RESEARCH ARTICLE Indian Journal of Agricultural Research, Volume 60 Issue 1: 147-155 (January 2026)

Trends and Direction of Land Use Change in the Perspective of Urbanization in Karnataka: A District Level Study

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ABSTRACT

Background: Urbanization and industrialization are mainly responsible for the conversion of large tract of agricultural lands and other vegetation-rich lands to non-agricultural purposes. Land and its utilization across various activities must be analysed to frame suitable policies for optimum land use. In Karnataka, the share of the net sown and non-agricultural areas increased. However, the share of permanent pasture and other grazing lands, barren and unculturable land, current and other fallow lands, culturable wasteland and land under miscellaneous tree crops and groves decreased compared to their share in 2000-01. The goal is to explore the direction of land use change between these land use categories in the context of urbanization.

Methods: We utilized the district-level data sourced from reports of the Directorate of Economics and Statistics of the Government of Karnataka, enabling us to conduct a robust panel data regression using fixed effects model that empirically establishes the relationships between different land use categories, particularly non-agricultural land, barren land and arable land, from 2000-01 to 2020-21. We recorded the land use changes in the major land use classes at the district level by comparing the temporal dynamics for 2000-01 to 2020-21 and also studied the dynamics of each category's land use outcomes and the changes in urbanization status at the district level.

Result: This study provides a detailed insight into the trends and direction of land use changes in Karnataka from the perspective of urbanization, which has been getting a significant focus in the country's development. The study's findings have significant policy implications, as they underscore how rapid population growth and the expansion of non-agricultural areas at the district level negatively impact arable and barren land.

Key words: Arable land, Barren land, Land use change, Non-agricultural land, Panel data regression, Urbanization.

INTRODUCTION

The per capita availability of agricultural land in India is 0.12 ha, which is 0.29 ha globally (Wasteland atlas, GOI, 2024). In 2021, India had the largest total cropland area, with 168 million ha (FAO, 2023), having the second-largest arable land area, covering 154 million hectares (World Bank, 2024), with the blend of high population, high agriculture production and diverse agro-climatic conditions create unprecedented pressure on land and raises the risk factor for land degradation in India. Around 97.85 million ha of the country is undergoing land degradation, *i.e.* 29.77% of the country's total geographic area (TGA) during 2018-19 (SAC, GoI, 2021) which has environmental implications also (Jagadish, 2004). India's growing economy demands a huge pressure on India's land resources and it is expected to further intensify in the future (Meiyappan *et al.,* 2017). During the years 2001-02, cropping intensity in India was 133.6, which has increased to 152.7 (DES, GoI, 2024), showing the increase in land pressure on the net sown area in India, similar to China, where urbanization has resulted in intensive use of agricultural land (Jiang *et al.*, 2013). India's urban population has increased significantly over the past two decades, from 217 million in 1991 to 377 million in 2011 (Census of India, 2011) and has put pressure on the country's agricultural resources (Pandey and Seto, 2015). Further, the simultaneous increase in non- agricultural area and net sown areas to meet both the demands on land which has been put a pressure on other land categories such as fallow land, pasture land and barren land. Moreover, due to the impact of both watershed development programmes and National Rural Employment Guarantee Scheme (NREGS) of Ministry of Rural Development since 2005, which contributed to higher rural wages through creation of alternative job opportunities in rural areas and

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How to cite this article: Radhika, C., Mahesh, E., Sutradhar, R., Kethineni, U. and Prasad, J. (2026). Trends and Direction of Land Use Change in the Perspective of Urbanization in Karnataka: A District Level Study. *Indian Journal of Agricultural Research*. **60(1):** 147-155. doi: 10.18805/IJARe.A-6328.

Submitted: 26-10-2024 **Accepted:** 23-11-2024 **Online:** 10-12-2024

new job opportunities in the fast-growing urban centres thereby pulling people to off-farm jobs in rural areas and non-farm jobs in urban areas (Meiyappan *et al.,* 2017).

In this view, optimizing land use is critical for achieving sustainable ecosystem objectives given the finite resources available. The main types of land include forests, grasslands, agricultural areas, non-agricultural lands and barren territories. Over recent centuries, there has been a significant shift in the structure and distribution of these land use categories. Economic activities and public policy decisions often drive changes in land use within a country. For instance, various state and national policies in India have supported land use activities to convert fallow and uncultivated land into agricultural use. Urbanization and population growth, for example, generate demand for non-agricultural land, leading to the conversion of fallow, pasture and other cultivable wastelands. Conversely, opportunities in agriculture encourage individuals to continue or start farming, keeping land in agricultural use. Factors influencing farming decisions at the individual level include the farmer's socio-cultural and educational background, economic returns from farming, technology adoption and resource availability. At the district level, land use preferences are shaped by economic, policy and biophysical factors, such as climate and soil characteristics. Economic development and job creation in the non-farm sector, coupled with urbanization, drive the demand for land conversion to non-agricultural uses.

The Directorate of Economics and Statistics of the Government of India categorizes land use into nine types, including forest areas, non-agricultural lands, barren lands, permanent pastures, land under miscellaneous tree crops, arable wasteland, fallow lands and net sown areas. Fallow land is divided into land left uncultivated for over a year but less than five (other fallow lands) and uncultivated for just the current year (current fallow land). Non-agricultural uses encompass human settlements, water bodies, infrastructure for mining and roads. Barren and uncultivable land refers to areas that cannot be used for cultivation without significant reclamation costs. There has been an increase in land allocated for non-agricultural purposes, driven by higher budg*et* allocations for agriculture, irrigation projects and infrastructure development (Rathee, 2014).

Our paper contributes to the literature on land use change studies as most of the studies either focus on household level difference using primary level data or concentrate on the trends in land use of a particular land use such as forests, agriculture *etc.* But we focus on the contextual effects of higher geographical levels *i.e.* districts to explain the geographical pattern of land use change in Karnataka and its determinants. First, we monitor the land use changes in the major land use classes at the district level by comparing the temporal dynamics for 2000-01 to 2020-21 and also study the dynamics of land use outcomes of each category along with the changes in urbanization status at the district level. Second, we study the direction of land use change and impact of changes in arable and barren land categories on non-agricultural land using the district-level land use data from the Directorate of Economics and Statistics of Government of Karnataka.

MATERIALS AND METHODS

Data

We gathered secondary data from 27[1] districts of Karnataka for 21 years from 2000-01 to 2020-21. Our data sources are Directorate of Economics and Statistics, Government of Karnataka; Land Use Statistics published by Department of Agriculture and Co-operation Network, Government of India.

The land use classification followed in India is a nine-fold classification recommended by technical committee constituted towards coordination of agriculture statistics under the then Ministry of Food and Agriculture in 1948 (Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, Government of India, 2024). This classification is mainly based on where the area is cultivated, grazed, forested or not in use.

We have studied the direction of land use change using three categories of land use classes *i.e.* arable area (sum of net sown area, culturable waste land, total fallow land and land under miscellaneous tree crops), non-agricultural area; under barren and unculturable wasteland.

Study area

Karnataka state of India, located in India's southwestern region has 191,791 km^2 with a population of 61.1 million of which 60.6% live in rural areas (Census of India 2011, Government of India). The diverse land and climate of the state has paved way for cultivation of variety of crops (Acharya *et al.,* 2011). More than two hundred types of crops are cultivated in different parts of Karnataka (Das *et al.,* 2018). The average annual temperature is 25.84°C and annual rainfall is 1376 mm.

Fig 1 and 2 shows the district and the Land Use Land Cover (LULC) maps of Karnataka.

Methodology

We use the panel data regression model with fixed effects (allows district-specific intercepts) to quantify the changes in land under non-agricultural uses when there is a change in share under both arable and barren and unculturable wasteland use categories which gives the direction of land use change. We use the short panel with 21 time periods from 2000-01 to 2020-21 and 27 cross-sections and two

[1]In Karnataka, an extensive reorganisation of the districts occurred between 1997 and 2007 and eight new districts were created. There are 30 districts in Karnataka after the bifurcation of a few districts due to political reasons. Therefore, 30 districts were reduced into 27 by combining three newly formed districts with their corresponding districts for uniformity and representativeness in data analysis.

independent variables with the variable *i.e.*, share of area under non agriculture land in total geographical area as a dependent variable.

It is assumed that disturbances in panel data models are cross-sectionally independent for short panels with large cross-sectional dimension (N) than time dimension (T) (Pesaran, 2021).

One of the assumptions of the fixed effects model is that the unobservable entity (district) effects are correlated with the observed independent variables, *i.e.*, covariance (Xi,α_i) is a non-zero value.

Where,

Xi = Regression variables.

α_i = Unobservable individual effects.

We apply the following empirical model (equation 1) to test the hypotheses. The fixed effects regression model for unit i and period t.

$$Y_{it} = \alpha + X_{it}\beta + v_i + \epsilon_{it} \quad ...(1)$$

Y_{it} = Response variable where i=1,2,3…. n and t=1,2,3…t.

X_{it}= Regression variables for i=1,2,3…. n and t=1,2,3…t.

β= Coefficients for the k regression variables in Xi.

ϵ_{it} = Idiosyncratic error term with zero mean and constant variance where i=1,2,3…. n and t=1,2,3…t.

v_i = Group-specific error term (omitted variables constant over time for every i also known as fixed effects to induce unobserved heterogeneity in the model) where i=1,2,3…n

For estimating b using the fixed effects estimator also known as the within estimator using OLS to perform the estimation of equation 1. For a given entity or group, which has the same value of νi across all time periods and the estimation of a fixed effects model involves estimating the coefficients b and the unit-specific effect νi for each unit i. This means the assumptions of fixed effects estimator, which is the estimates are conditional on the sample in that the íi are not assumed to have a distribution but are instead treated as fixed and estimable which can lead to difficulty when making out-of-sample predictions.

The choice of the preferred model from the panel regression to estimate the unbiased coefficients was done based on the diagnostic tests *viz.*, robust Hausman test (Schaffer and Stillman, 2010). Moreover, we tested the model for heteroscedasticity error in the model after estimating the panel regression (fixed effects) model using the Modified Wald test for group-wise heteroskedasticity test. The clustered or robust standard errors account for correcting heteroscedasticity and autocorrelation. We generate robust standard errors using robust techniques applied to the fixed effects regression model to obtain heteroscedasticity -robust standard errors instead of default standard errors to correct the problem of heteroscedasticity in the model (Cameron and Douglas, 2013). The regression function includes the complete set of year dummies, aka fixed time effects, to control general trends in predictor variables and cross-individual correlation.

Specification of the regression model with share under non-agricultural area as dependent variable

We estimate the following equation to assess the determinants of diversification at the district level.

$$\text{Share (non-agriculture)}_{it} = X_{k,it}\beta_k + \delta_t + v_i + \epsilon_{it} \quad ...(2)$$

Where,

Y_{it} = Response variable *i.e.* land share under non-agriculture.

X_{it}= Regressor variables for i=1,2,3…. n and t=1,2,3…t.

We have two regressor variables X_1 = Land under arable category and X_2= Share under Barren and unculturable land category.



Fig 1: Karnataka district map.

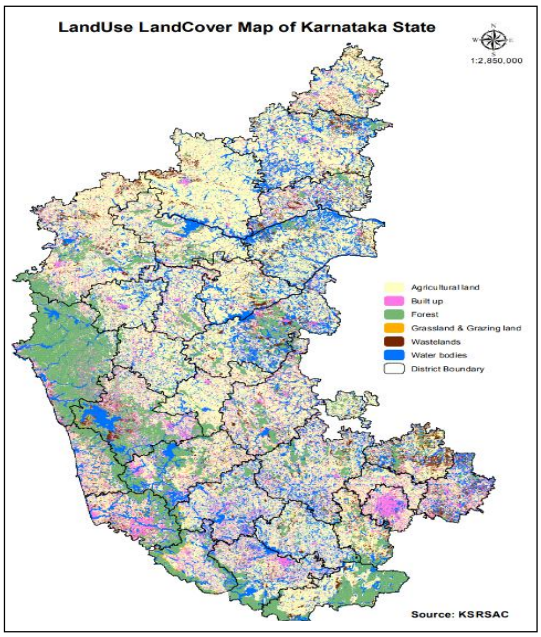


Fig 2: Land use land cover map of Karnataka source KSRSAC, 2024.

β_k= Coefficients for the respective k regression variables (both independent variables) in X_i.
In this case i= 27, t= 21 and k= 2.

RESULTS AND DISCUSSION

Status and trends of land use change in Karnataka

Land use change at the state level

The land use change analysis of Karnataka from 2001-02 to 2020-21 (Table 1) shows that the net sown area increased from 54.65 to 64.49% in 2020-21, similarly the land under non-agricultural uses increased from 6.89 to 7.96% in 2020-21. A significant positive trend is the decrease in total fallow land from 9.32% to 4.13%, indicating more efficient land use. The proportion of land categorized as permanent pasture and other grazing areas, barren and uncultivable land, culturable wasteland and land under miscellaneous tree crops and groves decreased compared to their proportions in 2001-02. The forest area remained unchanged during the study period.

Fig 3 shows how the shares of each land category grow during the period from 2001-02 to 2020-21 for the entire state of Karnataka. Using the data for the five periods we look into the trends in land use change in Karnataka and it shows that share under non-agricultural area has increased over the years whereas share of arable area has been continuously decreasing and off late after 2015 it has showed a slight increase. Gross cropped area has increased while barren land and total fallow land share has decreased.

Trends in land use change at the district level

Percentage distribution of each land category at the district level is given in Fig 4. The share of forests dominates the Uttara Kannada and Chamarajanagar districts. Chikkamagalur district showed a decrease in permanent pasture land share and an increase in arable area. Mysore district showed an increase in non-agricultural areas with a decrease in permanent pasture land share. Raichur, Koppal, Haveri, Gulbarga, Gadag, Bidar, Bijapur, Bagalkot, Belgaum and Dharwad districts have more than 75% share under the arable land category. Dakshina Kannada district showed a decrease in both the share of barren and unculturable and pasture land and an increase in non-agriculture and arable land share. Davanagare also showed a decrease in pasture land but increased arable area. Bangalore Urban showed an increase in non-agriculture areas with a decrease in arable land share.

The study analyzes the growth in share under different land use categories to total reported land (Fig 5).

Net sown area showed a positive growth in its share for all the districts except for Bangalore Urban and Davanagere

Table 1: Share of land use under each category in Karnataka during the years 2001-02 and 2020-21.

Land use category	Share of land use in TGA (%)	
	Year	
	2001-02	2020-21
Forests	16.11	16.13
Area under non-agricultural uses	6.89	7.96
Barren and unculturable land	4.17	3.91
Permanent pasture and other grazing land	5.04	4.58
Land under misc. Tree crops and groves not included in NSA	1.59	1.11
Culturable wasteland	2.24	2.06
Total fallow	9.32	4.13
Net sown area	54.65	64.49
Gross cropped area	60.12	78.26

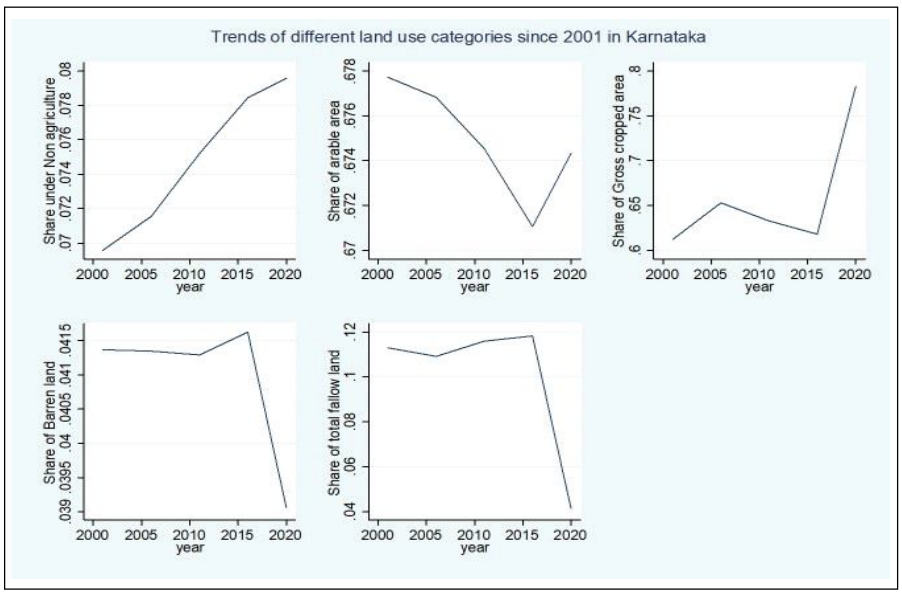


Fig 3: Trends in land use change in major land categories in Karnataka since 2000-01.

districts with a corresponding positive growth in share of fallow land in the case of Bangalore Urban district.

In the case of barren land category, Urban Bangalore, Bellary, Gadag and Mysore districts showed a positive growth during the study period. Population density and area under non-agricultural purposes positively affected common lands including barren land as the migration of significant population from rural to urban seeking better job opportunities as they provide higher wage rates (Nasim *et al.,* 2018).

When we look into change in fallow land share and its growth at the district level, our results indicate that over the years, the growth in the share of total fallow land in the total area has shown a negative trend in many districts, in line with the decreasing trends at the state level. However, there was a positive growth in its share for districts like Urban and Rural Bangalore, Mysore, Tumkur and Uttara Kannada. The study reveals the positive growth in urbanization accompanied by land conversion from fallow land into cultivated and non-agricultural land as more fallow land has been put under cultivation or converted into non-agricultural areas. Similar results are reported by Nasim *et al.* (2018) on larger concentration of current fallow lands from Bihar due to erratic monsoon, labour scarcity and increased use under non-agricultural use of land.

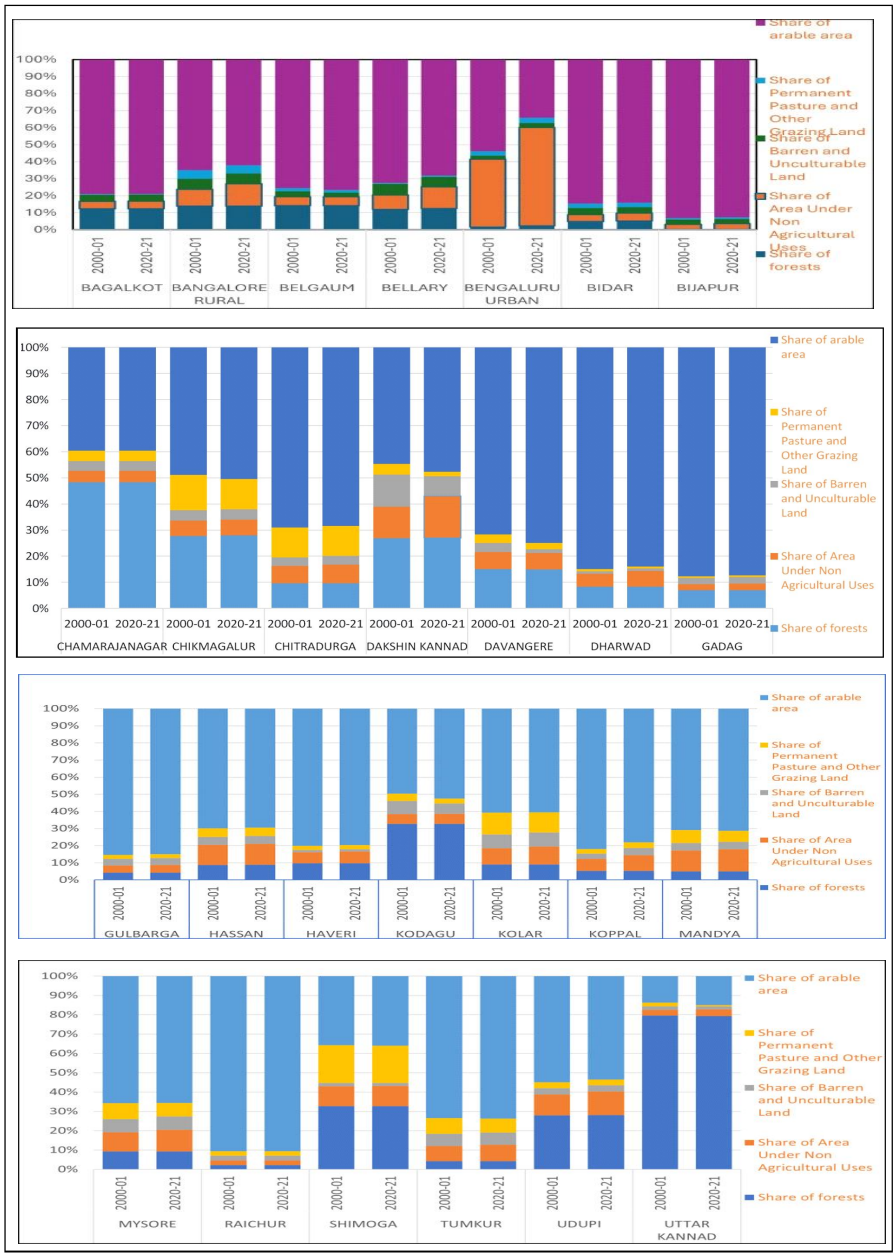


Fig 4: Percentage distribution of the land use categories across the districts of Karnataka.

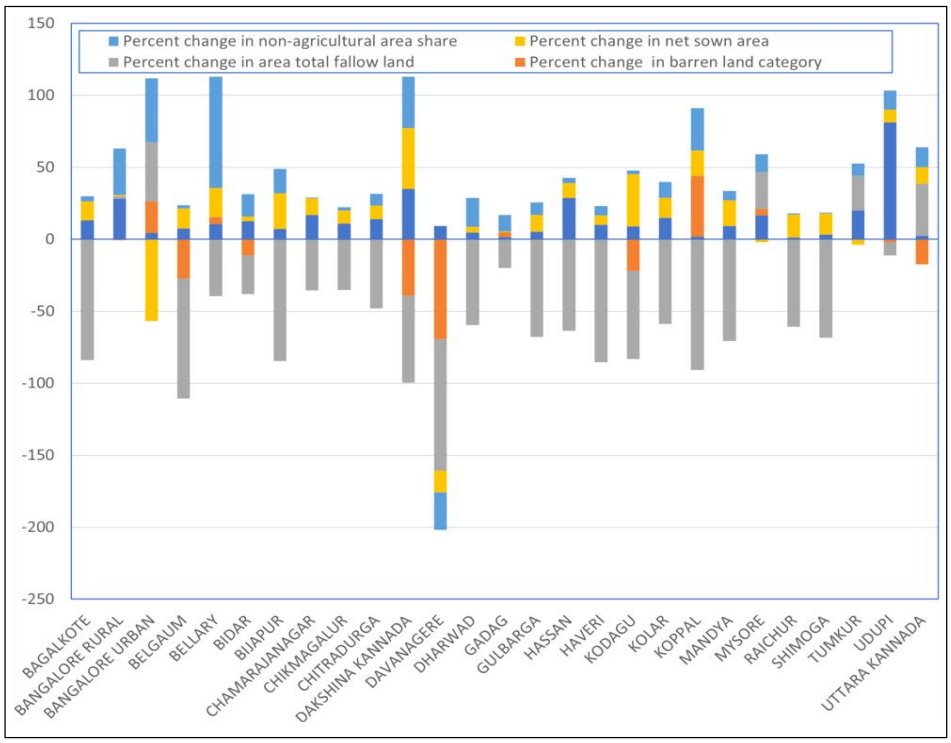


Fig 5: Growth in share under different land use categories from 2001 to 2021 across districts of Karnataka.

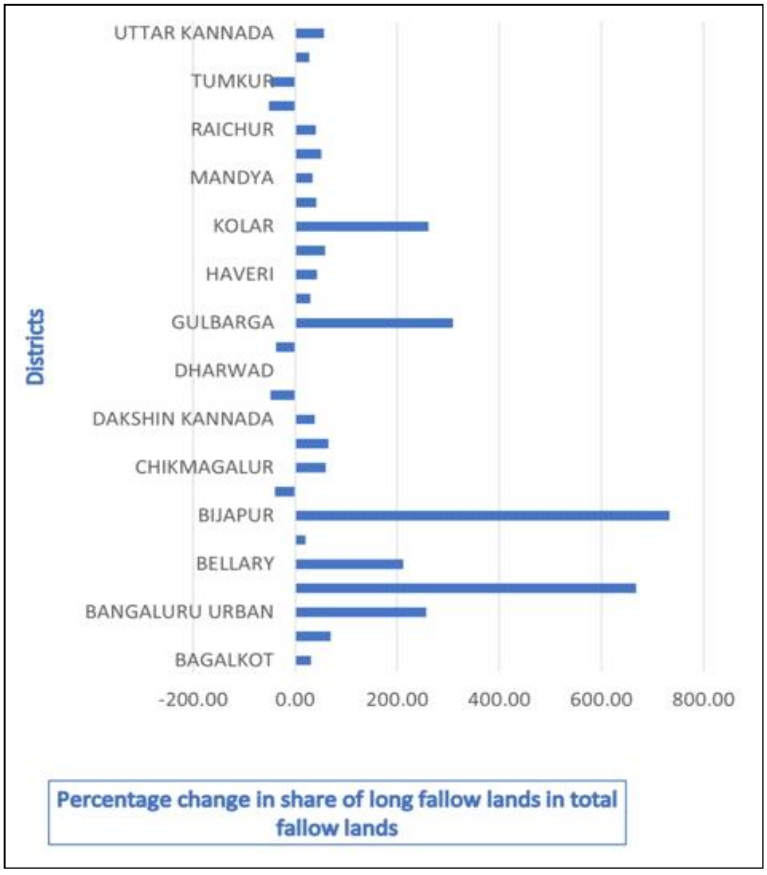


Fig 6: Growth in share under long fallow lands in total fallow lands from 2000-01 to 2020-21.

Since 2000-01, there has been an observed increase in the proportion of long fallow land in total fallow land (Fig 6), with the exception of five districts namely, Chamarajnagar, Davanagere, Gadag, Shimoga and Tumkur. Notably, the Bijapur and Belgaum districts have shown a significantly high increase in this land category. This trend of shifting from cultivated land to long-fallow land during the study period suggests a growing demand for land for non-agricultural purposes, driven by population pressure and urbanization in these districts.

In addition, we also studied the growth of arable area share across the districts (Fig 7). Apart from the districts of Bangalore Urban and Rural, Davanagere, Koppal and Udupi districts showed a significant negative growth in arable area share. Most of the other districts show a positive growth in the share of land under arable area. All the districts showed a positive rate of urbanization. Udupi, Tumkur, Mysore, Hassan, Dakshina Kannada, rural Bangalore and Chamarajanagar have shown more than a 15% growth in urbanization, with Udupi showing a growth of 81.26% from 2000-01.

Direction of land use change (Fixed effects panel regression analysis)

We conducted panel data regression over a 21-year period (2000-01 to 2020-21), testing the null hypothesis that changes in non-agricultural land use do not correlate with changes in arable or barren land categories. Table 2 shows the dependent and independent variables used in the model.
Table 3 shows the result of equation 2.
The regression result gives,

$$Y = 0.74 - 0.91\ X_1 - 1.30\ X_2$$

Y= Share of Land under non-agricultural category.
X_1= Share of arable land category.
X_2= Share of barren land category.

Table 2: General statistics of the share under different land use categories.

Variables	Mean	Std. dev.	Min	Max
Share of non-agricultural area (Dependent variable)	.09	.09	.02	.58
Independent variables				
Share under barren and unculturable land	.04	.02	.01	.12
Share under arable area	.66	.19	.14	.93

Table 3: Results of fixed effects regression using dependent variable share of non-agricultural area.

Variables	Share of non-agricultural area (%)
Share of arable area (%)	-0.91*** (0.02)
Share of barren and unculturable Area (%)	-1.30*** (0.06)
Constant	0.74*** (0.02)
Year fixed effects	Yes
Number of districts	27
R-squared	0.97

Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1.

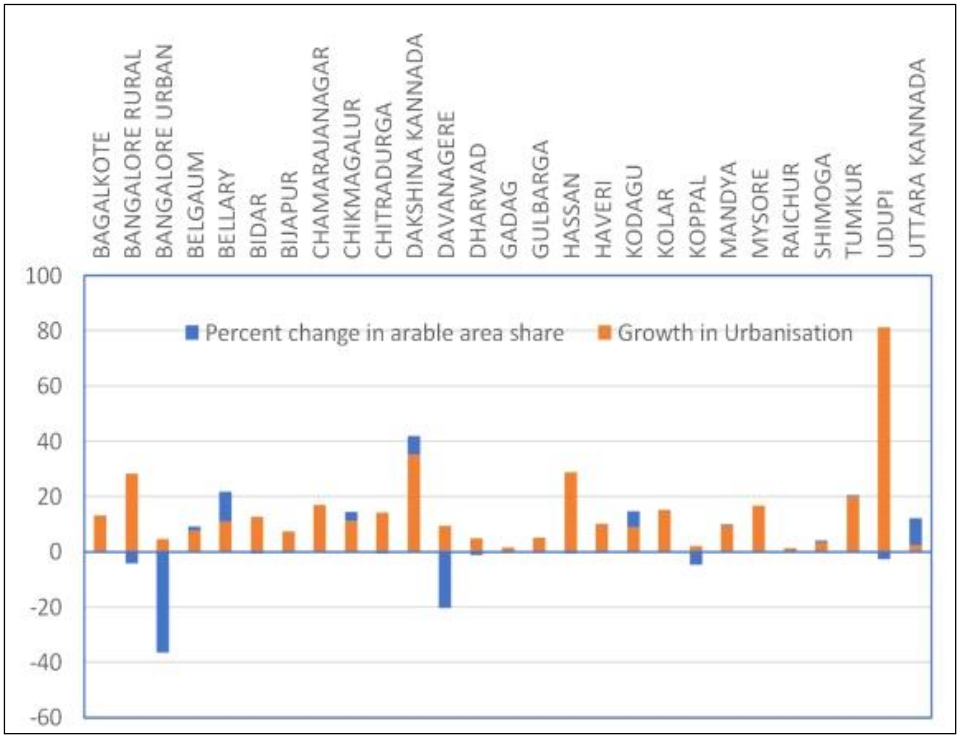


Fig 7: Growth in share under arable area and urbanisation rate from 2001 to 2021 across districts of Karnataka.

The significant p-values for all independent variables in the fixed effects model led us to reject the null hypothesis, indicating a relationship between changes in non-agricultural land use and both arable and barren land. The negative coefficient signs for both arable and barren land shares implies that an increase in non-agricultural land use is associated with a decrease in these land categories, as anticipated. The estimated mean rate of change indicates that a 1% decrease in arable land share results in an average expected increase in non-agricultural land share in the district of 0.91%. Similarly, 1% decrease in barren land share results in an average 1.3% increase in non-agricultural land share in the district. The model is selected based on robust Hausman test and is controlled for both time invariant unobservable variables and time variant unobservable variables through inclusion of both district fixed effects and year effects.

The above result is in line with other study results from the past, which reported a continuous and persistent expansion in land for non-agricultural uses mostly diverted from the desirable land categories (Pandey and Ranganathan, 2018) such as current fallow land, permanent pasture land, culturable waste land and net sown area. Meanwhile, during the post-liberalization period, agricultural labourers and marginal cultivators, especially male workers, migrated to urban areas primarily driven by urbanization and better income opportunities (Mitra and Murayama, 2009; Srivastava, 2011), which also triggered the land use change from agriculture to fallow land and non-agriculture land.

Rapid growth in areas under non-agricultural purposes, such as human settlement of a rising population and developmental activities, has been observed from the analysis. The most striking feature concerning the land use pattern in the state is that the current fallow land share has decreased during the study period compared with that of long fallow land. The total fallow land has decreased from 9.42 to 4.13 % and thus, the decrease in total fallow land has been attributed majorly to current fallow land, showing that farmers are converting the current fallow to cropping. The decrease in the current fallows may be due to the adoption of new technology, irrigation availability and crop diversification. In particular, the role of high-value crop adoption in farmers' decision-making is a key factor, as it helps them reap the price benefits by cropping under more areas. Crops such as vegetables has a shorter production cycle with regular stream of income (Birthal *et al.,* 2013) and high value crops such as vegetables, fruits, condiments and spices, flowers, aromatic and medicinal plants and plantation crops like tea and coffee generate higher net returns per unit of land compared to staples or other widely grown crops (Birthal *et al.,* 2015).

It is necessary to maximize the income of farmers when there is a continuously increasing non-agriculture area due to high rate of urbanization, unpredictable climatic conditions as well as labour scarcity and higher wages of labour arising out of diversion of labour to MNREGA and for better employment opportunities in urban areas. In the case of agriculture production, increasing or sustaining current production levels while preventing the degradation of available soil and water resources is a major challenge. Besides, higher levels of chemical inputs use have degraded natural and agroecosystems, leading to problems with changes in climate and the natural environment (Sangha, 2014).

The inevitable scarce nature of land, which encompasses many use opportunities, will be challenging as we need to understand the resulting undesired trade-offs when land conversion among the different land use categories acts in the opposite direction, such as cropland to fallow land along with wasteland reclamation to cropland (Meiyappan *et al.,* 2017). it is necessary to discourage the negative trend in other categories of arable areas such as long fallow land, permanent pasture land, culturable wasteland and miscellaneous tree crops and mangroves to boost the production and enhance farmer's income and promotion activities need to be encouraged to reduce the rate of their conversion to non-agricultural purposes.

CONCLUSION

The study understands that there are substantial changes in land use in Karnataka at the district level over the study period and it presents a comprehensive analysis of land use changes at the district level in Karnataka, focusing on the direction of land use change with respect to arable land, land allocated for non-agricultural purposes and barren land. The gain in the net sown area might be due to the shift from the total fallow land, particularly current fallow land, which points to improved irrigation and crop diversification to high-value crops such as vegetables, fruits, flower crops, plantation and spice crops as horticulture area in Karnataka witnessed a significant improvement during this period. More land is being diverted to non-agricultural purposes due to higher population pressure and industrial development; it under-scores the necessity for carefully designed and closely monitored land use policies to ensure sustainable land management practices. The study also presents the need for a comprehensive analysis of the causes of land use change, considering food production, resource conservation, climate vulnerability including intermittent dry spells and waterlogging, socio-economic factors, marketing, and geo-political perspectives. The findings of this study bear significant policy implications, offering insights into how the expansion of non-agricultural areas, driven by rapid population growth, negatively affects the land availability for cultivation. Future studies are essential to understand the desirability and sustainable nature of the trade-off in land use shifts across different categories, as there is an increase in net sown area and non-agricultural land at the cost of other land use categories.

ACKNOWLEDGEMENT

We acknowledge the Directorate of Economics and Statistics, Government of Karnataka for providing the reports and data.

We sincerely appreciate the support for this study from Christ (Deemed to be) University, Bangalore, Karnataka.

Author's contribution

Radhika C: Conceptualization and methodology development, Data analysis, Interpretation of data, original draft preparation and visualization; Mahesh E: Interpretation of data, Manuscript editing and guidance in the research; Rajib Sutradhar: Conceptualization and methodology development, Interpretation of data and manuscript editing and guidance in the research; Udayabhaskar Kethineni: Manuscript editing; Jagdish Prasad: Manuscript editing, visualisation and suggestions.

Conflict of interest

The authors declare that they have no conflicts of interest.

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