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An economic analysis of crop diversification and dynamics of cropping pattern in Karnataka, India

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The extent and nature of crop diversification and dynamics of cropping pattern in Karnataka state has been analyzed using secondary data collected from different publish sources of Directorate of Economics and Statistics (DES), Bangalore, Karnataka from a period of 1998-99 to 2020-21 (i.e., 23 years). Composite Entropy Index (CEI), double log model and Markov chain analysis were applied to assess the determinants of crop diversification and dynamics of cropping pattern in Karnataka. Results of C.E.I indicates that Kodagu, Dakshina kannada, Yadgir, Udupi and Shivamogga has low crop diversification. Although Karnataka's crop diversification values show a positive trend but its coefficient value is almost zero. It shows that there is a threat for Karnataka's crop diversification. The transition probability matrix diagram indicated that although cereals and millet groups occupied a larger share in terms of area under crops, it has a negative net gain in the probability of area retention. Double log model results revealed that the variable like MSP of coarse cereal, percentage of gross irrigated area to net irrigated area, credit inflow in to agricultural sector by the scheduled commercial bank and length of national highways are influencing the crop diversification positively. Therefore, the establishment of fundamental infrastructure, such as reliable irrigation water supply, access to credit, and well-developed transportation networks, is a crucial prerequisite for creating favorable conditions to promote agricultural development and crop diversification. These parameters have been identified as influential factors that shape the nature and extent of crop diversification. By addressing these infrastructure needs, it becomes possible to foster an environment conducive to agricultural growth and facilitate the process of diversification.

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Introduction

Crop diversification has been a subject of extensive discourse over a considerable period, with researchers striving to establish its connection with developmental possibilities (Birthal et al., 2013; Chakrabarti, Kundu (2009)). Numerous studies have proposed different strategies for diversifying land use and other resources to foster sustainable agricultural growth and rural livelihoods (Ergano et al. (2000), Papademetrio, Dent (2001); De UK, 2003a; Mehta, 2009; Manabendu (2010), Kumar Ghosh, 2011). The practice of crop diversification acts as a mechanism to mitigate risks linked to climate change, optimize land allocation, and is typically gauged by the distribution of land dedicated to various crops. Additionally, agricultural diversification is adopted to counteract the unfavorable consequences of current crop specialization and monoculture. This facilitates the utilization of resources, recycling of nutrients, restoration of soil fertility, and the enhancement of economic viability through value-added products and ecological enhancements (Acharya et al., 2011). The existing cropping pattern has witnessed reduced productivity due to shifting climatic patterns such as erratic and inadequate rainfall, along with diminishing water resources (Guiteras, 2007). In response to climate change, farmers are progressively embracing crop intensification through mixed cropping and the incorporation of high-value crops, particularly in the realm of horticulture. Various factors such as market dynamics, technological advancements (including access to inputs and tools), agro-climatic conditions, infrastructure development (encompassing communication, marketing, and storage facilities), and institutional elements such as government policies, protection, and risk management collectively act as driving forces behind diversification (Patnayak and Nayak, 2004).

Encompassing an area of 1.92 lakh sq km, Karnataka ranks as the sixth-largest state in India in terms of geographical expanse, constituting 5.83 percent of the nation's total land area. The 2011 population census reveals that the agricultural sector provides sustenance to 13.74 million laborers, with cultivators accounting for 23.61 percent and agricultural workers for 25.67 percent of this populace. Cultivated land in Karnataka spans 123,100 km², which equates to 64.6 percent of the state's entire geographical coverage. Over time, Karnataka's economic landscape has undergone significant transformations subsequent to the implementation of new policy frameworks during the 1990s. Despite agriculture remaining the predominant occupation for the majority of the rural populace, the state's economic structure has progressively shifted toward the tertiary sector. Consequently, there is an expected reduction in the share of agricultural and allied sectors in the state's overall income. The growth trajectory of Karnataka's agricultural sector has demonstrated notable fluctuations and variations. In absolute terms, the Gross State Domestic Product (GSDP) originating from agriculture and its allied sectors witnessed a sustained decline from Rs. 289.67 billion in 1999–2000 to Rs. 187.09 billion in 2003–04. Subsequently, it exhibited a trajectory of growth, culminating at Rs. 674.57 billion in the fiscal year 2020–21. According to the Agriculture Census 2015–2016, the operational area of holdings in Karnataka experienced a decrease of 2.97 percent, while the count of operational holdings exhibited an increase of 10.83 percent.

Against this backdrop, this paper aims to achieve specific objectives: first, to analyze the nature and extent of crop diversification in Karnataka; second, to study the factors influencing crop diversification; and third, to assess the direction of shifts in the cropping pattern.

Methodology

To conduct an economic analysis of crop diversification, the state of Karnataka in India was deliberately chosen as the study area. The data

utilized in this research was gathered from multiple reliable sources, including the Directorate of Economics and Statistics (DES), the Reserve Bank of India (RBI) website, and the Ministry of Statistics and Program Implementation (MoSPI) website. Time series data pertaining to area, production, productivity of different crops, Fertilizer Consumption (Kgs/Hectare), Area Sown More Than Once (Hectare), Annual Rainfall (mm), Average size of landholding (Hectare), MSP of Paddy (Rs./Qtl), MSP of Coarse cereal (Rs./Qtl), Percentage of gross irrigated area to gross cultivated area, Cropping intensity (%), Credit to Agricultural sector by SCB (Billion), Per-capita Net State Domestic Product (Rs.), Per-capita Availability of Power (Kilowatt), Length of National Highways (kms) and Number of factories (units) were collected for the period 1998–1999 to 2020–2021.

Crop diversification–composite entropy index. Various methods have been proposed to analyze the concentration (specialization) or diversification of crops or activities over time and space. Each method possesses its own limitations and strengths when examining these patterns (Shiyani, Pandya (1998)). In the context of assessing the extent of crop diversification in this analysis, the composite entropy index (CEI) was employed. The CEI was utilized to examine the nature of crop diversification within different crop groups, as well as across all crops collectively. The crop groups considered in this analysis include Cereals and millets, Pulses, Sugar crops, Condiments and Spices, Fresh fruits, Dry fruits, Vegetable crops, Oilseeds, Fiber crops, Dyes and Tanning materials, Drugs, Narcotics, and Plantation crops.

$$CEI = - \left[\sum_{i=1}^N p_i \log_n^{p_i} \right] \times \left\{ 1 - \left(\frac{1}{N} \right) \right\}$$

where, N is the total number of crops and p_i is the average proportion of the i th crop in total cropped area.

Cereals and millets category included Paddy, Jowar, Bajra, Maize, Ragi, Wheat, Barley and Other Cereals and Millets. Pulses category included Gram, Arhar (Tur) and Other Pulses. Sugar crop category included Sugarcane and Other Sugar crops. Condiments and Spices category included Black pepper, Chilies, Ginger, Turmeric, Cardamom, Betelnut, Garlic, Coriander and Other Condiments and Spices. Fresh fruits category included Mango, Banana, Citrus Fruits, Grapes, Pome Fruits, Papaya, Apple and Other Fruits. Dry fruits category included Cashew nut and Other Dry Fruits. Vegetable category included Potato, Tapioca, Sweet Potato, Onion and Other Vegetables. Oilseeds category included Groundnut, Castor seed, Sesamum, Rapeseed and Mustard, Linseed, Soyabean, Coconut, Niger seed, Sunflower, Safflower and Other Oilseeds. Fiber crops category included Cotton, Jute, Mesta, Sun hemp and Other Fiber. Dyes and Tanning materials category included Indigo and Other Dyes and Tanning Materials. Drugs, Narcotics and Plantation category included Opium, Tobacco, Chinchona, Indian hemp, Tea, Coffee, Rubber and Other Plantation Crops and for all crops.

Determinants of crop diversification. Multiple regression analysis was carried out using the time series data for the period from 1998–1999 to 2020–2021 to identify the important factors affecting crop diversification (Joshi et al., 2004; 2006). Double log model has been attempted in the study. The CEI (Y) was specified as a function of the following independent variables.

$$\ln Y = a + b_1 \ln X_1 + b_2 \ln X_2 + \cdots + b_n \ln X_n + U$$

The explanatory variables considered were:

X_1 = fertilizer consumption (kgs/hectare), X_2 = area sown more than once (hectare), X_3 = annual rainfall (mm), X_4 = average size of landholding (hectare), X_5 = MSP of paddy

(Rs./Qtl), X_6 = MSP of coarse cereal (Rs./Qtl), X_7 = percentage of gross irrigated area to gross cultivated area, X_8 = cropping intensity (%), X_9 = credit to agricultural sector by SCB (Billion), X_{10} = per-capita net state domestic product (Rs.), X_{11} = per-capita availability of power (kilowatt), X_{12} = length of national highways (kms), X_{13} = number of factories (units), X_{14} = time, X_{15} = squared value of time, U = error-term and \ln = natural logarithm.

Shift in cropping pattern–Markov chain analysis. Markov chain model was used to analyze the dynamics of cropping pattern in Karnataka. Cropping pattern data were collected from 1998–1999 to 2019–2020. Lingo software was used to derive the transition probability matrix further diagram was created using R-studio.

$$E_{jt} = \sum_{i=1}^n E_{it-1} \times P_{ij} + e_{jt}$$

E_{jt} = shift in per capita share of j th crop during the period t ; E_{it-1} = per capita share of i th crop during the period $t-1$; P_{ij} = probability that share will shift from the i th crop to j th crop; e_{jt} = error-term which is statistically independent of $e_{jt} - 1$; and n = number of crops.

Results and discussion

Crop diversification. District wise crop diversification index (CEI) were calculated and presented in Figs. 1 and 2. Figure 1 shows the district wise crop diversification index for the year 2019–2020. It shows that out of 30 districts 11 districts (Chamarajanagar, Bagalkote, Dharwad, Mysuru, Koppal, Chikkamagaluru, Hassan, Belagavi, Ballari, Chikkaballapura and Chitradurga) are in the high crop diversity category, 12 districts (Gadag, Uttara kannada, Tumakuru, Haveri, Kolar, Mandya, Bengaluru urban, Vijayapura, Bangalore rural, Ramanagara, Shivamogga and Udupi) are in the medium category and 7 districts (Bidar, Davangere, Raichur, Yadgir, Dakshina kannada, Kalaburagi and Kodagu) are in the low crop diversity category. Districts are classified based on the score obtained from the CEI. Districts are categorized as having low, medium and high levels of diversification with the help of mean and standard deviation. This classification was based on previous studies by Baraker et al. (2021) and Nagaraj et al. (2013). Besides that, district wise average CEI was calculated for the period from 1998–1999 to 2019–2020 and presented in Fig. 2. It is evident that 10 districts (Chamarajanagara, Dharwad, Belagavi, Chikkamagaluru, Hassan, Koppal, Chitradurga, Ballari, Mysuru and Gadag) are in the high

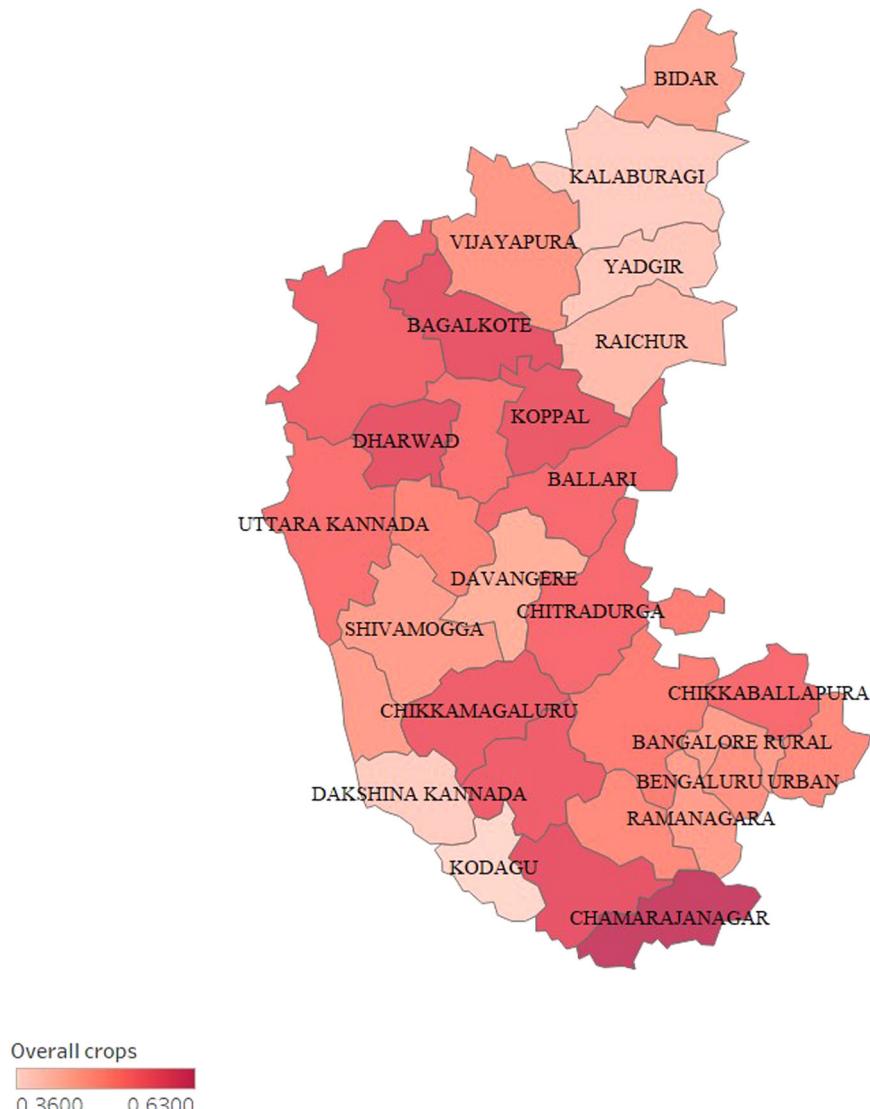


Fig. 1 Karnataka's Composite entropy index (2020_21). State wise composite entropy index of Karnataka during the year 2020-21.

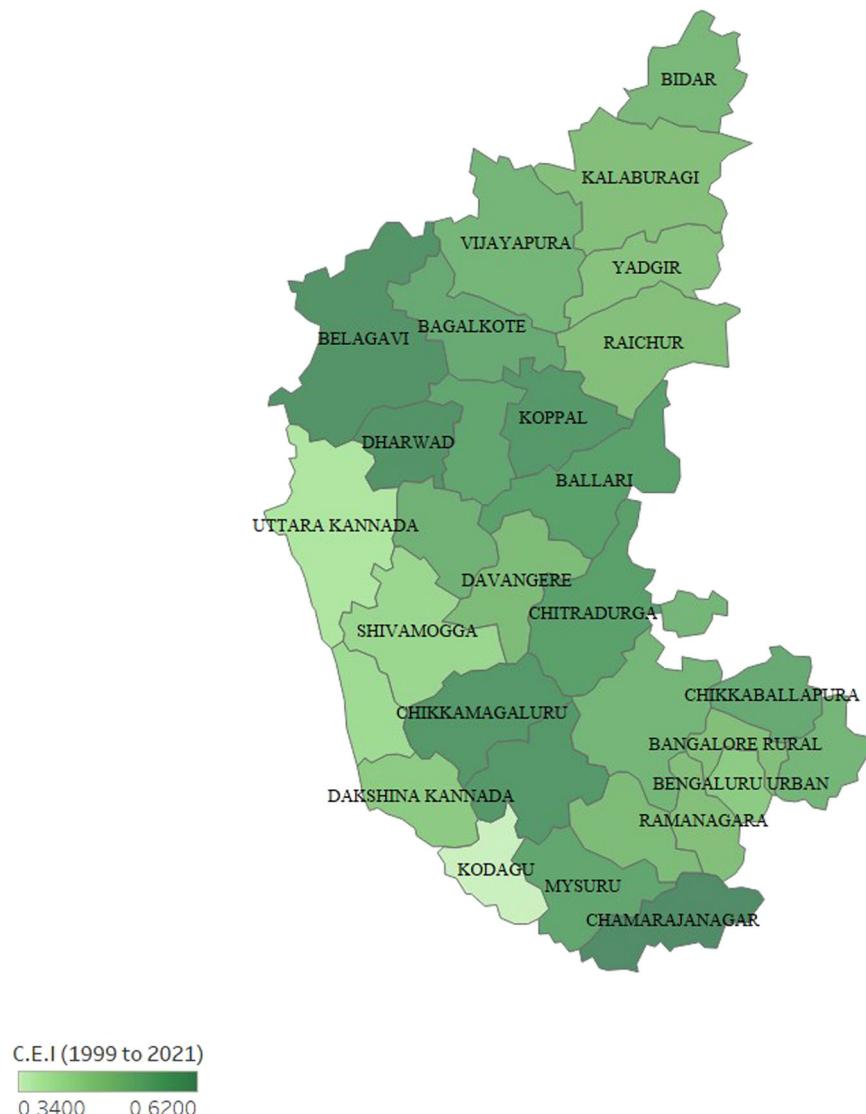


Fig. 2 Karnataka's average composite entropy index (1998-1999 to 2020-2021). State wise average composite entropy index of Karnataka. The average was taken from the year 1998 to 2020-21.

crop diversity category. It is to be noted that some districts (Belagavi, Ballari, Chitradurga, Koppal, Dharwad, Chikkamagaluru and Gadag) in the high crop diversity category are having negative CAGR. Around 13 districts (Bagalkote, Chikkaballapura, Haveri, Tumakuru, Vijayapura, Kolar, Bidar, Mandya, Davangere, Bangalore rural, Ramanagara, Raichur and Kalaburagi) are in the medium category and 7 districts (Yadgiri, Bengaluru urban, Dakshina kannada, Shivamogga, Udupi, Uttara kannada and Kodagu) are in the low crop diversity category. The trend of crop group wise diversification indices of Karnataka for the period of twenty-three years i.e., 1998–1999 to 2019–2020 are presented in Fig. 3. The analysis of the CEI revealed that the CEI for cereals remained relatively constant throughout the period of investigation. This indicates that farmers in the region prioritize the cultivation of paddy, wheat, and maize, as these crops serve as staple food sources for the state. Despite the relatively low income generated from these crops, farmers are compelled to cultivate them to ensure food security.

In contrast, the CEI for pulses exhibited a decreasing trend, declining from 0.728 in 2000–2001 to 0.689 in 2014–2015. This decline can be attributed to several factors. Firstly, the profitability of pulses cultivation may be lower compared to other

crops, influencing farmers to shift away from pulse cultivation. Additionally, crop losses resulting from pest infestations and animal attacks may have further contributed to the diminishing CEI values for the pulses group.

Determinants of crop diversification. It is evident from Table 1 that the annual rainfall, average size of land holding and per capita Net State Domestic Product are significant and negatively influencing the crop diversification. The negative co-efficient value of rainfall indicates that the higher rainfall areas in Karnataka have less crop diversification. Because the farmers in the high rainfall areas prefer to cultivate paddy. Only the medium and low rainfall area farmers cultivating different crops to increase their income. The results are in line with the results of Asif Ali Abro (2012). The farmers who are having less landholding are risk taker comparing to the farmers have large landholding (Calle et al., 2022; Felix et al., 2021). The small land holding farmers are diversifying their cultivation to minimize the risk may be a reason for the negative coefficient value. One might expect larger farms to be more specialized when there are scale economies in an enterprise, and larger farms are less risk averse.

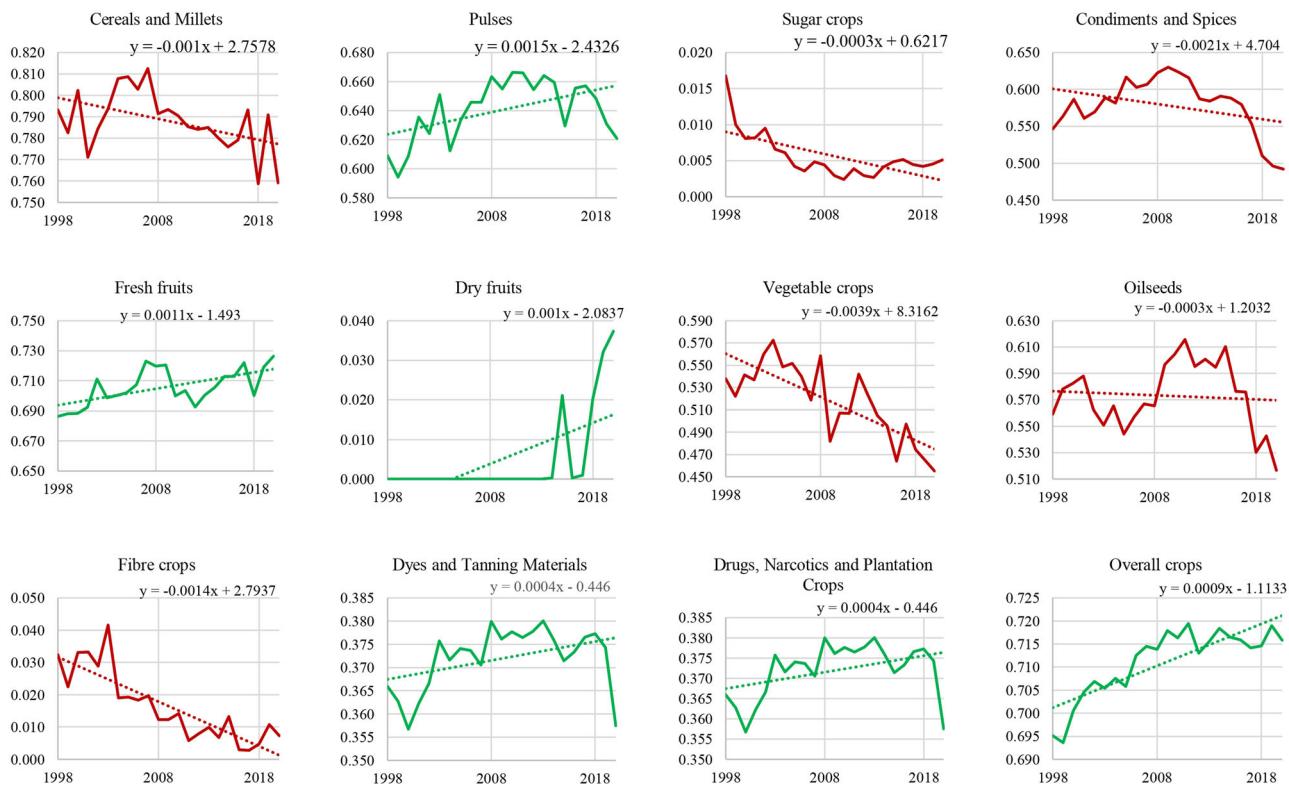


Fig. 3 Trend of Karnataka's crop diversification (CEI) from 1998-1999 to 2020-2021. Crop/crop group wise trend of crop diversification using composite entropy index from 1998-99 to 2020-21.

Table 1 Determinants of crop diversification in Karnataka.

Particulars	Coefficients	Standard error	t Stat
Intercept	3.936NS	0.782	5.030
Fertilizer consumption (kgs/hectare)	0.003NS	0.005	0.490
Area sown more than once (hectare)	-0.031NS	0.040	-0.776
Annual rainfall (mm),	-0.025***	0.007	-3.553
Average size of landholding (hectare)	-0.045**	0.015	-2.966
Difference between MSP of coarse cereal & paddy (Rs./Qtl)	0.052**	0.018	2.88
Percentage of gross irrigated area to net irrigated area/irrigation intensity (%)	0.030**	0.012	2.533
Cropping intensity (%),	0.182NS	0.274	0.665
Credit to agricultural sector by SCB (Billion),	0.021**	0.008	2.724
Per-capita net state domestic product (Rs.),	-0.016**	0.006	-2.890
Per-capita availability of power (kilowatt)	0.030NS	0.018	1.707
Length of NAtional Highways (kms)	0.027**	0.011	2.420
Number of factories (units)	-0.004NS	0.013	-0.319
Time	0.008***	0.002	3.772
Squared value of time	0.000NS	0.000	-3.216

*** indicates 1% significant, ** indicates 5% significant, NS indicates non-significant.

The per-capita Net State Domestic Product has a negative influence on crop diversification, indicating that wealthier farms are more specialized. This shows that the wealthier farmers are less risk averse and less diversified. The variables difference between minimum support price (MSP) of coarse cereals and paddy, percentage of gross irrigated area to gross cultivated area, credit supplied to agricultural sector by the schedule commercial bank and length of national highways are significant and positively influencing the crop diversification. MSP is a policy tool which provides price security to the farmers as well as encourage the farmers to diversify the crops, especially the difference between minimum support price of coarse cereals and paddy. MSP as an incentive for diversification is superior to other

incentives (Aditya et al. 2017; Singh and Sidhu, 2004; Ghose and Hassan 2019). Because of that the elasticity value of the difference between MSP of coarse cereal and paddy is higher than the other variables. The irrigation intensity (ratio of gross irrigated area to net irrigated area) has a positive impact on crop diversification indicating that with the availability of irrigation all-round the year, diversification will increase. The results are in line with the results of Gupta and Tewari (1985). The variables like length of national highways and the time has a significant and positive relation with Karnataka's crop diversification. This result shows that over the years there is positive crop diversification trend has witnessed in Karnataka. Although the time variable has a positive coefficient value, the quadratic term of time variable has a

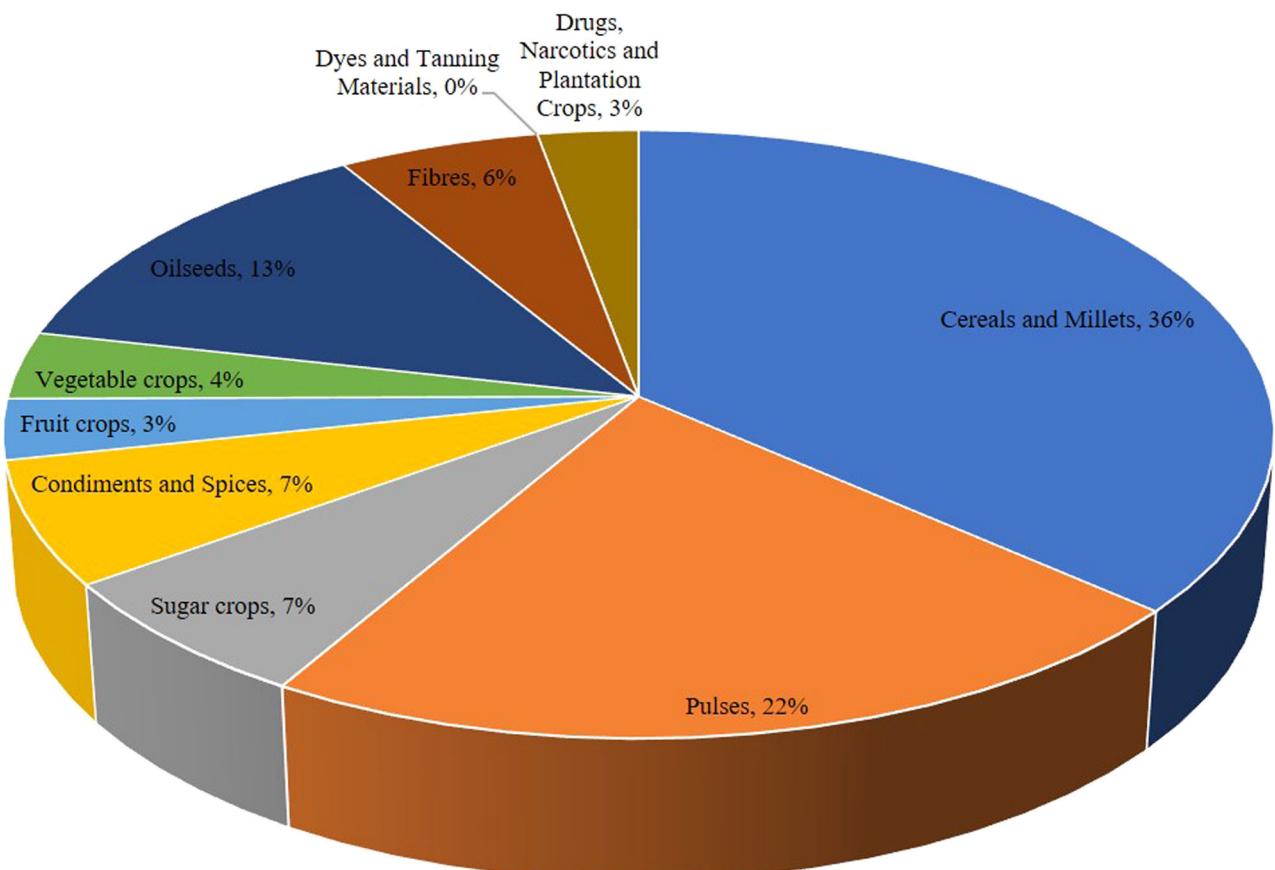


Fig. 4 Karnataka's cropping pattern (2019-2020). The cropping pattern/ share of each crop category in Karnataka in 2019-20.

negative coefficient indicates that there is inverted U shaped relation between time and crop diversification. Even though there is positive trend in the crop diversification, in recent years the crop diversification has started to decline. The same has replicated in Fig. 3 (Trend of Karnataka's Overall crop's diversification index).

Dynamics of cropping pattern. Over the years the share of non-food crops area has declined (from 31.55% to 23.54%) but the share of food crops has increased from 68.45% to 76.46%. It is evident from Fig. 4 cereals and millets; pulses and oilseed crops occupied a major share in Karnataka's cropping pattern. Hence this paper focused only on these crops. The changes in Karnataka's cropping pattern over the last 23 years was analyzed and the transition probability matrix of cereals and millets; pulses and oilseed crops are presented in Figs. 5–7 respectively. It is evident from Fig. 5, the probability of area retention within the cereals and millets group is higher for maize (0.92) followed by jowar (0.67), paddy (0.64), wheat (0.47), other cereal and millets (0.46), ragi (0.29). The area retention rate of bajra and barley in Karnataka is less. It is to be noted that bajra lost its major area to paddy, ragi and wheat. Similarly, barley lost its almost entire area to ragi. High minimum support price for ragi and paddy may be a reason for this shift. Net gain in the probability of area retention has found positive for ragi, jowar, paddy and maize but it is negative for barley, other cereals and millets and wheat. The area attrition of barley, other cereals and millets and wheat is the reason for negative trend of crop diversification in the cereals and millets group. It is to be noted from Fig. 6 that the probability of area retention within the pulses group is higher for "other pulses" (0.93) category followed by gram (0.61) and arhar (0.55). High

retention rate of "other pulses" category may be a reason for increasing trend in the crop diversification of pulses crop. **It is to be noted that gram and arhar has a positive net gain in the probability of area retention.** Although "other pulses" category has a higher retention rate but it's net gain in the probability of area retention has found negative. The "other pulses" category losses its area to arhar with a probability value of 0.07. This may a reason for recent decline in the pulses crop diversification.

It is evident from Fig. 7 that the probability of area retention within the oilseed group is higher for sunflower (0.94) followed by groundnut (0.83), soyabean (0.80), coconut (0.77), niger seed (0.74), sesamum (0.34), castor seed (0.31), other oilseeds (0.21), linseed (0.16) and safflower (0.16). Area retention of Rapesed and Mustard is very low. It is to be noted that except groundnut, sunflower, safflower and coconut all other oilseed crops has a negative net gain in the probability of area retention. This may be a reason for negative trend in the oilseed crop diversification. It is to be noted from Fig. 8, the probability of area retention of overall crops in Karnataka shows that cereals and millets have a higher retention rate (0.85) followed by oilseeds (0.81), sugar (0.81), Condiments and Spices (0.71), pulses (0.66), fiber (0.51), drugs, narcotics and plantation crops (0.48), vegetables (0.32) and fruits (0.06). It is to be noted that except pulses all the crop categories including cereals and millets has a negative net gain in the probability of area retention.

Conclusion

The analysis of crop diversification at both the district and state levels in Karnataka, using the CEI, has yielded insightful conclusions. The findings highlight that Kodagu occupies the lowest position in terms of C.E.I values for both the year 2019–20 and

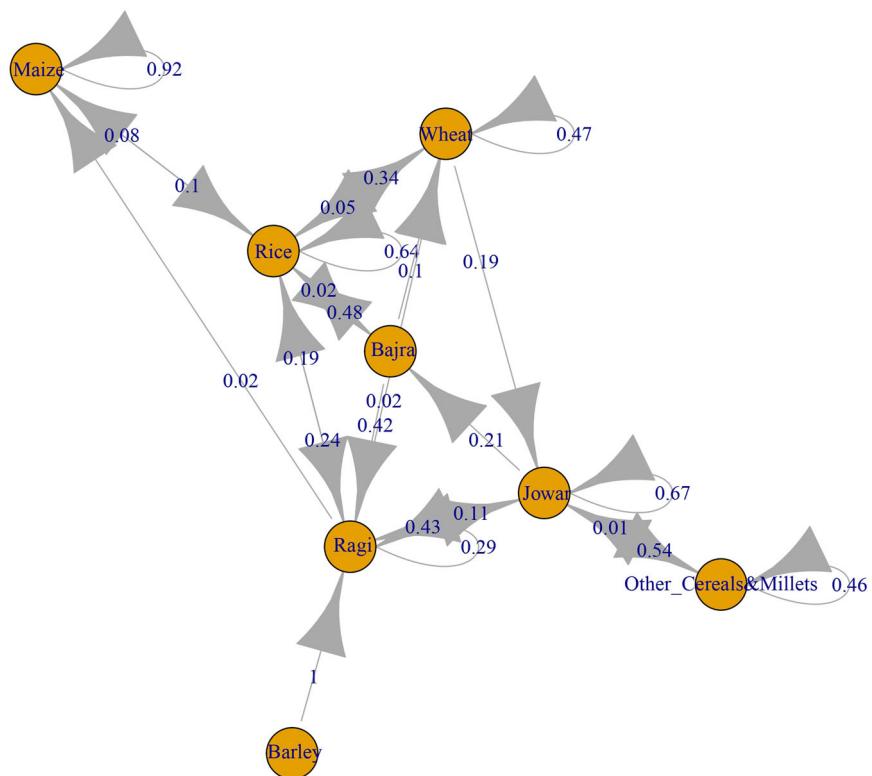


Fig. 5 Direction of shift with in cereals and millets category. The direction of cropping area shift with in the cereals and millet crop category in Karnataka.

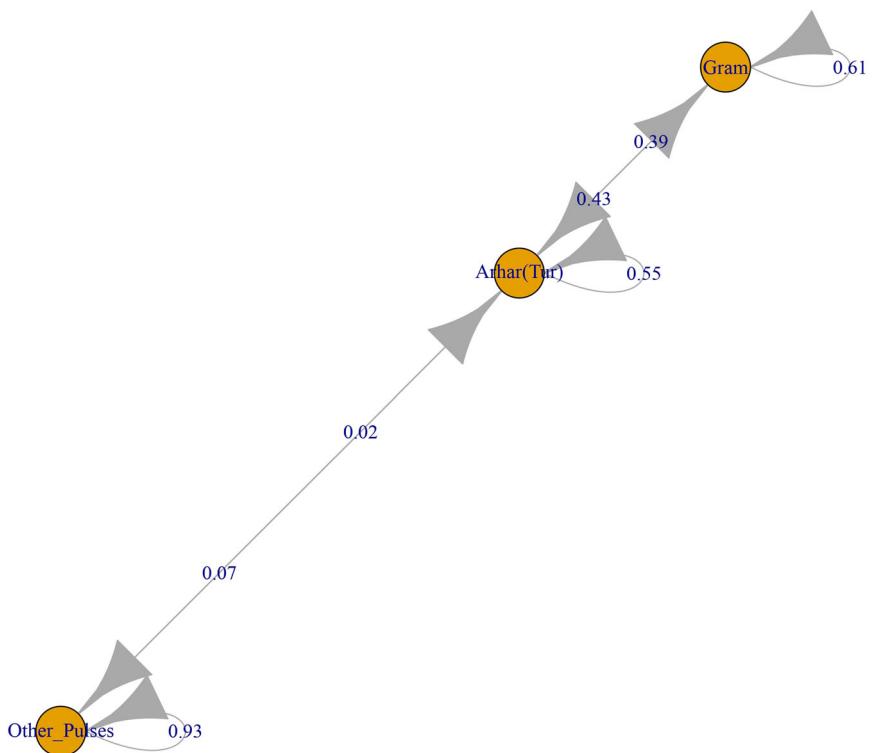


Fig. 6 Direction of shift with in pulses. The direction of cropping area shift with in the pulses crop category in Karnataka.

the average spanning from 1998–1999 to 2019–2020. This points towards Kodagu having a relatively low level of crop diversification, followed by districts such as Dakshina Kannada, Yadgir, Udupi, and Shivamogga. While Karnataka's overall crop diversification trends exhibit a positive trajectory, the coefficient value

associated with this trend is nearly zero, signifying a potential vulnerability in Karnataka's crop diversification landscape. The visualization of the transition probability matrix underscores that although the category of cereals and millets retains a substantial share in terms of cultivated area, it experiences a negative net gain

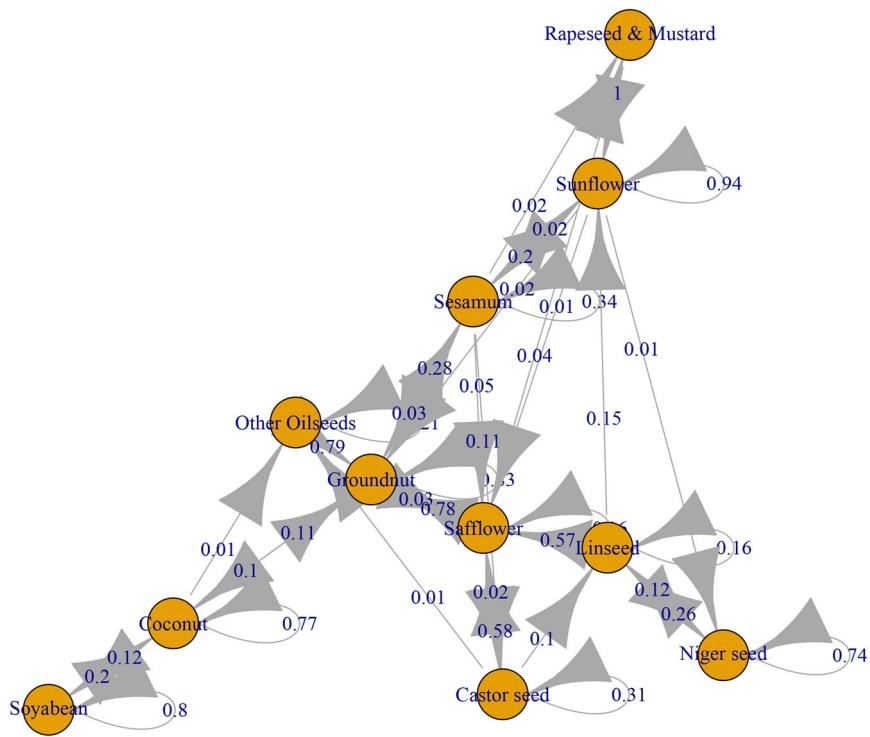


Fig. 7 Direction of shift with in oilseeds category. The direction of cropping area shift with in the oilseed crop category in Karnataka.

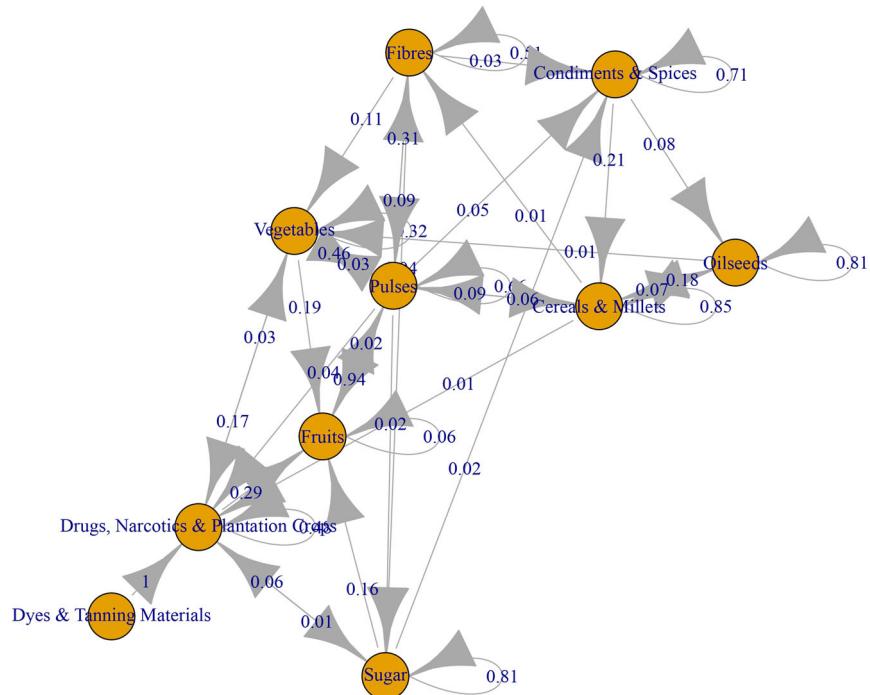


Fig. 8 Direction of cropping pattern shift among major crop categories in Karnataka. The direction of cropping area shift with in the major crop category in Karnataka.

in terms of the probability of area retention. This suggests an area of concern for this particular crop group's sustainability. The insights from the double log model analysis shed light on several influencing variables. Notably, factors such as the minimum support price (MSP) for coarse cereals, the proportion of gross irrigated area to net irrigated area, credit inflow into the agricultural sector through scheduled commercial banks, and the

length of national highways have been identified as positive influencers of crop diversification. This underscores the importance of robust infrastructure, including dependable irrigation water supply, accessible credit facilities, and well-connected transportation networks, as pivotal prerequisites for fostering an environment conducive to agricultural growth and promoting crop diversification. The culmination of these influential

parameters serves as a blueprint for shaping the nature and extent of crop diversification. Addressing these infrastructure requirements emerges as a strategic approach to nurturing a propitious environment that supports agricultural advancement and facilitates the diversification process.

Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Author contributions

Dr. K conceived of the presented idea and he developed the theory and performed the computations. Dr. K collected the secondary data. Dr. K B verified the analytical methods. Both the authors discussed the results and contributed to the final manuscript.

Ethical approval

This article does not contain any studies with human participants performed by any of the authors.

Informed consent

This article does not contain any studies with human participants performed by any of the authors.

Competing interests

The authors declare no competing interests.

Additional information

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