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Spatio-Temporal Dynamics of Growth, Instability and Crop Diversification in Karnataka

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Abstract

Crop diversification is considered as a pathway to promote agricultural development. The present paper examines the subtleties of crop diversification in Karnataka through spatial and temporal trends across the districts. The analysis carried out from 2000-01 to 2018-19 indicated steady improvement in crop diversification in the State. The Compounded Annual Growth Rate (CAGR) in cereal crops was negative whereas, it was positive in horticulture and plantation crops and commercial crops. However, higher instability was found in other crop groups compared to cereal crops. The districts falling in the southern part of the state tend to be more diversified than other districts. The spectral changes have revealed improvement in spatial diversity over the years in the state. Transitional probability matrix revealed that the shift in area was towards horticulture and plantation crops, commercial crops and condiments and spice crops in the State. However, the major retention in area was found in cereal crops since the share in total gross cropped area is more compared to other crop groups.

Keywords : Growth, Instability index, Composite entropy, Transitional probability matrix, Diversification

Crop diversification is a process of reallocation of resources across crops based on their comparative advantage. It is generally viewed as a shift from traditional lower-value to higher-value crops and is an important pathway for agricultural development. It also enhances farmer's adaptability to biotic and abiotic stresses and promotes self-reliance and sustainability in agriculture. Diversification serves as a sole source of combating risk against climate and weather vagaries in both rain fed and erratic rainfall ecosystems. The significance of crop diversification becomes more pronounced in the WTO-led globalized regime that restricts the scope for prices as an incentive to increase production. Farmers will remain in a disadvantageous position unless they adapt to market signals.

Several studies have highlighted the importance of crop diversification as a means of agricultural sustainable development. Joshi *et al.* (2006) and Birthal *et al.* (2014) decomposed agricultural growth into area effect, yield effect, price effect and diversification effect and found diversification to be an important source of growth. The shift from lower-value to higher-value crops is identified as an important factor in poverty reduction (Birthal *et al.* 2015;). Aheibam *et al.* (2017) observed that crop diversification is an important step towards poverty reduction and transition from subsistence to commercial agriculture. As regards farm sustainability, diversified farming systems incorporate functional biodiversity at multiple temporal and spatial scales to enhance ecosystem services critical to agricultural production. Diversification helps in minimizing the

adverse effects of the current system of crop specialization and monoculture through nutrient recycling.

Crop Instability is one of the important decision making parameters in the context of agricultural production. Wide fluctuations in crop output not only affect prices but also result in wide variations in the disposable income of the farmers. High growth in production accompanied by low level of instability for any crop is desired for sustainable development of agriculture (Tripathi and Prasad, 2009). The specific objectives of the article is to analyze the growth, instability and extent of crop diversification comprehensively for all the districts in Karnataka State considering the various crop groups.

METHODOLOGY

The present study is carried out in Karnataka state of India and secondary data was used for analyzing crop growth, instability and diversification. Secondary data used for the study was collected from published sources of Directorate of Economics and Statistics (DES), Bengaluru, Karnataka. Time series data from 2000 to 2019 pertaining to area, production, productivity of different crops were collected for each district and compiled accordingly for the analysis. Due to accounting and compiling ambiguities, the data of newly formed districts was combined with original district and analysis has been carried out considering the 27 districts as of 2007.

The crops were classified into seven major crop groups as a standard grouping followed by Directorate of Economics and Statistics (DES), Karnataka. The major crop groups were Cereal crops, millet crops, oilseed crops, pulse crops, horticulture and plantation crops, commercial crops and last one is condiments and spice crops. The cereal crops includes paddy, jowar, bajra, maize, ragi and wheat. Millet crops considered were navane, save, haraka, baragu and minor millets. Pulse crops included redgram, blackgram, horsegram, greengram, bengalgram and other pulses. The oilseed crops were groundnut, castor, sesamum, linseed, soybean, niger, mustard, sunflower and safflower. Commercial crops were cotton, sugarcane, tobacco, mesta and sunhemp. Horticulture and plantation crops considered were potato, onion, tomato, beans, brinjal, banana, sweet potato, tapioca, grapes, mango, papaya, cashewnut (raw), guava, sapota, cashewnut (processed), lemon and coconut. Condiments and spice crops were dry chillies, turmeric, dry ginger, black pepper, cardamom, garlic, areca nut (raw), coriander and arecanut (processed).

Compounded Annual Growth Rate

For analyzing the growth in area, production and productivity in different crop groups across the districts of Karnataka from 2000-2019 Compounded Annual Growth Rate (CAGR) was used. The methodology followed by Nadkarni and Deshpande (1982) was used to calculate the CAGR. It was calculated using the formula;

$$Y = ab^t e... \quad (1)$$

Where

Y= Dependent variable for which the growth rate is estimated (area, production, productivity of maize).

a = Intercept

b = Regression co-efficient

t = Time variable

e = Error term

The compound growth rate was obtained from the logarithmic form of the equation (1) as below :

$$\ln Y = \ln a + t \ln b$$

The per cent compound growth rate was derived using the relationship

$$CAGR = (\text{Anti ln of b} - 1) \times 100$$

Instability Analysis

The co-efficient of variation was used as a measure to study the variability in area, production,

productivity. The Coefficient of Variation (CV) was computed using the following formula given by Kent (1924),

$$CV = \frac{Standard\ Deviation\ (SD)}{Mean} \times 100$$

Whenever the trend of series was found to be significant, the variation around the trend rather than the variation around mean was used as an index of instability. The formula suggested by Cuddy and Della (1978), was used to compute the degree of variation around the trend.

$$Instability\ Index = CV * \sqrt{1 - R^2}$$

Where, R^2 = Coefficient of determination from a time-trend regression adjusted by the number of degrees of freedom.

Composite Entropy Index

The extent of crop diversification was captured using Composite Entropy Index (CEI). The CEI has two components *viz.* distribution and number of crops or diversity. The value of CEI increases with the decrease in concentration and rises with the number of crops. The value of C.E.I. ranges from zero to one. The index possesses all desirable properties of Modified Entropy Index and is used to compare diversification across situations having different and large number of crops since it gives due weightage to the number of crops (Pandey and Sharma, 1996; Chand, 1996). The formula of C.E.I. is given by,

$$CEI = -\left(\sum_{i=1}^{N} P_i * log_N P_i\right) * \left\{1 - \left(\frac{1}{N}\right)\right\}$$

Where,

N= is the number of crop groups

P= is the proportion of area of a given crop group to the total gross cropped area

Markov Chain Model

Markov chain analysis is used to study the changes occurred in the cropping pattern of crop groups. The estimation of the probability matrix (P) is central to this analysis and was done by LINGO software package. The elements P_{ij} of the matrix indicated the probability that area would switch from the i^{th} crop group to j^{th} crop over a period of time and the diagonal elements P_{ii} indicated the probability that the area share of a crop would be retained in successive time periods. Each row of the matrix sums to 1.00. The average area under a particular crop is considered to be a random variable which depended only on its past area of cultivation to that crop and which is denoted algebraically by:

$$A_{jt} = \sum_{i=1}^{n} A_{it-1} * P_{ij} + e_{jt}\ (i = 1,2,\ldots..n)$$

Where,

A_{jt} = Area under j_{th} crop group during period t

A_{it-1}= Area under i^{th} crop group during t-1

P_{ij} = Probability of shifting area from i^{th} crop group to j^{th} crop group

e_{jt} = The error term which is statistically independent of e_{it-1} and

n = Number of crop groups

The transitional probabilities P_{ij}, which can be arranged in a (c x n) matrix, have the following properties,

$$\sum_{i=1}^{n} P_{ij} = 1 \quad \text{And}$$
$$0 \leq P_{ij} \leq 1$$

Thus, the expected shift in area under cultivation of each crop group during period 't' is obtained by multiplying the area under cultivation of crop group in the previous period (t-1) with the transitional probability matrix.

Results and Discussion

Changes in Area Share of Crops

A preliminary insight into crop diversification can be gained from the changes in area share of crops. The decadal changes in shares of different crops show that agriculture in Karnataka has remained dominated by cereal crops Table 1. Pulse crops are the next important crops, followed by commercial crops and

TABLE 1

Per cent cropped area of major crop groups of Karnataka (% GCA)

Crop group	Years		
	2000-01	2010-11	2018-19
Cereal crops	46.32	41.92*	33.64*
Millet crops	0.58	0.19*	0.14*
Oilseed crops	15.43	12.54	7.44*
Pulse crops	16.67	21.58	26.63*
Horticulture and Plantation crops	6.15	8.59*	10.31
Commercial crops	10.99	10.20	11.94*
Condiments and spice crops	3.86	4.99	9.89*
Gross Cropped Area (GCA)	100.00	100.00	100.00

Note: '*' denotes significance at 5 per cent level.

horticulture and plantation crops. However, area shares of cereal crops have declined from 46 per cent to 34 per over the period and found to be statistically significant. The same trend was observed in oilseed crops where area share to the total gross cropped area decreased from 15 per cent to seven per cent and found to be statistically significant. Also, this trend was surprisingly observed in millet crops where the area share declined significantly. However, the area share of pulse crops, commercial crops and condiments and spice crops have shown increasing trend over the period and was statistically significant. The proportional increase was high in case of pulse crops and condiments and spices crop group, where the pulse crop area share has increased from 17 per cent to 27 per cent and four per cent to 10 per cent in case of condiment and spice crops. The major factors which had influenced increase in pulse area were Technology Mission on Oilseeds and Pulses (TMoP) and significant effects of Accelerated Pulse Production Program (APPP) in the state started post 2000's. The findings of the study conducted by Mohan *et al.* (2020) and Shivagangavva and Reddy (2016) revealed significant increase in area and production of pulses in the state and the authors concluded that above factors were the reason for the same.

Compounded Annual Growth Rate of different Crop Groups in Karnataka (2000-2019)

The Compounded Annual Growth Rate (CAGR) in area, production and productivity of different crop groups is presented in Table 2. The spatial and temporal variation in growth rates helps in understanding the complex cropping pattern and the dynamics of crop diversity shifts in the State comprehensively. The results indicated that the total cereal area in the State was decreasing at a rate of 0.98 per cent annually and found to be significant. Among the districts high declining growth was observed in Bengaluru Urban, Bidar and Dakshina Kannada. The similar declining trend was observed in production pattern of these districts. In case of millets declining growth of -6.51 per cent was observed in the State over the years. The major reduction in growth of millet crops area was found in Raichur with a CAGR of -49.27 per cent and Mysore had shown high positive CAGR of 38.78 per cent along with similar values of production over the years. The growth of oilseed crops in the State was found to be negative and significantly decreasing over the years at a rate of -4.26 per cent. The declining rate was most profoundly observed in Dakshina Kannada, Bengaluru Urban, Shivamogga, Hassan and Vijayapura districts. The highest positive and significant rate was observed in Bidar with a CAGR of 8.64 per cent over the years. The CAGR of area (2.73 %) and production (5.64 %) in case of pulse crops were found to be positive and statistically significant and Vijayapura (11.11 %) had the highest positive growth rate in area whereas highest negative growth was found in Kodagu (-24.13 %) over the years. In the case of horticulture and plantation crops, the CAGR of area (2.32%) and production (6.61%) were found to be positive and statistically significant, with Koppal (10.53%) having the highest positive growth rate and Bengaluru Urban (-3.04%) having the highest negative growth rate in area over the years. The CAGR of area (2.67%) and production (4.20%) in commercial crops were found to be positive and statistically significant, with Gulbarga (14.54%)

TABLE 2

Compounded annual growth rate of area, production and productivity in different crop groups in Karnataka (2000-2019)

Districts	Cereal crops			Millet crops			Oilseed crops			Pulse crops		
	A	P	Y	A	P	Y	A	P	Y	A		
Bagalkote	-1.09*	2.19	3.32*	-23.80*	-26.19*	-28.86*	-4.01*	-1.92*	2.18*	8.83*	9.70*	0.80
Bengaluru - Rural	-1.94*	-2.24	-0.68	24.33	19.69	38.18*	-9.33*	-10.08*	-1.21	-2.67*	1.00	3.38
Bengaluru - Urban	-6.32*	-6.43*	-0.12	-18.00	-18.51	-18.87	-13.18*	-12.97*	-0.34	-7.48*	-4.45*	3.28*
Belagavi	-0.98*	3.30*	4.32*	-12.17*	-11.80*	0.43	-1.99*	0.03	2.07	3.45*	8.02*	4.43*
Bellary	1.08*	2.74*	1.64*	-8.36*	-8.34*	0.02	-5.50*	-2.04*	3.66*	1.57	3.67*	2.02*
Bidar	-6.04*	-6.47*	-0.46	-23.81*	-25.74*	-13.70	8.64*	11.53*	2.66*	-1.56*	-0.35	3.78*
Vijayapura	-2.89*	1.20	4.21*	-33.22*	-30.17*	-31.71*	-10.29*	-8.29*	2.23	11.11*	12.66*	1.40
Chamarajanagar	-1.44*	1.88	3.37*	-19.67	-20.13*	-29.58*	-1.53	-3.67*	-2.17	-0.07	2.17*	2.24
Chikmagalur	-0.98*	-0.04	0.94	6.28*	6.88*	0.57	-3.68*	-2.10	1.64	0.88	5.54*	4.62*
Chitradurga	-0.03	1.93	1.96	-2.37*	-1.39	1.00	-4.50*	-7.15*	-2.77	2.14*	2.29	0.14
Dakshina Kannada	-4.64*	-3.29*	1.42*	0.00*	0.00*	0.00	-17.11*	-14.79	-14.35	-7.57*	-5.03	2.78*
Davanagere	-0.22	1.21	1.43	-10.76*	-13.00*	-2.51*	-5.76*	-4.29*	1.56	-2.93*	-0.05	2.96*
Dharwad	-0.63*	2.95	3.61	-16.23*	-15.22*	1.20	1.56	3.66*	2.06	2.57*	5.72*	3.07
Gadag	-0.17	2.83	3.00	-14.53*	-17.11*	-3.02*	-4.44*	-2.18	2.36*	5.05*	6.47*	1.33
Gulbarga	-2.04*	1.44	3.13*	-15.62*	-18.19*	-3.44*	-5.48*	-3.58*	1.60	1.17*	5.11*	3.48*
Hassan	0.11	2.39*	2.27*	-1.79	-5.03	-7.15	-10.60*	-10.48*	0.13	-2.59*	-0.68	1.96*
Haveri	0.68*	3.56*	2.86*	-16.63*	-14.50*	2.56*	-2.02*	0.98	3.06*	-8.09*	-5.44*	2.88*
Kodagu	-2.02*	-0.52	1.53	11.52	10.31	18.72	6.66	6.19	-4.40	-24.13*	-22.29*	2.44*
Kolar	1.54*	1.93	0.01	-4.48	-6.68*	-2.67*	-3.73*	-3.91*	-0.56	1.63*	7.06*	4.95*
Koppal	0.69	2.15	1.46	-4.43*	-3.84	0.62	-3.95*	-2.44*	1.57	5.23*	6.89*	2.42
Mandya	-1.31	-1.11	0.20	24.48	34.18*	35.18	-5.13*	-6.62*	-1.57	-0.10	0.25	0.35
Mysore	-1.62*	-0.55	1.09*	38.78*	34.99*	48.94*	-6.22*	-5.89*	0.36	-0.39	0.44	0.84
Raichur	-1.64*	1.73*	3.43*	-49.27*	-46.38*	-45.89*	-8.88*	-5.69*	3.50*	9.00*	14.01*	4.60*
Shivamogga	-0.46	2.12*	2.59*	-20.43	-20.11*	-31.71*	-12.47*	-10.09*	2.71*	-9.43*	-7.80*	1.79*
Tumkur	-1.64*	-2.37	-0.74	-4.39*	-5.76*	-1.42	-5.66*	-7.29*	-1.73	-2.60*	-3.81*	-1.25
Udupi	-2.58*	-1.06*	1.56*	0.00	0.00	0.00	-2.12*	0.02	2.18*	-7.15*	-5.95*	1.30
Uttara Kannada	-1.36*	1.30*	2.70*	9.92	8.73	18.72	-5.41*	-3.48*	2.05*	-3.96*	-2.88*	1.13
State Total	-0.98*	1.33	2.34*	-6.51*	-6.94*	-0.46	-4.26*	-2.42*	1.93*	2.73*	5.64*	2.84*

Note: '*' indicates significance at 5 % LoS, A- Area (hectare), P-Production (tonnes), Y-Producitivty (Kg/hectare) except in Commercial crops (tonnes/hectare)

Table 2 cont…

Districts	Horticulture and Plantation crops			Commercial crops			Condiments and Spice crops		
	A	P	Y	A	P	Y	A	P	Y
Bagalkote	8.56*	12.22*	3.37*	5.37*	5.47	0.09	15.01*	19.32*	3.74*
Bengaluru - Rural	2.94*	3.42*	0.47	-7.71*	-8.06*	-0.38	5.19*	11.39*	5.89*
Bengaluru - Urban	-3.04*	-1.42	1.67*	-10.63*	-11.15*	-0.58	1.70	7.56*	5.77*
Belagavi	4.64*	8.58*	3.77*	3.19*	5.29*	2.03	1.60	7.79*	6.10*
Bellary	5.15*	8.65*	3.32*	3.82*	4.27*	0.43	5.25*	11.77*	6.20*
Bidar	3.33*	6.31*	2.88*	-1.76*	-1.82	-0.06	-3.73*	4.52	8.57*
Vijayapura	4.74*	9.09*	4.16*	9.43*	10.59*	1.06	1.16	7.73*	6.49*
Chamarajanagar	4.91*	13.84*	8.51*	-0.78	-4.51*	-3.76*	5.09*	7.26*	2.07*
Chikmagalur	2.94*	8.88*	5.77*	-0.56	-2.53	-1.98*	5.27*	6.43*	1.10
Chitradurga	2.81*	8.32*	5.36*	0.67	-17.91*	-18.45*	4.44*	10.51*	5.81*
Dakshina Kannada	0.30	4.46*	4.15*	-21.44*	-26.21*	-0.02	3.42*	5.84*	2.34*
Davanagere	1.53*	5.45*	3.87*	-2.42	-5.73*	-3.39*	5.16*	11.86*	6.37*
Dharwad	-1.35	2.23	3.63	-1.46	8.79*	10.41*	-4.55*	-8.66*	-4.31*
Gadag	1.73	3.09	1.34	-0.61	24.53*	25.29*	-1.34*	1.18	2.55
Gulbarga	2.31*	6.20*	3.80*	14.54*	14.59*	0.04	-2.54*	-2.96	-0.44
Hassan	-0.06	1.57*	1.62	0.60	-6.05*	-6.61*	5.10*	10.83*	5.45*
Haveri	2.32*	6.35*	3.94*	2.56*	12.05*	9.25*	-3.83*	7.39*	11.66*
Kodagu	0.97	5.42*	4.41*	-21.81*	-20.29*	1.63	5.18*	10.79*	5.33*
Kolar	2.61*	4.74*	2.08*	-7.62*	-11.62*	-4.33*	1.33	5.52*	4.14*
Koppal	10.53*	16.03*	4.97*	-1.89	18.87*	21.16*	7.21*	15.24*	7.49*
Mandya	3.78*	9.61*	5.62*	1.91	1.76	-0.15	0.07	3.26*	3.19*
Mysore	3.40*	9.75*	6.14*	0.60	-1.99	-2.57*	7.98*	14.90*	6.41*
Raichur	-0.32	3.41*	3.75*	6.39*	15.40*	8.46*	5.23*	12.00*	6.43*
Shivamogga	1.22*	3.73	2.48	-9.26*	-8.19*	1.18	5.94*	8.61*	2.52*
Tumkur	3.13*	6.56*	3.33*	0.82	-1.21	-2.01	6.93*	11.38*	4.16*
Udupi	0.42*	6.46*	6.02*	-8.96	-9.09	-0.15	5.20*	7.35*	2.05*
Uttara Kannada	3.94*	8.91*	4.79*	-0.43	13.06*	13.54*	4.23*	9.65*	5.20*
State Total	2.32*	6.61*	4.19*	2.67*	4.20*	1.49	3.51*	7.62*	3.98*

Note: '*' indicates significance at 5 % LoS, A- Area (hectare), P-Production (tonnes), Y-Producitivty (Kg/hectare) except in Commercial crops (tonnes/hectare)

having the highest positive growth rate and Kodagu (-21.81%) having the highest negative growth rate in area over the years. The similar trend was also found in condiments and spice crops where both area (3.51 %) and production (7.62 %) of State have positive and significant growth over the years. Among the districts, Bagalkote had high positive CAGR of 15.01 per cent and Dharwad had high negative growth rate of 4.55 per cent in area over the years.

The CAGR of area in various crop group over the years revealed that the growth rate was negative and statistically significant in case of cereals, millets and oilseed crops. Whereas, the CAGR was significantly positive in case of pulses, horticulture and plantations, commercial crops and condiment and spice crops. The trend clearly exhibits the shift in area from traditional conventional crop groups towards modern remunerative crop groups over the years. It was evident from the study conducted by Anjum and Madhulika (2018) that growth rate of cereals crops like paddy and wheat was found negative and whereas the case was opposite in commercial crops and horticultural crops. It was mainly attributed to shift in consumer preference towards high nutrient rich alternate diet and also income oriented production systems. Within the farm sector, diversification towards High Value Crops (HVCs), including vegetables, condiments, spices, fruits and plantations, is claimed to be an important means of securing agriculture-based livelihoods, accelerating growth and reducing rural poverty (Bigsten and Tengstam, 2011; Birthal *et al.,* 2015; Michler and Josephson, 2017). Sustained rise in per capita income, increasing urbanization and changing lifestyle, accompanied by liberalization of agri-food markets, have been triggering rapid changes in the food basket in favor of high value food commodities, including fruits, vegetables (Kumar and Joshi, 2017). These factors have been quite robust in the recent past and are unlikely to subside in the foreseeable future, implying a faster growth in the demand for high value food commodities (Kumar and Joshi, 2017). Besides, increasing globalization of agri-food markets is also crafting opportunities for exports of high value food commodities.

Instability Indices in different Crop Groups of Karnataka (2000-2019)

The results of instability examination in different crop groups of Karnataka are presented in Table 3. The indices help in understanding the stability in cropping pattern over time and space in State. Low level of instability accompanied by high growth in production for any crop is desired for sustainable development of agriculture (Tripathi and Prasad, 2009).

In the various crop groups, low instability index was observed in area of cereals (5 %) and horticulture and plantation crops (5 %) compared to other crop groups in the State. In production of millets (35 %) and condiment and spice crops (35 %) moderate instability was observed in the State. In case of cereals all the districts had low (0-20 %) to moderate (20-35%) instability indices in area, production and productivity over the years. However, in millet crops the instability was in the high range (>35 %) in all the districts for area, production and productivity. In oilseed crops, low instability was seen in area of Haveri (14 %) and Gadag (15 %). In area under pulse crops, the lowest instability was observed in Bidar (9 %) but the instability in production was on the extreme side with 125 per cent. The indices in case of horticulture and plantation crops showed better stability with low to moderate instability (0-35 %). In commercial crops, the instability was lowest in Mysore (11 %) with moderate instability in production and productivity. In the case of condiment and spice crops, Shivamogga had good stability in area with instability value of nine per cent followed by Tumkur (10 %) along with low instability values in production and productivity. Instability in agricultural production, for any reason, results in unpredictable behavior and decision making from the population engaged in primary sector which is passed on to the economy as a whole (Krishnan and Chanchal, 2014). With the passage of time adoption of green revolution technology spread to much larger area and a large number of improvements in various aspects of technology

TABLE 3

Instability indices of area, production and productivity in different crop groups of Karnataka (2000-19)

Districts	Cereal crops			Millet crops			Oilseed crops			Pulse crops		
	A	P	Y	A	P	Y	A	P	Y	A	P	Y
Bagalkote	9	26	20	184	237	58	23	25	20	20	40	35
Bengaluru - Rural	14	33	25	183	178	49	27	31	21	14	31	29
Bengaluru - Urban	14	36	26	122	121	64	27	29	39	14	39	45
Belagavi	8	25	24	20	41	42	19	24	29	25	39	21
Bellary	13	16	8	46	85	34	23	23	36	32	35	18
Bidar	12	23	21	81	87	34	17	46	41	9	125	37
Vijayapura	13	30	24	163	196	110	34	34	31	20	38	31
Chamarajanagar	14	26	19	89	79	54	29	35	35	21	37	36
Chikmagalur	7	17	13	34	80	52	29	41	24	13	25	14
Chitradurga	8	31	31	23	42	37	15	37	38	15	35	25
Dakshina Kannada	19	20	7	0	0	0	30	39	36	27	41	23
Davanagere	10	25	19	45	45	25	18	22	22	24	22	17
Dharwad	7	38	36	37	55	41	20	29	27	16	34	38
Gadag	9	36	33	23	45	29	15	32	28	21	40	43
Gulbarga	8	21	18	65	81	37	24	31	34	10	32	27
Hassan	7	31	29	92	72	56	31	48	27	24	36	21
Haveri	7	28	31	16	32	35	14	27	28	21	45	26
Kodagu	9	11	5	394	387	402	104	111	38	50	64	28
Kolar	16	41	30	108	96	20	20	49	39	12	46	40
Koppal	12	28	21	51	112	75	18	27	32	13	35	37
Mandya	19	26	14	312	247	139	37	47	22	24	25	28
Mysore	12	20	10	264	263	201	31	43	25	14	24	20
Raichur	11	19	13	86	93	58	30	27	27	24	25	28
Shivamogga	7	17	13	194	189	166	28	39	18	25	29	15
Tumkur	13	33	25	18	36	35	19	57	48	11	36	30
Udupi	6	8	6	0	0	0	37	33	22	30	29	20
Uttara Kannada	3	15	13	384	367	402	24	21	32	21	40	20
State Total	5	18	14	23	35	20	18	20	24	9	21	19

Table 3 contd.....

Districts	Horticulture and Plantation crops			Commercial crops			Condiments and Spice crops		
	A	P	Y	A	P	Y	A	P	Y
Bagalkote	25	27	18	21	28	17	31	36	32
Bengaluru - Rural	14	24	24	33	38	15	17	27	22
Bengaluru - urban	47	36	17	87	90	19	40	26	23
Belagavi	14	20	18	18	33	24	25	62	34
Bellary	21	36	23	35	37	42	50	102	54
Bidar	30	33	17	16	29	23	22	113	62
Vijayapura	21	29	25	33	35	22	26	49	32
Chamarajanagar	18	36	27	28	38	31	28	37	18
Chikmagalur	6	11	10	26	44	25	22	46	22
Chitradurga	6	16	17	44	115	87	20	22	25
Dakshina Kannada	9	19	22	123	134	95	29	37	15
Davanagere	11	19	11	44	46	25	14	27	28
Dharwad	22	44	42	20	31	35	33	41	38
Gadag	29	39	30	32	60	49	36	47	54
Gulbarga	23	45	26	29	41	39	33	55	32
Hassan	18	18	22	20	37	24	27	36	15
Haveri	15	17	15	19	59	56	33	32	22
Kodagu	23	40	31	40	45	52	25	18	18
Kolar	9	19	14	72	66	29	22	37	23
Koppal	26	40	38	56	70	73	41	39	42
Mandya	17	20	18	30	31	10	22	40	15
Mysore	12	21	15	11	30	34	22	29	18
Raichur	28	32	17	50	49	35	40	31	26
Shivamogga	10	49	44	16	27	24	9	17	15
Tumkur	4	19	19	33	53	30	10	16	13
Udupi	3	23	23	180	181	21	28	32	28
Uttara Kannada	7	32	32	30	40	27	11	25	23
State Total	5	12	12	19	28	21	23	35	19

have taken place. As the benefit of these advancements got translated at farm, the variability in yield of food grains had declined and that led to decline in variability of food grains production as well. Other factors which might have contributed to the decline in variability in food grains yield and production seems to be (i) policy of minimum support prices (ii) expansion of irrigation and (iii) improvement in availability of other inputs and institutional credit (Chand and Raju, 2008).

Composite Entropy Indices for Crop Diversification in Karnataka

To have a closer look at the changes in crop diversification across districts three different time points of almost decadal interval *viz.* 2000-01, 2010-11 and 2018-19 were considered. Table 4 shows Composite Entropy Index (CEI) indicating extent of diversification in various districts of the State.

TABLE 4

Composite entropy indices of districts in Karnataka for different time periods.

Rank	Districts	2000-01	Districts	2010-11	Districts	2018-19
1	Dharwad	0.76	Dharwa	0.75	Chitradurga	0.74
2	Gadag	0.70	Gadag	0.72	Dharwad	0.74
3	Haveri	0.68	Chamarajanagar	0.68	Chamarajanagar	0.72
4	Chitradurga	0.66	Chitradurga	0.68	Bagalkote	0.68
5	Tumkur	0.63	Tumkur	0.68	Tumkur	0.66
6	Chikmagalur	0.63	Hassan	0.66	Belagavi	0.64
7	Chamarajanagar	0.61	Chikmagalur	0.65	Mysore	0.63
8	Belagavi	0.60	Bagalkote	0.63	Mandya	0.63
9	Bellary	0.60	Mysore	0.63	Gadag	0.62
10	Hassan	0.58	Belagavi	0.61	Chikmagalur	0.61
11	Mysore	0.58	Bellary	0.60	Bellary	0.57
12	Bagalkote	0.57	Vijayapura	0.59	Hassan	0.57
13	Kolar	0.56	Mandya	0.57	Uttara Kannada	0.56
14	Koppal	0.55	Haveri	0.57	Kolar	0.56
15	Mandya	0.55	Kolar	0.57	Koppal	0.56
16	Udupi	0.54	Bidar	0.56	Haveri	0.55
17	Uttara Kannada	0.53	Koppal	0.56	Raichur	0.55
18	Dakshina Kannada	0.52	Bengaluru - Rural	0.54	Udupi	0.53
19	Bidar	0.52	Uttara Kannada	0.51	Bidar	0.53
20	Vijayapura	0.51	Dakshina Kannada	0.51	Gulbarga	0.49
21	Bengaluru - Rural	0.50	Udupi	0.51	Bengaluru - Urban	0.49
22	Davanagere	0.50	Raichur	0.51	Bengaluru - Rural	0.47
23	Shivamogga	0.48	Davanagere	0.49	Vijayapura	0.47
24	Raichur	0.48	Gulbarga	0.48	Davanagere	0.46
25	Gulbarga	0.48	Kodagu	0.45	Shivamogga	0.41
26	Kodagu	0.41	Shivamogga	0.44	Dakshina Kannada	0.32
27	Bengaluru - Urban	0.41	Bengaluru - Urban	0.44	Kodagu	0.27
	State Total	0.67	State Total	0.69	State Total	0.72
	CV (%)	14.40	CV (%)	14.64	CV (%)	19.96

TABLE 5
Results of paired t-test

Pair	CV (%)	Mean	SD	t-value	p-value
CEI 2000-01 - CEI 2010-11	14.40	0.0165	0.0236	2.0555	0.0000
CEI 2010-11 - CEI 2018-19	14.64	0.0202	0.0735	3.2305	0.0127
CEI 2000-01 - CEI 2018-19	19.96	0.0037	0.0773	2.0565	0.6343

There was a wide variation in diversification index and changes therein across the districts. Some districts in the northern region (e.g., Bagalkote and Belagavi), central region (e.g., Chitradurga) and southern region (e.g., Chamarajanagar and Mysore) have shown an improvement in crop diversification. On the other hand, districts like Gadag and Bellary (northern), Haveri and Chikmagakur (central), Dakshina Kannada (coastal) have shown an increase in crop concentration. For remaining districts, there is no discernible trend in crop diversification. Interestingly, agriculture in Chitradurga, the lowest rainfall receiving district, has remained more diversified than others, while coastal and hilly districts like Dakshina Kannada and Kodagu are at the bottom of crop diversification index. However, the State diversification was steadily improving over the years and this trend was also observed in study conducted by Saraswati *et al.* (2011) where the results showed that diversification was high among horticultural and commercial crops and it was attributed to shift in area towards high value crops and improved livelihood income from alternate crops.

In order to understand the trend in diversification, Coefficient of Variation (CV) in CEI was calculated across districts over the years. The CV had remained nearly constant till 2010, but has increased afterwards. Further, test of significance for the change in CEI was carried out and the results are presented in Table 5. From 2000-01 to 2018-19, there was increase in CEI and it was found to be statistically significant.

However, ranking of the districts had not changed much during 2000-01 to 2010-11. This is explained with the help of correlation matrix of CEI - 2000 - 01, CEI - 2010 - 11 and CEI - 2018 - 19 (Table 6). The correlation coefficients were significant at 1 per cent level between CEI - 2000 - 01 and CEI - 2010 - 11 indicating that neither CEI values nor ranking of districts has changed significantly over time. Similar pattern was observed during CEI - 2010 - 11 and CEI - 2018 - 19 at 5 per cent level of significance. However, the correlation coefficients during CEI - 2000 - 01 and CEI - 2018 - 19 were found to be statistically insignificant indicating CEI values and ranking of districts have changed significantly over time and space (Fig. 1). The similar pattern was reported by Nayak and Kumar (2019) where the crop diversification indices in different periods were highly correlated and found statistically significant.

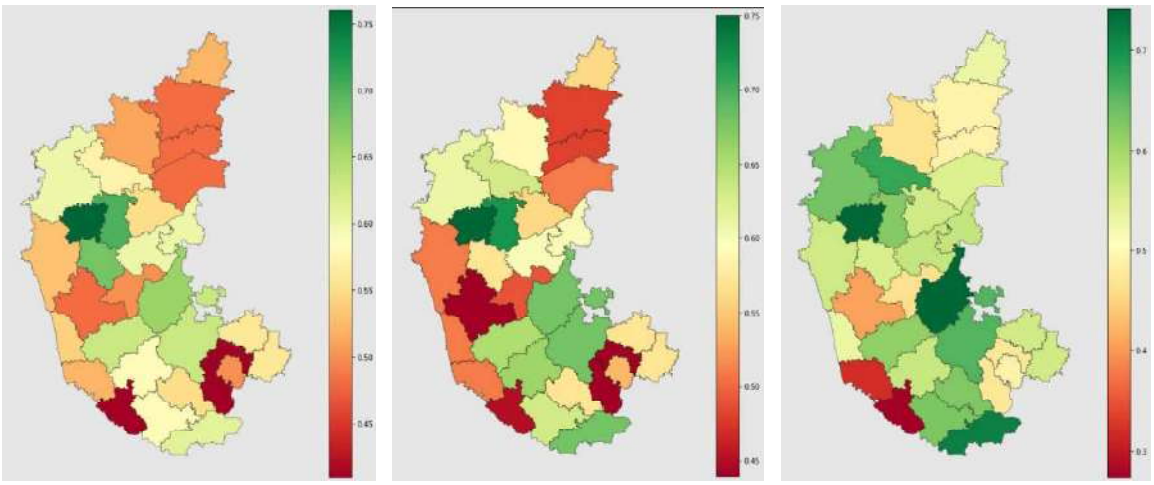
TABLE 6
Correlation coefficients

	CEI 2000-01	CEI 2010-11	CEI 2018-19
CEI 2000-01	1	0.982***	0.964
CEI 2010-11	0.982***	1	0.958**
CEI 2018-19	0.964	0.958**	1

Note: '***'- significant at 1 % level, '**'-significant at 5 % level (2-tailed for both)

Shift in Area of Major Crop Groups of Karnataka

The results of transitional probability matrix for Karnataka Table 7, revealed that cereals crops had the highest retention (97.86 %) of area under cultivation followed by pulse crops (95.03 %), oilseed crops (55.91 %) and commercial crops (49.44 %). From the table it was evident that the area lost by cereal crops was majorly shifted to horticulture and plantation crops and commercial crops. Also, the area shift from different crop groups was seen towards horticulture and plantation crops, commercial crops and condiments and



CEI_2000-01 CEI_2010-11 CEI_2018-19

Fig. 1: Spectral changes in crop diversification over time and space in Karnataka

spice crops in the State. Sathishkumar and Umesh (2017) also observed similar trend in shift of area from various crops towards high value crops in the southern dry zone of Karnataka. Hence, the results of the transitional probability matrix are in line with the above study.

There has been a steady rise in crop diversification across the districts in Karnataka. The improvement in crop diversification index for the entire span of 2000 to 2019 was significant. However, a regional divide in crop diversification was observable between the districts (mostly the coastal and hilly region) vis-a-vis other districts. High value crop groups had positive growth over the years indicating good improvement in area and production which eventually enable farm livelihood with better income and food security. But, the instability in these crops was found to be on the higher side compared to cereals crops. Hence, for sustainable agricultural development in the State, integration of horizontal and vertical supply chains, market integration, symmetric price discovery and enhanced processing linkages has to be improved in order to reduce the instability. However, the macro level analysis provide broader picture and status of diversification of the State which may be contradictory to the micro ecosystems depending on regional factors which influence the diversification. However, some insights were provided in study

TABLE 7

Transitional probability matrix

	Cereal crops	Millet crops	Oilseed crops	Pulse crops	Horticulture and Plantation crops	Commercial crops	Condiments & Spices
Cereal crops	0.9786	0.0013	0.0037	0.0000	0.0098	0.0065	0.0000
Millet crops	0.0000	0.3211	0.6789	0.0000	0.0000	0.0000	0.0000
Oilseed crops	0.0000	0.0069	0.9503	0.0000	0.0428	0.0000	0.0000
Pulse crops	0.0164	0.0000	0.0000	0.5163	0.1641	0.0891	0.2142
Horticulture and Plantation crops	0.0000	0.0000	0.0000	0.6832	0.3168	0.0000	0.0000
Commercial crops	0.0000	0.0000	0.0000	0.2246	0.1857	0.4944	0.0953
Condiments & Spices	0.0000	0.0000	0.0000	0.3853	0.0000	0.6037	0.0110

conducted by Basavraj *et al.* (2016) where the micro level evidences on crop diversification were found to be in favor of high value crops in Gadag district of Karnataka. Although the results of the present paper need further scrutiny at micro level, the following broad suggestions are made. As the extent of crop diversification varies across regions, there is a need to go for an agro-climatic regional planning (ACRP) by explicitly recognizing the local resource endowments and constraints of the agro-climatically homogeneous regions.

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