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RESEARCH PAPER

Crop diversification and its determinants in north eastern agro-climatic zones of Karnataka

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Abstract: The present study was conducted in north-eastern agro climatic zones of Karnataka using farm level primary data to arrive at micro level empirical evidences on extent and determinants of crop diversification.The North Eastern Transition Zone (NETZ) and the North Eastern Dry Zone (NEDZ) were selected for the study. Aurad (rainfed) and Humnabad (irrigated) taluks from NETZ and Sedam (rainfed) and Devdurga (irrigated) taluks from NEDZ were selected for the study based on the percentage of net irrigated to net area sown. Cultivation of food crops, vegetables and perennial crops like sugarcane was predominant in NETZ whereas it was cultivation of food and commercial crops in NEDZ.The crop diversification indices values of NETZ revealed a moderate level of diversification in Aurad taluk and high diversification in Humnabad taluk. In NEDZ, the index values indicated that the farmers in Sedam taluk were shifting towards crop specialization and the values implied that farmers in Devdurga were increasingly adopting diversified cropping practices, supported by the availability of irrigation facilities from the left bank canal of Upper Krishna Project, which enable the cultivation of multiple crops. In the NETZ, the majority of farmers (66.67%) were engaged in diversified cropping patterns due to the high income from specific crops, with some degree of diversification reflecting the zone's transition between dry and irrigated conditions. Conversely, in the NEDZ, farmers were practicing both diversified (35.56%) and specialized cropping patterns (48.89%), driven by water availability and varying market demands. The determinants like access to irrigation and access to credit were the major diversification enablers influenced level of diversification in NETZ. Whereas, market distance and access to irrigation were the major diversification enablers influenced level of diversification in NEDZ.

Key words: Crop diversification, Determinants, Irrigation, Specialization

Introduction

The agriculture sector supports 54.6 per cent of the people directly or indirectly and makes up around 18.4 per cent of the country's Gross Value Added (GVA) at current prices. The land use statistics 2021-22 shows that the country's total geographic area is 328.7 million hectares out of which 141 million hectares is the reported net sown area and 219.16 million hectares is the gross cropped area with a cropping intensity of 155.4 per cent. The net area sown works out to 42.8 per cent of the total geographical area (Anon, 2023-24).

The agriculture sector faces the daunting challenge of providing adequate food and other necessitates to a growing world population which is projected to increase to nine billion by 2050 (FAO, 2012). There is limited scope for expansion of arable land and the emerging threat to agriculture from climate change in the form of unpredictable weather, floods and other disastrous events makes the task of providing enough food for the global population even more challenging.

Crop diversification is one of the most environmentally friendly, practical, economical and logical solution to reduce agricultural uncertainty, particularly among small-scale farmers.In dry land agriculture, diversification serves as a sole source of combating risk against climate and weather vagaries (Basavaraj *et al*., 2016). Additionally, crop diversification promotes resilience or an ecosystem's capacity to revert to its pre-disturbed state of productivity as well as higher levels of spatial and temporal biodiversity on farms.In crop diversification the cropping pattern and the choice of the alternative crop is vital. Any crop which produces more economical remunerative can very well replaces the existing crop.With this background, the present paper focuses on understanding the extent of crop diversification and its determinants across north-eastern agro climatic zones of Karnataka.

Material and methods

The present study used primary data to provide empirical evidences on crop diversification and its determinants acrossnorth-eastern agro climatic zones of Karnataka.Multi-stage random sampling design was employed for the selection of respondents across the study regions. At first stage, North Eastern Transition Zone (NETZ) and the North Eastern Dry Zone (NEDZ) of Karnataka were selected based on the distinct agro-climatic features and other edaphic features of the zones in order to derive economic implications under two distinct regions. In the next stage two taluks representing irrigated and rainfed taluk, each from NETZ and NEDZ were selected based on percentage of net irrigated area to the net area sown. Accordingly, Aurad taluk (rainfed area) and Humnabad taluk (irrigated area) were selected from NETZ. Sedam taluk (rainfed area) and Devdurga taluk (irrigated area) were selected from NEDZ.In the next stage 45 sample farmersfrom each taluk were selected randomly. The total sample was 180 sample farmers, consisting of 90 sample farmerseach from NETZ and NEDZ. The primary data related to area under different crop groups for the year 2022-23 was considered for the study. To assess the extent of crop diversification, the following indices were used.

Herfindahl index (HI): It is the sum of square of the acreage proportion of each crop in the total cropped area.

$$HI = \sum_{i=1}^{N} P_i^2$$

Where, P_i represents acreage proportion of the i^{th} crop in total cropped area.

With an increase in diversification, the sum of square of the proportion of activities decreases, so also the indices (HI). The Herfindahl index takes a value of one when there is complete specialization and approaches zero as N gets large, *i.e.* if diversification is perfect.

Simpson index (SI): It is the most suitable index for measuring diversification of crops in a particular geographical region.

$$SI = 1 - \sum_{i=1}^{N} P_i^2$$

Where, $P_i = A_i / \Sigma A_i$ is the proportion of the i^{th} activity in acreage. If SI is near zero, it indicates that the zone or region is near to the specialization in growing of particular commodity and if close to one, the zone is fully diversified in the commodities that it has grown.

Tobit regression model

Tobit model, also called censored regression model, is designed to estimate linear relationships between variables when there is either left or right-censoring in the dependent variable. Tobit model was employed to identify the determinants of crop diversification in the study area, measured by using Herfindahl Index.

Tobit model is a statistical model to describe the relationship between the non-negative censored dependent variable Y_i and independent variable X_i. Tobit model can be described in terms of a latent variable Y_i^*. $Y_i^*$is observed when $Y_i^*>0$ and Y_i^* is not observed when$Y_i^* \leq 0$.

So the observed Y_i is defined as: $Y_i = \{Y_i^* = bX_i + e_i$, if $Y_i^*>0\}$ $\{0$, if $Y_i^*< 0\}$

where:

Y_i^* = Crop diversification (Index or crop richness)

b_i = regression parameters/coefficients,

e_i = error term,

X_i = vector of explanatory variables listed/mentioned below.

The model specification for the Tobit regression model for estimation of determinants of crop diversification is given as:

$$Y_i = a_i + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + e_i$$

Where,

Y_i = Herfindahl Index (HI) for crop diversification

X_1 = Age of the respondent (Years)

X_2 = Education (Literate = 1, Illiterate = 0)

X_3 = Size of land holding (ac)

X_4 = Distance to market (within 10 Km = 1, otherwise = 0)

X_5 = Type of Farming (Irrigated = 1, Rainfed = 0)

X_6 = Access to credit (Yes = 1, otherwise = 0)

X_7 = Family size (No.)

e_i = Random error and a_i is the constant term.

Results and discussion

Socio-economic profile of the sample farmers across the zones

The socio-economic profile of the sample farmers offers a multifaceted perspective on their personal and social condition. Key variables such as age of the sample respondents, educational attainment, size of the family, landholding dimensions and cropping patterns were rigorously analyzed and the findings discussed in subsequent sections. The in-depth analysis provides critical insights into the interplay between crop diversification and the socio-economic dynamics of farmers, shedding light on the broader implications for the agricultural sector.

Age appeared as a pivotal determinant in shaping decisions regarding crop diversification. The age of the household head exerts a significant influence on a range of agricultural decisions and the strategic allocation of resources. The average age of farmers in NEDZ stood slightly higher at 46 years, compared to 45 years in NETZ. Furthermore, a greater proportion of old age farmers (Above 50 years) was found in NEDZ (35.56%) relative to NETZ (31.11%), indicated that NEDZ farmers likely possessed greater farming experience (Table 1). Conversely, younger (21-35 years) and middle-aged (36-50 years) farmers were more predominant in NETZ.

Literacy rate, defined by the years of schooling among the sample respondents, emerged as a key differentiat or between

Table 1. Socio-economic profile of the sample farmers across the study regions

Particulars	North Eastern Transition Zone (n=90)		North Eastern DryZone (n=90)	
	No.	%	No.	%
I.	Age group			
a. 21-35 years	25	27.78	24	26.67
b. 36-50 years	37	41.11	34	37.78
c. Above 50 years	28	31.11	32	35.55
Average age (Years)	45.35		46.50	
II.EducationLevel				
a. Primary	12	13.34	15	16.67
b. High school	40	44.44	17	18.89
c. College and above	20	22.22	22	24.44
d. Illiterate	18	20.00	36	40.00
III.FamilySize				
a. Small (<4)	16	17.78	18	20.00
b. Medium (4-6)	45	50.00	48	53.33
c. Large (>6)	29	32.22	24	26.67
Average family size	4.56		5.34	
IV.Average Landholdings				
Rainfed land (ac)	2.48	29.81	5.10	80.68
Irrigated land (ac)	5.95	70.19	1.19	19.32
Land holding (ac)	8.43	100.00	6.29	100.00

the regions. The educational attainment was notably higher among NETZ farmers, attributable to the younger age profile prevalent in this group. A markedly lower proportion of NETZ farmers (20%) were illiterate, compared to 40 per cent among NEDZ farmers (Table 1). Furthermore, approximately 67 per cent of NETZ farmers had completed secondary education or higher, a significant contrast to the 44 per cent observed in NEDZ.

Most of the sample farmers in both North Eastern Transition Zone (NETZ) and North Eastern Dry Zone (NEDZ) were part of medium-sized households (4-6 members), followed by large families (> 6 members) and small families (< 4 members). Family size was a critical factor, as larger households reduce the need for hired labor, might have potentially promoting crop diversification in the study area. The average family size was smaller in NETZ compared to NEDZ, indicated a greater reliance on family labor in NEDZ than in NETZ (Table 1).

In terms of land holdings, farmers in the North Eastern Transition Zone (NETZ) possessed relatively larger tracts of land, averaging 8.43 acres, compared to 6.29 acres in the North Eastern Dry Zone (NEDZ). A significant portion of cultivable land in NETZ was irrigated (70.19%), while agriculture was predominantly rainfed (80.68%) in NEDZ. The average size of rainfed land was smaller than that of irrigated land in NETZ, leading farmers to cultivate both commercial and subsistence crops (Table 1). Access to irrigation was regarded as the key driver of diversification, with areas benefiting from groundwater and open well irrigation showing a higher degree of diversification.

Farm assets possession of sample farmers across the NETZ

In the North Eastern Transition Zone (NETZ), the distribution of farm assets among sample farmers highlighted a mix of traditional and modern farming tools. A significant majority, 83.33 per cent of farmers utilized wooden or metal ploughs, underscoring their continued importance in tillage despite the availability of modern alternatives. The presence of bullock carts and cattle sheds with 28.89 per cent and 66.67 per cent of farmers, respectively, indicated their ongoing reliance on traditional livestock and manual transport systems (Table 2).

Table 2. Possession of farm assets among sample farmers across the study regions

Particulars	North Eastern Transition Zone(n=90)		North Eastern Dry Zone (n=90)	
	No.	%	No.	%
Bullock cart	26	28.89	24	26.67
Seed drill	18	20.00	20	22.22
Wooden / M.B. Plough	75	83.33	64	71.11
Power tiller	12	13.33	08	08.89
Tractor and accessories	18	20.00	16	17.78
Sprayers	85	94.44	88	97.78
Irrigation pump (IP Set)	70	77.78	40	44.44
Tube well / Open well	65	72.22	58	64.44
Pump house	35	38.89	24	26.67
Cattle shed	60	66.67	56	62.22

Note: Percentage do not add up to 100 due to multiple responses

The use of modern equipment was found but limited usage was noticed. Power tillers were owned by 13.33 per cent of farmers and 20 per cent had tractors and accessories, reflecting limited adoption of mechanization in farming practices. This might be due to higher costs and limited access to that equipment.

Sprayers are a common asset, with 94.44 per cent of farmers using them, highlighted their crucial role in crop protection. Irrigation infrastructure is well-represented, with 77.78 per cent of farmers having irrigation pumps and 72.22 per cent using tube wells or open wells, demonstrated the importance of effective water management in the region. Additionally, 38.89 per cent of farmers had pump houses, which supported irrigation efforts.

It is clear from the above findings that the NETZ farmers exhibited a strong reliance on traditional farming methods complemented by essential modern tools, especially for irrigation and crop protection. The higher access and use of irrigation infrastructure and sprayers indicated an adaptation to the region's agricultural needs, while the lower adoption of advanced mechanization indicated opportunities for increasing productivity and modernizing farming practices.

Farm assets possession of sample farmers across the NEDZ

In the North Eastern Dry Zone (NEDZ), the distribution of farm assets among sample farmers revealed a focus on traditional farming tools, with varying levels of modern equipment and infrastructure. About 71.11 per cent of farmers used wooden or metal ploughs, revealed continued reliance on traditional tillage methods. The use of bullock carts and pump houses was relatively common, with 26.67 per cent of farmers utilizing these assets, reflecting their ongoing role in farm operations.

Modern farming equipment was less prevalent, with only 17.78 per cent of farmers owning tractors and accessories while only 8.89 per cent using power tillers. This indicated that while some mechanization was present, the adoption of advanced machinery was limited, potentially due to cost or availability constraints. Sprayers were widely used, with 97.78 per cent of farmers had access to them, highlighting their importance in crop protection. The findings are in line with those of Sureshkumar *et al.* (2015), who observed that the majority of farmers owned sprayers followed by bullock carts, sprinklers and tractors with accessories. Irrigation infrastructure was also notable, with 44.44 per cent of farmers possessed irrigation pumps and 64.44 per cent had tube wells or open wells, underscoring the reliance on irrigation to support agriculture in the dry zone (Table 2). Additionally, 62.22 per cent of farmers

Table 3. Crop diversification indices across the study area at farm level

Crop diversification indices	NETZ		NEDZ	
	Aurad (Rainfed) (n=45)	Humnabad (Irrigated) (n=45)	Sedam (Rainfed) (n=45)	Devdurga (Irrigated) (n=45)
Herfindahl Index (HI)	0.46	0.18	0.68	0.32
Simpson Index (SI)	0.54	0.82	0.32	0.68

Table 4. Extent of crop diversification based on Herfindahl index values

Particulars	NETZ			NEDZ		
HI Range	Aurad (Rainfed) (n=45)	Humnabad (Irrigated) (n=90)	Overall (n=45)	Sedam (Rainfed) (n=45)	Devdurga (Irrigated) (n=90)	Overall (n=45)
Low (<0.40)	15(33.33)	45(100.00)	60(66.67)	00(0.00)	32(71.11)	32(35.56)
Medium (0.40-0.60)	28(62.22)	00(0.00)	28(31.11)	01(2.22)	13(28.89)	14(15.55)
High (>0.60)	02(4.44)	00(0.00)	02(2.22)	44(97.78)	00(0.00)	44(48.89)

Note: Fig indicate number of farmers falling under particular category of diversification
Fig in parentheses indicate percent to the respective total farmers

had cattle sheds, depicted the importance of livestock in their farming system.

The traditional tools remained predominant. There was significant use of irrigation and crop protection equipment, pointing to a mixed approach of traditional and modern practices. However, lower uptake of advanced mechanization and infrastructure reflected potential areas for development to enhance productivity and support more efficient farming practices.

Crop diversification indices at the farm level for NETZ of Karnataka

An analysis was carried out to assess the extent of crop diversification using primary data collected from 45 sample farmers in Aurad taluk, representing rainfed areas and 45 sample farmers in Humnabad taluk, representing irrigated areas. To determine the level of diversification, the Simpson Index and Herfindahl Index were employed and the results are summarized in Table 3.

In Aurad taluk, the average Herfindahl Index was 0.46, while the average Simpson Index was 0.54. The index values indicated a moderate level of diversification in Aurad taluk. Conversely, Humnabad taluk high diversification was recorded with average Herfindahl and Simpson Index values of 0.18 and 0.82, respectively. The calculated indices indicated that farmers in the study area were shifting towards more diversified farming practices, primarily due to the region's demographic characteristics and the availability of irrigation facilities.

Crop diversification indices at the farm level for NEDZ of Karnataka

In Sedam taluk, the average Herfindahl Index was 0.68, while the average Simpson Index was 0.32 (Table 3). The index values indicated that the farmers in Sedam taluk were shifting towards crop specialization, likely due to the region's reliance on monsoon rains for irrigation, as it was entirely dryland. Similar results were found in a study conducted by Narmadha and Karunakaran (2022) while agricultural diversification in Tamil Nadu, wherein sample respondents were shifting towards crop specialization. In contrast, Devdurga taluk recorded average Herfindahl and Simpson Index values of 0.32 and 0.68, respectively. These values implied that farmers in Devdurga were increasingly adopting diversified cropping practices, supported by the availability of irrigation facilities from the left bank canal of Upper Krishna Project, which enable the cultivation of multiple crops.

Extent of crop diversification across the zones

In the North Eastern Transition Zone (NETZ), the Herfindahl Index values reveal significant differences in crop diversification among the regions. Humnabad stands out with a predominance of higher diversification, having the cent percent of farmers falling under low Herfindahl Index (HI) category (Table 4). The findings indicated that farmers in Humnabad diversified their crops extensively, supported by better irrigation facilities in the area. In contrast, Aurad had a notable number of farmers (62.22%) with moderate diversification, showing a balanced variety in their crop choices. Additionally, 33.33 per cent farmers in Aurad fall into the low HI category, indicated a shift towards cultivating high-value crops like sugarcane.

In the North Eastern Dry Zone (NEDZ), a similar pattern was observed with regional variations. Sedam featured a large number of farmers (97.78%) with high HI values, reflecting a focus on specialized high-value crops. Conversely, Devdurga had a majority of farmers (71.11%) in the low HI category, indicated a more diversified cropping pattern facilitated by available irrigation resources. The medium diversification category was represented by a smaller number of farmers (28.89%), depicted a moderate level of crop variety.

It can be interpreted that on an overall conclusion, the Herfindahl Index data highlighted a distinct regional disparity in crop diversification across both zones. In the NETZ, the majority of farmers (66.67%) were engaged in diversified cropping patterns due to the high income from specific crops, with some degree of diversification reflecting the zone's transition between dry and irrigated conditions. Conversely, in the NEDZ, farmers were practicing both diversified (35.56%) and specialized cropping patterns (48.89%), driven by water availability and varying market demands.

Determinants influencing crop diversification in NETZ of Karnataka

The determinants influencing crop diversification in the North Eastern Transition Zone (NETZ) of Karnataka is presented in Table 5. The Herfindahl index value was considered as dependent variable. The value ranges from zero to one, with index value nearing to zero indicating crop diversification and near to one shows crop specialization. The negative beta coefficient values indicate that the factors considered are influencing for crop diversification. While, positive beta coefficient values indicate that they are negatively influencing towards crop diversification.

Table 5. Factors influencing the crop diversification in NETZ

Variables	Parameters	Coefficients	t-value
Dependent variable: Herfindahl Index values			
Constant	a_0	0.3006 (0.0735)	4.09
Age of the respondent (years)	b_1	0.0019** (0.0009)	2.12
Education (Literate = 1, illiterate = 0)	b_2	0.0167 (0.0203)	0.82
Size of land holding (ac)	b_3	0.0029** (0.0011)	2.58
Distance to market (within 10 Km = 1, otherwise = 0)	b_4	0.0288 (0.0233)	1.24
Type of Farming (Irrigated = 1, Rainfed = 0)	b_5	-0.2256** (0.0265)	-8.52
Access to credit (Yes = 1, otherwise = 0)	b_6	-0.0360* (0.0197)	-1.82
Family size (No.)	b_7	-0.0012 (0.0050)	-0.24
Co-efficient of determination	R^2	0.84	

Note:'**'significant at 5 per cent level of significance, '*'significant at10 per cent level of significance.
The fig in parentheses indicates standard errors

Table 6. Factors influencing the crop diversification in NEDZ

Variables	Parameters	Coefficients	t-value
Dependent variable: Herfindahl Index values			
Constant	a_0	0.6383(0.0794)	8.04
Age of the respondent (years)	b_1	0.0011(0.0010)	1.08
Education (Literate = 1, illiterate = 0)	b_2	0.0007(0.0203)	0.03
Size of land holding (ac)	b_3	0.0041**(0.0015)	2.70
Distance to market (within 10 Km = 1, otherwise = 0)	b_4	-0.0742**(0.0229)	-3.24
Type of Farming (Irrigated = 1, Rainfed = 0)	b_5	-0.3954**(0.0301)	-13.14
Access to credit (Yes = 1, otherwise = 0)	b_6	0.0336(0.0224)	1.50
Family size (No.)	b_7	-0.0011(0.0042)	0.27
Co-efficient of determination	R^2	0.88	

Note:'**'significant at 5 per cent level of significance, '*'significant at10 per cent level of significance.
The fig in parentheses indicates standard errors.

The results revealed that the type of farming (-0.2256), access to credit (-0.0360) had significant effects on crop diversification (Table 6). The access to irrigation motivated farmers to incorporate multiple cropping patterns leading to crop diversification. Credit access facilitated farmers to purchase more inputs and incorporate multiple cropping patterns. Family size (-0.0012) also had impact on crop diversification, but it was statistically non-significant.

Age of the sample respondents (0.0019) and the size of land holding (0.0029) had a significant negative influence on crop diversification. As the age of the sample respondents increased they were likely to adopt mono-cropping due to lack of managerial abilities associated with diversified cropping patterns. The result was in contrary to the findings of Pavitra and Gaddi (2022), who reported that the average age of the household head contributed to greater farming experience, which in turn led to improved efficiency of cropping patterns. The larger farms showed a higher propensity for crop specialization. This trend reflected the capacity of larger farms to absorb the higher remuneration associated with adopting specialized cropping pattern. The results are in contrary with the study of Trailukya (2019), wherein regression analysis result revealed that the landholding of farmer had positive influence on crop diversification but its coefficient was found to have insignificant.Overall, the model, with an R-squared value of 0.84, explained a substantial proportion of the variation in crop diversification

Determinants influencing crop diversification in NEDZ of Karnataka

The analysis of factors influencing crop diversification in the North Eastern Dry Zone (NEDZ) highlighted several key determinants. (Table 6). Distance to the market (-0.0742) and type of farming (-0.3954) played a crucial role in crop diversification. Market near to farm had significantly encouraged diversification, indicated that the farmer closer to markets are more likely to engage in diverse cropping patterns due to better access to market information and selling opportunities.

The distinction between rainfed and irrigated farming had a strong negative impact on diversification, with farmers in rainfed areas less likely to diversify, likely due to the uncertainty and risk associated with rainfed agriculture. This finding aligns with Birthal *et al.* (2006), who examined the factors driving producers to capitalize on high-value agriculture in northeastern India. They identified irrigation as a crucial factor which influenced diversification. However, it was noteworthy that the cost of cultivation tends to be higher for irrigated farming in the study area.

Size of the landholding (0.0041) had a significant negative impact on crop diversification, with an increase in the land holding lead to a lesser diversification of crops, implying that farmers were adopting mono-cropping in case of large farms. The findings are in line with the study conducted by Bansal *et al*. (2020), who examined the factors influencing for crop

diversification in Haryana. They reported farmers having large land holding size were more indulged in taking risk of diversifying towards high value crops. This disproved the fourth hypothesis that size of the holding is not only a major determinant of crop diversification.

Conclusion

The crop diversification indices revealed a moderate level of diversification in Aurad taluk and high diversification in Humnabad taluk of NETZ. Whereas, in NEDZ, the indices values indicated that the farmers in Sedam taluk were shifting towards crop specialization and farmers in Devdurga were increasingly adopting diversified cropping practices. The access to credit and irrigation, distance to market were key determinants of crop diversification in the study areas. The varying levels of crop diversification across regions implies that region specific interventions and need to stabilize and strengthen diversification enablers like credit, irrigation infrastructure and local market, so that full potential of diversification can be harnessed along with risk reduction.

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