (t/ha) of each specific land use conversion.

Results and Discussion

The results of LU/LC change detection based on comparative change analysis are given in Table 1, 2 and 3. Various categories of LU/LC were delineated from the study area including agricultural land (crop land and agricultural plantation), built-up land, forest (evergreen/semi-evergreen, forest plantations, forest blank, scrub forest), water bodies and waste lands (scrub land, barren rocky/stony waste, sandy area).

Land Use/ Land Cover- 1967

The detailed area-wise description of LU/LC of KRB for the period of 1967 is given in Table 1 and Figure 2. A total of five LU/LC categories have been identified for Level I classification. These are agricultural land (91.04%), built-up (5.90%), water bodies (1.18%), wasteland (1.2%) and forest land (0.67%) respectively.

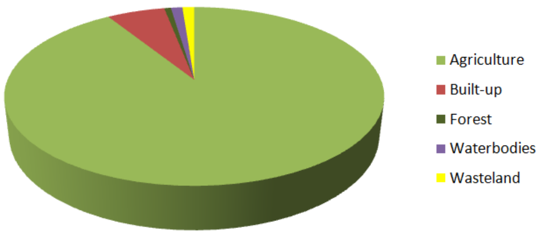


Fig.2: Distribution of Categories of LandUse/ Land Cover (Level-I), 1967

Among these, the agricultural land covered an area of 753.92 km^2 that accounted for 91% of total area. It included double crops (2.01%), single crops (0.001%), and plantation crops comprising cashew (0.001), coconut (1.75), rubber (7.11) and other mixed plantation crops (80.17%).The total area of settlements in 1967 was 48.53 km^2 (5.86%) and it falls in the built-up land. The water body consisting of rivers, streams and ponds together constitute 9.84 km^2 (1.18%).Most of the natural vegetation/ forest is seen in the highlands which come to 5.58 km^2 (0.67%). It constitutes evergreen/ semi-evergreen forest and forest plantations. Evergreen/ semi-evergreen forest occupied most of the forest area covering 4.90 km^2 (0.59%) and rest of the area occupied by forest plantations of 0.69 km^2 (0.08%).

The total wasteland of all categories in the basin was 10.06 km^2 (1.2%). This include barren/stony waste/ sheet rock areas which accounts for a considerable area, i.e., 3.78 km^2 (0.45%) and sandy area occupying 0.23 km^2 (0.02%). The scrub land was the most predominant class observed under wasteland with an area of 6.05 km^2 (0.83%).

Land Use/Land Cover – 2005

The detailed area-wise description of the LU/LC of KRB for the period 2005 is given in Table 2, Figure 3 and Figure 6. A total of five categories have been identified for Level–I. These are agricultural land (82.87%), built- up land (15.28%), forest land (0.36%), water bodies (0.96%) and wasteland (0.53%).

Table 1: Land Use/Land Cover Classification of Killiar River Basin (KRB)-1967

Level I	Level II	Level III	Area (km^2)	Total Area (%)
Agriculture	Crop land	Double Crop(Kharif+Rabi)	16.69	2.01
		Cropland(Kharif)	0.01	0.001
	Plantation	Cashew	0.01	0.001
		Coconut	14.53	1.7
		Rubber	58.89	7.11
		Mixed	663.79	80.17
Sub total			753.92	91.04
Built-up	Towns/Cities/Villages		48.53	5.86
Sub total			48.53	5.90
Forest	Evergreen/ Semi evergreen		4.90	0.59
	Forest Plantation		0.68	0.08
Sub total			5.58	0.67
Water bodies	River/Streams/Ponds		9.84	1.18
Sub total			9.84	1.18
Wasteland	Scrub land		6.05	0.83
	Barren/Stony waste/ Sheetrock		3.78	0.45
	Sandy Area		0.23	0.02
Sub total			**10.06**	**1.2**
Grant Total			**827.93**	**100**

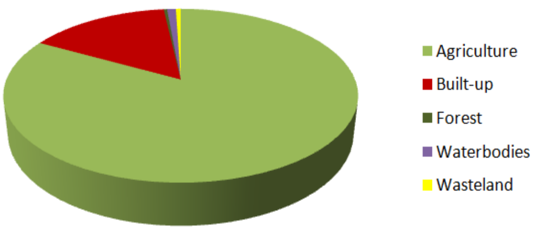


Fig.3: Distribution of Categories of Land Use/ LandCover (Level- I), 2005

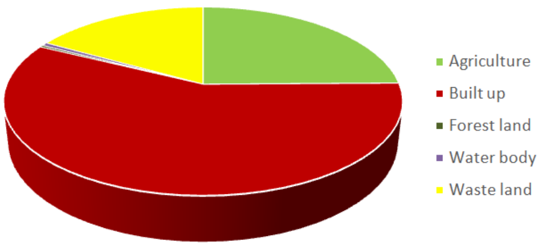


Fig.4: Distribution of Categories of Land Use/ Land Cover(Level-I), 2021

Agriculture land covered an area of 685.44 km^2 and accounted for 82.87% of total area. It comprises of plantation crops (5.79%), horticulture crops (47.65%), agro-horticulture crops (27.73%) and double crops (1.60%). Built-up land is recorded as 126.68 km^2 comprising 15.28%. Rural settlements are the dominant one (7.20%), followed by urban settlements (3.93%), mixed built-up (3.36%), residential (0.59%) and transportation (0.19%).

Table 2: Land use/Land cover classification of Killiar River Basin (KRB)-2005

Level I	Level II	Level III	Area (km^2)	Area (%)
Agriculture	Plantation	Plantation	47.99	5.79
		Horticulture	394.58	47.65
		Agro Horticulture	229.59	27.73
	Cropland	Two Crop Area	13.28	1.60
Sub total			685.44	82.87
Built-up	Towns/ Cities/ Villages	Rural	59.69	7.20
		Urban	32.58	3.93
		Residential	4.89	0.59
		Mixed Built-up	27.87	3.36
		Transportation	1.65	0.19
Sub total			126.68	15.28
Forest	Scrub Forest		0.06	0.007
	Forest Blank		0.15	0.01
	Forest Plantation		0.74	0.08
	Natural Semi Natural Grassland and Grazing Land	Temperate/ Sub Tropical	0.30	0.03
	Ever green/ Semi evergreen	Dense/ Closed	1.96	0.23
		Open	0.04	0.004
Sub total			3.25	0.36
Water bodies	River/ Stream/ Ponds	Perennial	7.94	0.95
		Dry	0.11	0.01
Sub total			8.05	0.96
Wasteland	Scrub Land		0.90	0.10
	Barren rocky/ Stony waste		0.75	0.09
	Sandy Area	Coastal	2.59	0.31
	Mining/ Industrial Waste	Mine/ Quarry	0.27	0.03
Sub total			**4.51**	**0.53**
Grand Total			**827.93**	**100**

Out of all classifications, the total forest land in the basin was 3.25 km^2 (0.36%). Under this forest sub class, five categories have been demarcated, viz., evergreen/semi-evergreen (0.24%), forest plantations (0.08%), natural/semi-natural grassland and grazing land (0.03%), forest blank (0.01%) and scrub forest (0.007%).The water body consisting of river, streams and ponds together constitute about 8.05 km^2 (0.96%). Of which, perennial water body constitute 7.94 km^2 (0.95%) and dried ones comprise 0.11 km^2 (0.01%). The total area of wasteland in the basin was 4.51 km2 (0.53%). This include scrub land which accounts for 0.90 km^2 (0.10%), barren rocky/ stony waste of area 0.75 km^2 (0.09%) and mining/ industrial area of area 0.27 km^2 (0.03%). Majority of the wasteland sub class was dominated by the sandy area with an areal coverage of 2.59 km^2 (0.31%) in the coastal area.

Land Use/ Land Cover – 2021

The detailed area-wise description of the LU/LC of KRB for the period 2021 is given in Table 3,

Figure 4 and Figure 7. A total of five categories have been identified for Level–I. These are agricultural land (24.81%), built- up land (57.49%), forest land (0.34%), water bodies (0.56%) and wasteland (16.8%).

Analysis of LU/LC status of KRB in the year 2021 revealed that agriculture land covered an area 205.57 km^2 (24.82%) of total area. It comprises of plantation crops (23.5%) and Cropland (1.31%). The total area of Built-up land is increased from 2005 to 2021 and it is about 57.49% (474.98 km^2). In the year 2021, area of urban (24.25 km^2), residential (84.68 km^2) and transportation (11.21 km2) area is increased compared with previous years. The total area of forest land (2.89 km^2) and water body (4.70 km^2) decreased in the study area while area of waste land (139.79 km^2) increased.

Comparative Change Analysis of Land Use/Land Cover (1967-2021)

Comparative analysis of land use pattern in 1967, 2005 and 2021 in the KRB (Table 4, Figure 8), it is evident that there has been significant change in the area during 1967-2021. The reduction in agriculture plantation (-548.35 km^2) and cropland (-5.8 km^2) have occurred during this period.

There was an upsurge in built-up area during the period (426.45 km^2; +51.51%) possibly due to over-population and urbanization. Areal extent of wasteland increased by 129.73 km^2 (+15.697%) falling under sandy area category. Wasteland also increased in mining/industrial sector by 22.13 km^2 (+2.67%). Barren rocky/ stony waste showed remarkable decrease in area of about 58.8 km^2 (+7.10%).

Table 3: Land Use/Land Cover Classification of Killiar River Basin (KRB) -2021

Level I	Level II	Level III	Area (km^2)	Area (%)
Agriculture	Plantation		194.67	23.5
	Cropland	Two Crop Area	10.9	1.31
Sub total			205.57	24.81
Built-up	Towns/ Cities/ Villages	Rural	216.28	26.12
		Urban	124.25	15.13
		Residential	84.68	10.23
		Mixed Built-up	38.56	4.66
		Transportation	11.21	1.35
Sub total			474.98	57.49
Forest	Scrub Forest		0.04	0.004
	Forest Blank		0.12	0.014
	Forest Plantation		0.78	0.091
	Natural Semi Natural Grassland and Grazing Land	Temperate/ Sub Tropical	0.28	0.04
	Ever green/ Semi evergreen	Dense/ Closed	1.65	0.19
		Open	0.02	0.002
Sub total			2.89	0.34
Water bodies	River/ Stream/ Ponds	Perennial	4.61	0.55
		Dry	0.09	0.01
Sub total			4.70	0.56
Wasteland	Scrub Land		12.69	1.53
	Barren rocky/ Stony waste		62.58	7.55
	Sandy Area	Coastal	42.39	5.1
	Mining/ Industrial Waste	Mine/ Quarry	22.13	2.67
Sub total			**139.79**	**16.8**
Grand Total			**827.93**	**100**

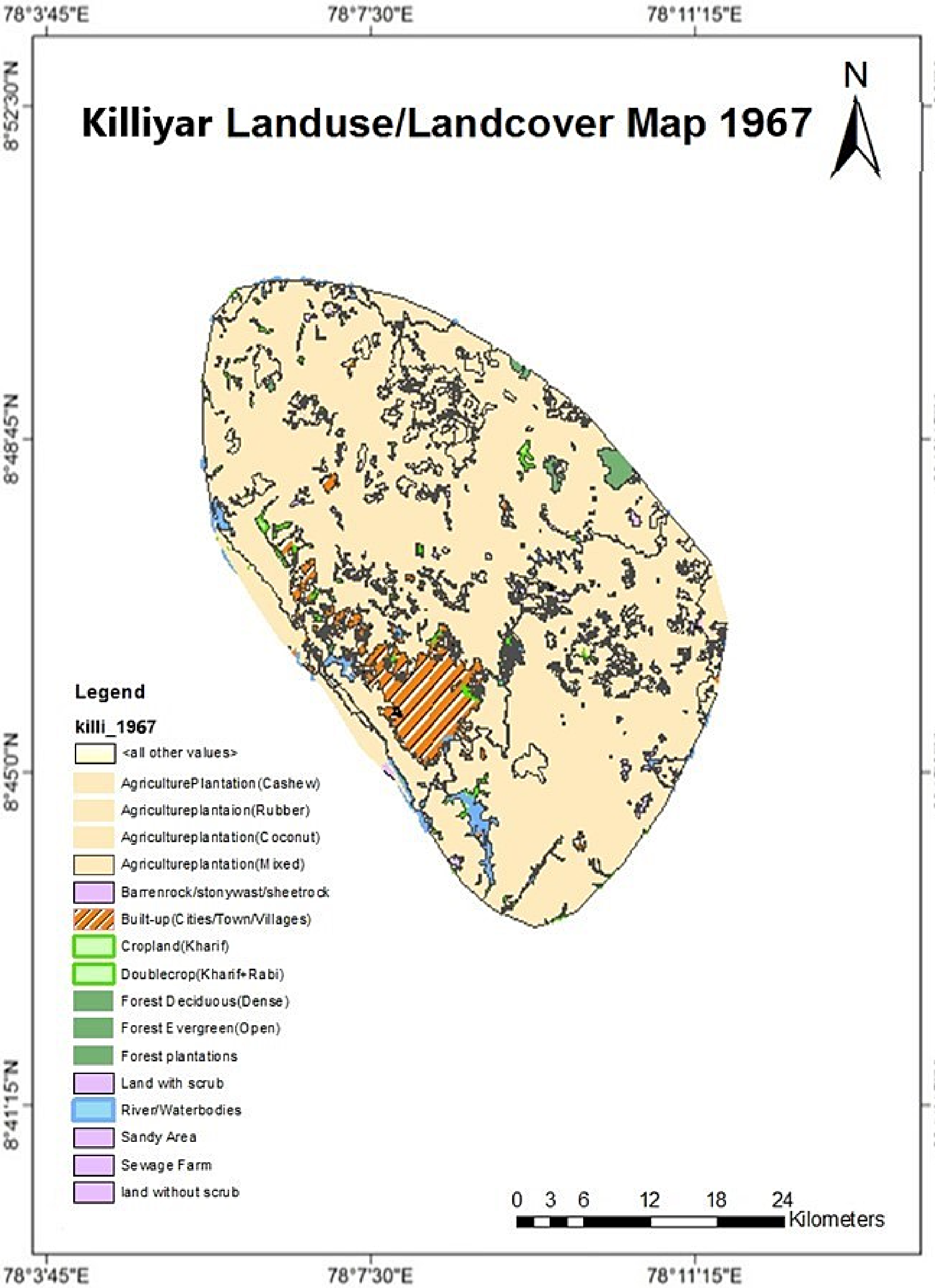


Fig.5: Land Use/Land Cover Map 1967 of Killiar Basin

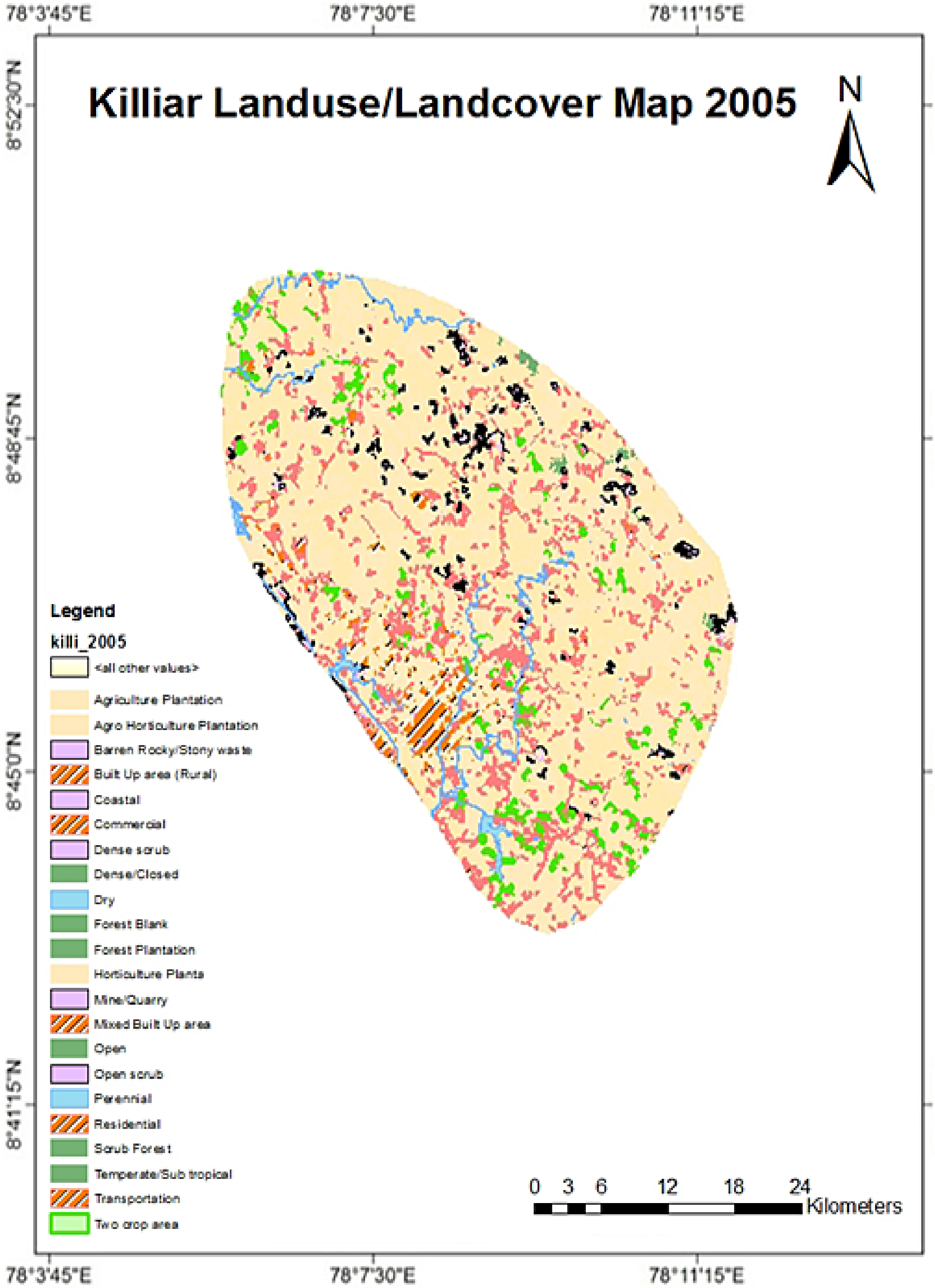


Fig.6: Land Use/Land Cover Map 2005 of KilliarBasin

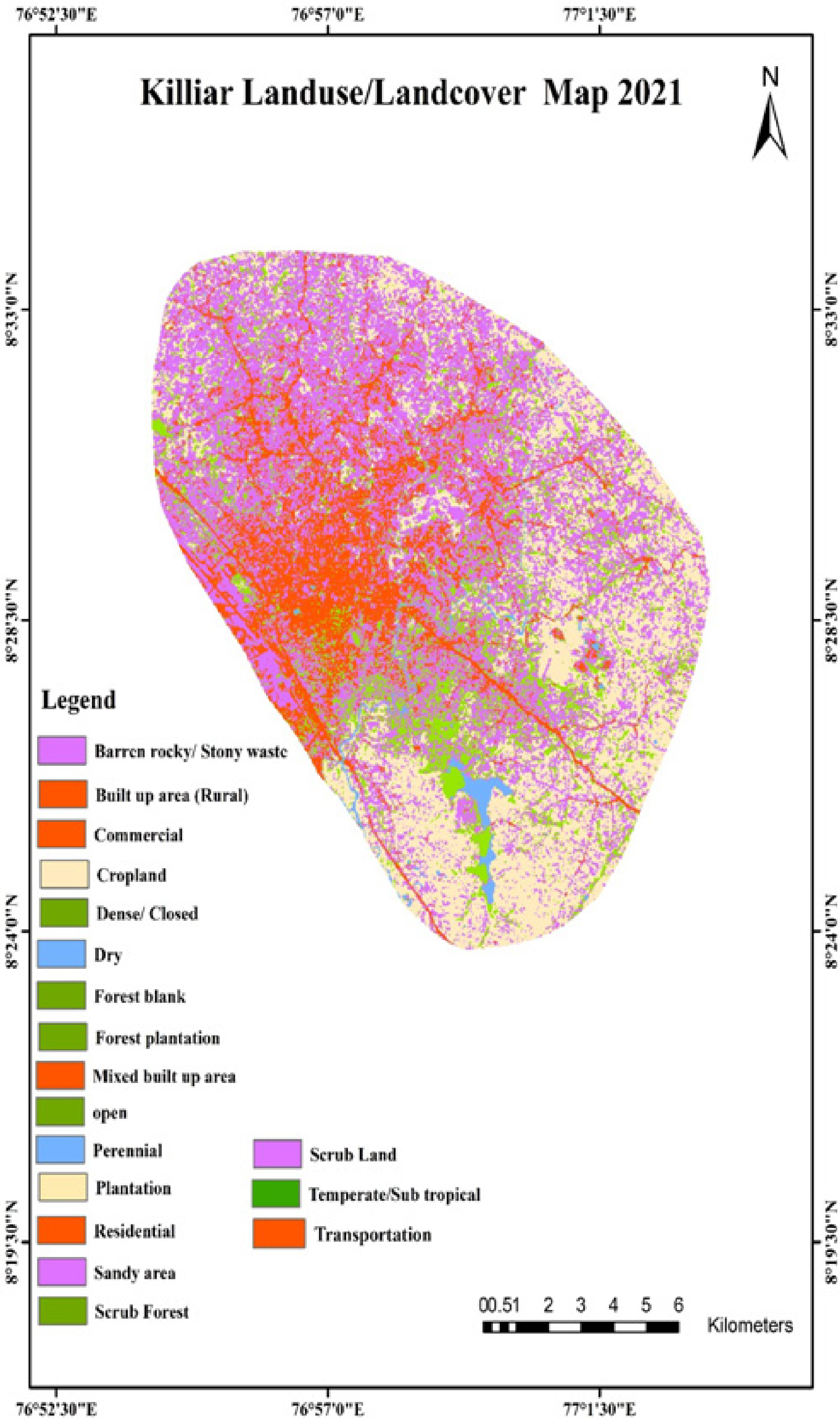


Fig. 7: Land Use/Land Cover Map 2021 of Killiar Basin

Table 4: Change in Land Use/Land Cover of KRB- 1967-2021

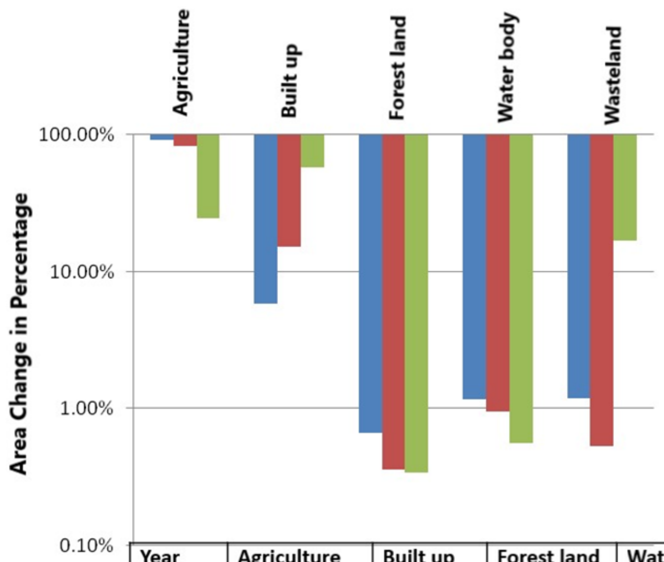
LEVEL I	LEVEL II	1967	2005	2021	Change in Area (km^2) 1967 - 2021	Change of Area in Percentage (%)
Agriculture	Cropland	16.70	13.28	10.9	-3.42	-0.70%
	Plantation	737.22	672.16	194.67	-542.55	-65.53%
Sub total		**753.92**	**685.44**	**48.96**	**-548.35**	**-66.23%**
Built- up	Towns/ Cities /Villages	48.53	126.68	474.98	+426.45	+51.51%
Sub total		**48.53**	**126.68**	**474.98**	**+426.45**	**+51.51%**
Forest	Evergreen/ Semi evergreen	4.90	2.00	1.67	-3.23	-0.39%,
	Forest Plantation	0.68	0.74	0.78	+0.1	+0.001%
	Forest Blank	0.00	0.15	0.12	+0.12	
	Natural/ Semi Natural Grassland and Grazing land	0.00	0.30	0.28	+0.28	
	Scrub Forest	0.00	0.06	0.04	+0.04	
Sub total		**5.58**	**3.25**	**2.89**	**-2.69**	**-0.32%**
Water bodies	River/ Streams/Lakes	9.84	8.05	4.70	-5.14	-0.62%
Sub total		**9.84**	**8.05**	**4.70**	**-5.14**	**-52.24%**
Wasteland	Scrub Land	6.05	0.90	12.69	+6.64	+0.80%
	Barren Rocky/ Stony Waste	3.78	0.75	62.58	+58.8	+7.10%
	Sandy Area	0.23	2.59	42.39	+42.16	+5.09%
	Mining/ Industrial Waste	0.00	0.27	22.13	+22.13	+2.67%
Sub total		**10.06**	**4.51**	**139.79**	**+129.73**	**+15.67%**
Grand Total		**827.93**	**827.93**	**827.93**	**0.00**	**0.00%**

Forest area recorded a decrease in evergreen and semi-evergreen category by 3.23 km^2 (-0.39%), but showed marginal increase in forest plantation area (0.1 km^2; +0.001%). Other forest categories of 2005 showed marginal increase in areal extent as follows; forest blank by 0.15 km^2 (+0.01%), natural/ semi natural grassland and grazing land by 0.30 km^2 (+0.03%) and scrub forest by 0.06 km^2 (+0.007%). This shows the deterioration of native forest species which have been replaced with plantation.

Decline in water body area was noted with a decrease in areal extent (-5.14 km^2; -0.62%).Land use change in a tropical river basin influences the organic matter dynamics in tropical rivers.[24] The percentage area lost by the LU/LC classes especially the agricultural land, has been converted to built-up land, resulting in the increase of built-up area. Water bodies, forest land also showed marginal reduction in area resulting in the overall conspicuous increase of built-up area.

The area wise description of LU/LC of KRB for the period 1967 shows agriculture land as the major class with an area of about 753.92 km^2 (91.04%) out of the total area of 827.93 km^2, followed by built- up with an area of 48.53 km^2 (5.90%). Forest covered an area of about 5.58 km^2 (0.67%), water bodies covered 9.84 km^2 (1.18%) and wastelands, 10.06 km2 (1.2%).

A noteworthy rise in built-up lands (+9.43%) is apparent in the study area during the period of 1967-2005. A remarkable fall in agricultural area has been noted in the 48 year time span, whereas a threefold increase in built up area has been observed. Compared to 2005, built-up land further expanded four times in 2021 (Figure 7), in contrast to the agriculture lands where a huge areal decline from 685.44 km^2 to 48.96 km^2 was noted (Table 4, Figure 7). Within the period of 2005 to 2021, wastelands including scrublands, barren rocky waste, sandy area, mining and industrial wastelands showed an abrupt increase from 4.51 km^2 to 139.79 km^2.



Year	Agriculture	Built up	Forest land	Water body
1957	91.04%	5.9%	0.67%	1.18%
2005	82.87%	15.28%	0.36%	0.96%
2021	24.81%	57.49%	0.34%	0.56%

Fig. 8: Changes of KRB from 1967- 2021

This points out that the cultivated lands have undergone reclamation and converted into settlement with agglomerated settlements. Shrinking of agriculture lands up to 16.31% due to urban expansion was noticed in South Indian city Bengaluru.[25] The increase in the urban settlement may be attributed to the decrease in areal extent of water bodies. In India, extreme conversion of water bodies (~-40%) as a result of horizontal urban expansion was observed in Srinagar City within a time span of almost four decades.[26] The decline in wastelands also could be related to the conversion of this land surface into built up land.

Impact of Land Use Change on Regional Soil Carbon Stocks

A pilot investigation on net change in Soil Organic Carbon (SOC) pool from 1967–2021 in Killiar basin was carried out. Built-up area, water bodies, barren rocky waste, sandy area and mining (wasteland) were not included in stock estimation. SOC in top soil (0–30 cm) under different types of management practices for different land use patterns was estimated in the present work. This particular layer of selection was based on the fact that soil carbon storage in the topsoil is more labile, more sensitive to land use changes, and directly interacts with the atmosphere compared to deeper layers.[27] Based on IPCC (2003)[23] SOC estimation method (eqn. 2), in 1967 maximum soil carbon stock was found in forests covering (60.07 t/ha), followed by agriculture land (51.16 t/ha), and wastelands (16.36 t/ha). However, in 2005, this decreased to 31.13, 43.86 and 13.96 t/ha for forest, agriculture land and wasteland respectively. In 2021, this further decreased to 21.1 t/ha for forest, 36.7 t/ha for agriculture and 11.74 t/ha for wasteland.

From the analyses of present study, it could be further inferred that agricultural lands (cropland and plantation) turned out to be the category with most significant temporal change in the SOC stock. Area dependent SOC stock during 1967 (Table S[2]) was higher (evergreen forests=176.66, forest plantation = 144.28, agriculture croplands=394.74, agriculture plantation=412.46 and scrubland=164.58 Mt C) compared to that during 2005 (evergreen forests=70.65, forest plantation=55.21, agriculture cropland=196.14, agriculture plantation=204.5 and scrubland=36.15 Mt C).

SOC stock during 2021 declined substantially compared to its previous years (evergreen forests=14.87, forest plantation=9.52, agriculture cropland=41.65, agriculture plantation=52.4 and scrubland=39.42 Mt C). Highest SOC stock flux (ΔCCCsoil) was noted as a result of agriculture land conversion (cropland= -198.6, plantation = -353 Mt C) due to intense unsustainable urban development during 1967–2021 period (Table S2). Conversion of evergreen forest to agriculture land resulted in a loss of -161.8 Mt C soil organic carbon (Table S2). In 1967, total SOC of all land use types was 1292.72 Mt C and in 2005 this reduced to 562.65 Mt C. In 2021, total SOC decreased to 152.86 Mt C with a net loss of 1139.86 Mt C compared to 1967. This drastic net soil carbon decrease within a time span of more than half a century implies to the remarkable shift of agricultural/forest/wasteland into built-up land. Similar studies in China indicated that considerable SOC loss (~ 52%) was occurred due to conversion of agricultural lands as a result of urbanization in coastal region.[17]

Again, several previous studies have revealed that rapid urbanization significantly impacts regional SOC stocks distribution.[15,16,17,28] Introducing agroforestry practices in wastelands could be a feasible way to increase carbon stocks storage in the region. Numerous studies have proved that agroforestry improves land cover as well as provide carbon inputs to the soil by means of root biomass, litter, prunings etc., especially in tropical region.[29,30,31,32] The carbon sequestration potential of afforestation in changing land use scenarios have been explored by several researchers worldwide.[33,34,35] However, Deng *et al*.,[36] found that afforestation induced soil carbon stocks in native forests were always lower compared to the stocks in natural forests globally. A more lucid concept put forth by Brown[37] strongly pointed out the need for spatially targeted-land use specific afforestation approach than 'one size fits all' conventional tree planting programmes.

Conclusion

The study on the spatial pattern of LU/LC change detection along the Killiar River Basin (KRB), Kerala over half a century (1967-2021) revealed drastic LU/LC changes over this period. In 1967, the LU types were agricultural land (91.04%), built-up (5.90%), water bodies (1.18%), wasteland (1.2%) and forest land (0.67%) in the decreasing order. The general trend followed within this period is the increase in built-up area (+51.51%) and wastelands (+15.67%) resulting in the decrease of all other classes viz., agricultural lands (-66.23%), forest cover (-0.32%) and water bodies (-0.62%). This conversion and land use for built-up is likely to follow as the population is rising and over-exploitation of natural and agricultural resources is increasing every year. Using IPCC guidelines, the soil organic carbon (SOC) stock from 1967–2021 were estimated in the study area and in 1967, total SOC of all land use types was 1292.72 Mt C and in 2005 this reduced to 562.65 Mt C, which further declined to 152.86 Mt C in 2021. Maximum SOC loss has been observed for agriculture land category. Hence, the study points out the need for monitoring regional land use shift and implementation of carbon neutral plans for the city and towns in the basin. This can be achieved through sustainable land use management practices and conservation of agricultural productive lands by employing improved carbon farming.

Acknowledgment

The author(s) thankfully acknowledge the Director, Kerala State Remote Sensing and Environment Centre (KSREC), Trivandrum for providing data for the study to carry out this work.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Conflict of Interest

The authors do not have any conflict of interest.

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