Agricultural Economics Research Review 2019, 32 (1), 67-80
DOI: 10.5958/0974-0279.2019.00006.5

Crop diversification in Odisha: an analysis based on panel data

Chittaranjan Nayak* and Chinmaya Ranjan Kumar

Department of Economics, Ravenshaw University, Cuttack, Odisha, India

Abstract Crop diversification is considered as a pathway to promote agricultural development. The present paper examines the subtleties of crop diversification in Odisha, an eastern state in India through spatial trends across 30 districts and determinants of crop diversification. The analysis carried out from 1993-94 to 2012-13 indicates sluggishness and unevenness in crop diversification. The coastal districts lack diversification while several of the districts falling in the southern part of the state tend to be more diversified. The analysis reveals that greater use of high-yielding crop varieties and access to irrigation have influenced crop concentration, whereas rural roads and income have led to crop diversification.

Keywords Crop diversification, Determinants, Theil index, Pooled regression

JEL classification Q15, Q18

1 Introduction

India has achieved record food grain production from 51 million tonnes in 1950-51 to 252 million tonnes in 2015-16. However, this is primarily restricted to cereals. Although cereal production has increased substantially, the production of pulses and oilseeds has not made a dent. As a result, there is a chronic shortage of edible oils and pulses in the country (Chand & Pal 2003). Concomitantly, a perceptible change in consumer preferences away from cereals towards high-value non-cereal nutrient-rich diets including fruits and vegetables is visible (Joshi et al. 2007; Birthal et al. 2013). The question arises whether farmers respond to changes in consumer preferences by altering their crop portfolio.

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 farmers' adaptability to external shocks and promotes self-reliance and sustainability in agriculture. The significance of crop diversification becomes more pronounced in the WTO-led globalised 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 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 (often for exports) is identified as an important factor in poverty reduction (Birthal et al. 2015; Pingali & Rosegrant 1995; Raju 2005; Von Braun 1995).

Aheibam (2017) observes 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

*Corresponding author: crnayak@ravenshawuniversity.ac.in

services critical to agricultural production. Diversification helps in minimizing the adverse effects of the current system of crop specialization and monoculture though nutrient recycling.

Vyas (2006) observes that the share of output and employment of non-crop activities, viz. animal husbandry, forestry and fisheries, though small, has been gradually increasing. Among field crops, area under commercial crops has been increasing, while that under inferior cereals has been decreasing. Although, a number of studies have assessed the spatial trends in agricultural diversification, only a few have looked into their determinants. Birthal et al. (2006) find labour availability, main occupation, irrigation status, road density and market facilities as important determinants of diversification. Kumar & Gupta (2015a) also find a positive relationship between access to irrigation and crop diversification.

In the context of Odisha, some recent studies have emphasised the importance of infrastructure in enhancing the pace of crop diversification. Reddy (2013) argues that infrastructure leads to diversification. Nayak (2015) and Nayak & Kumar (2018) have found that infrastructure motivates farmers to adopt yield-enhancing practices. Nayak & Kumar (2018) find a higher level of diversification associated with backwardness of agriculture in Odisha (higher in KBK[1] region than in the relatively advanced coastal districts). The availability of infrastructure including irrigation and electricity, and the use of inputs such as HYV seeds and fertilisers are higher in coastal Odisha, but not the crop diversification. Nayak (2016) had also revealed that most of the districts in coastal Odisha are undergoing crop specialization, whereas the tribal-dominated and technologically less-developed districts are experiencing crop diversification. Basantaray & Nancharaiah (2017) find diversification higher among marginal farmers. Birthal et al. (2013) had a similar finding at the national level - "the gradual diversification of agriculture towards high-value crops exhibits a pro-smallholder bias, with smallholders playing a proportionally larger role in the cultivation of vegetables versus fruits."

Most of the studies are based on cross-sectional data. Robustness of their findings can only be ascertained using panel data. Exploring determinants is important for better targeting and restructuring of public policy. This paper assesses the extent of crop diversification and explores its determinants by using district level data for Odisha.

2 Data and methods

This study is based on a set of panel data on all the thirty districts of Odisha, for the period from 1993-94 to 2012-13. Initially, with a view to assess the extent of crop diversification, an attempt is made to construct a crop diversification index by considering area under ten major crops.

2.1 Description of the variables

Crop diversification index (*cdi*): We measure crop diversification through the Theil and Herfindahl indices. Theil Entropy index measures an entropic "distance" the population is away from the "ideal" egalitarian state of every cross sectional unit having the same value. On the other hand, the Herfindahl index provides concentration ratio, that gives more weight to larger values. It is actually a measure of concentration, which can be transformed to a measure of diversification. We find very high correlation coefficient between Theil index and (cdi^T) and Herfindahl index (cdi^H). Hence, we use cdi^T for further scrutiny. Theil Entropy index is estimated as:

$$Crop\,diversification\,index\,(cdi^T) = \frac{\sum_i^n P_i \log \frac{1}{P_i}}{\log n}$$

Where, P_i is the share of i^{th} crop in the gross cropped area (GCA), n is the number of crops. The value of *cdi* lies between zero and one, i.e., $0 < cdi^T < 1$; 0 implies complete concentration or no diversification, and 1 implies complete diversification.

---

[1] KBK stands for the erstwhile districts Kalahandi, Balangir, and Koraput of Southern and Western Odisha, which are regarded as the most backward regions by the Planning Commission. During 1992-93, three larger districts were re-organized into eight districts viz. Malkangiri, Koraput, Nabarangpur, Rayagada, Kalahandi, Nuapada, Balangir and Sonepur. Out of the 80 CD Blocks in the region, 49 CD Blocks are regarded as "very backward" and 28 CD Blocks are considered as "backward". Persistent crop failure, lack of access to the basic service and entitlements, starvation, malnutrition and migration are the leading manifestations in the region.

In estimating diversification, we have taken ten crops or crop groups, viz. rice, other cereals, pulses oilseeds, vegetables, spices, fibres, sugarcane, tobacco and fruits. The data on these crops were compiled from the Agricultural Statistics of Odisha (GoO, various years).

Irrigation intensity (*irin*): Irrigation is crucial for agriculture. Several studies have found that irrigation influences crop diversification positively (Birthal et al. 2006; Kumar et al. 2012; Basavaraj et al. 2016), while others show that irrigation discourages diversification (Joshi et al. 2004; Basantaray & Nancharaiah 2017; Mukherjee & Chattopadhya 2017). Most of the above studies have considered irrigation potential in their analyses. We include irrigation intensity, defined as the ratio of total irrigated area to the culturable command area (CCA). In the absence of panel data on CCA, we use gross cropped area as a proxy of CCA.

Cropping intensity (*ci*): Cropping intensity, defined as the ratio of gross cropped area to net sown area, is expected to have a positive impact on crop diversification because farmers have the tendency to rotate crops to improve farm sustainability (Kumar & Gupta 2015a).

High yielding varieties (*hyv*): Crop variety is a crucial determinant of farm profitability (Singh et al. 2018). If a particular variety is expected to raise productivity, farmers may have a selection bias in its favour. In the absence of data on crop-wise area under high yielding varieties we have taken paddy area under high yielding varieties as percent of gross cropped area. It is expected that *hyv* promotes concentration.

Agricultural income (*ddp*): Crop diversification may require more investment in land, seeds, implements, etc., and higher investment depends on higher income. On the assumption that returns on nonfarm investment are higher than those on farm investment, it may not be pertinent to take nonfarm income to channel into farm investment. In our analysis, we have observed a higher correlation coefficient between *cdi* and agricultural income than with income from all sources. We have taken district domestic product per capita as a proxy for district income, and per capita district domestic product from agriculture (*ddp*) as a proxy for agricultural income. We expect a positive effect of agricultural income on diversification as has also been shown in some other studies (Joshi et al. 2004; Rao et al. 2004; Gulati et al. 2005; Dube & Guveya 2016). In order to smoothen the data, we have taken log transformation of *ddp* (i.e., *lnddp)* as a determinant of diversification.

Agricultural credit (*crdt*): Credit enhances investment and the risk-taking ability of farmers, and may lead to diversification. Disbursement of agricultural credit, more often than not, is defined on the basis of per hectare of cultivated land. We have, therefore, considered *crdt* as agricultural credit in rupees per hectare of gross cropped area. The impact of credit may be either positive or negative. Farmers may go for a structural change in cropping pattern, especially from lower-value to higher-value crops if supported by credit (Birthal et al. 2006; Panda 2015). On the other hand, if the existing crop is remunerative or the supporting infrastructures like marketing facilities, roads, etc., are underdeveloped, then farm credit may be diverted towards nonfarm uses. Like *ddp*, we have also log-transformed *crdt*.

Rural road density *(rrg):* Rural road comprises all roads except national highways and state highways. The present paper has measured rural road density per hectare of gross cropped area. It is expected that the farmers having access to improved rural road infrastructure diversify their crop portfolio (Shamdasani 2016). Therefore, the districts having higher rural road density are expected to witness higher crop diversification.

Rainfall (*rnf*): Climatic conditions like rainfall, temperature and moisture have also their role in crop diversification. The paper considers rainfall, as a proxy of the climatic conditions. Kumar & Gupta (2015a) have shown rainfall as one of the major determinants of crop diversification. However, one can argue that if rainfall deviates from normal, it may have negative impact on crop productivity. So, farmers may prefer a crop mix rather than a single crop as an adaptation strategy to weather fluctuations. In our analysis, rainfall is included as a dummy variable, taking a value of one if it is normal, zero otherwise. It is taken as normal if $\mu-\sigma < rnf < \mu+\sigma$, where μ is the normal rainfall for the district and σ is the standard deviation of rainfall of all the districts during the year.

2.3 Model and estimation procedure

We analyse spatial variations in crop diversification; and explore its determinants through the application of panel data models, like the fixed effects (FE)/random effects (RE) that make it possible to minimize bias due to omitted variables and help in controlling unobserved disturbances that are correlated with crop diversification. The selection between FE and RE is done on the basis of Hausman specification that tests whether the unique errors (μ_i) are correlated with the regressors. Further, we conduct diagnostic checks for heteroscedasticity, cross-section dependence, and autocorrelation. As a remedy, we use pooled regression with Driscoll-Kraay standard errors with a cross check by regression with Panel-corrected Standard Errors (PCSE) to verify robustness of the results.

The model used for the analysis is

$$cdi_{it} = \alpha_0 + \beta_1\, hyv_{it} + \beta_2\, ci_{it} + \beta_3\, ir\, in_{it} + \beta_4\, rrg_{it} + \beta_5\, rnfd_{it} + \beta_6\, lnddp_{it} + \beta_7\, lncrdt_{it} + \varepsilon_{it} \quad \ldots(1)$$

3 Results and discussion

3.1 Changes in area share of crops

A preliminary insight into crop diversification can be gained from the changes in area share of crops. The quinquennial average shares of different crops show that Odisha agriculture has remained dominated by rice (table 1). Pulses are the next important crops, followed by oilseeds and vegetables. While, area shares of rice and pulses has been fluctuating around 50% and 20%, respectively; area shares of fruits and fibres have been rising.

3.2 Crop diversification index

To have a closer look at the changes in crop diversification index (*cdi*) across districts we have picked up three different time points of almost decadal interval viz. 1993-94, 2002-03 and 2012-13. Table 2 shows *cdi* for the districts.

There is a wide variation in diversification index and changes therein across the districts. Some districts in the coastal region (e.g., Bhadrak and Jajpur), western region (e.g., Kalahandi and Nuapada), southern region (e.g., Rayagada and Koraput) and central region (e.g., Nayagarh and Kandhamal) have shown an improvement in crop diversification. On the other hand, districts like Kendrapara (coastal), Nabarangpur (southern) and Baragarh (western) have shown an increase in crop concentration. For remaining districts, there is no discernible trend in crop diversification. Interestingly, agriculture in Kandhamal, a tribal-dominated district, has remained more diversified than in others, while paddy-producing districts like Baragarh (western) and Bhadrak (coastal) are at the bottom of crop diversification index. In order to have an idea on whether diversification is increasing or not, we measure coefficient of variation (CV) in *cdi* across districts over the years, which shows an increase in 2002, but has remained almost constant afterwards. Further, we have tested significance of the change in cdi, and the results are presented in table 3. From 1993-94 to 2002-03, there was actually a decline in *cdi*. Conversely, there has been a significant increase in *cdi* from 2002 to 2012.

Table 1. Area share of crops (% of GCA)

Crops of Odisha	1993-1997	1998-2002	2003-2007	2008-2012
Rice	49.00	53.65	50.55	46.95
Other cereals	5.24	5.27	4.92	5.28
Total pulses	20.78	18.41	20.57	22.76
Total oilseeds	11.30	9.30	9.35	8.67
Total vegetables	7.60	6.04	7.38	7.66
Total spices	1.75	1.84	1.64	1.69
Total fibres	0.85	1.10	1.06	1.28
Sugarcane	0.51	0.40	0.40	0.44
Tobacco	0.10	0.07	0.05	0.03
Fruits	2.88	3.92	4.07	5.24
Gross cropped area	100	100	100	100

Source: Authors' estimates from the Agricultural Statistics of Odisha

Table 2. Crop diversification in Odisha, 1993-94 to 2012-13

Rank	District	2012-13	District	2002-03	District	1993-94
1	Kandhamal	0.83	Gajapati	0.81	Kandhamal	0.77
2	Rayagada	0.83	Kandhamal	0.80	Gajapati	0.76
3	Gajapati	0.80	Rayagada	0.80	Rayagada	0.74
4	Koraput	0.79	Koraput	0.74	Koraput	0.74
5	Keonjhar	0.71	Anugul	0.71	Anugul	0.69
6	Anugul	0.71	Ganjam	0.69	Ganjam	0.68
7	Malkangiri	0.70	Keonjhar	0.66	Malkangiri	0.67
8	Debagarh	0.68	Debagarh	0.63	Cuttack	0.66
9	Ganjam	0.68	Nayagarh	0.63	Nuapada	0.65
10	Jharsuguda	0.67	Dhenkanal	0.62	Balangir	0.65
11	Nuapada	0.67	Jajapur	0.62	Nabarangpur	0.65
12	Balangir	0.67	Balangir	0.62	Keonjhar	0.64
13	Kalahandi	0.66	Malkangiri	0.61	Kalahandi	0.64
14	Dhenkanal	0.65	Jagatsingpur	0.61	Sundargarh	0.64
15	Jajapur	0.65	Nabarangpur	0.60	Jharsuguda	0.64
16	Nayagarh	0.65	Nuapada	0.60	Debagarh	0.63
17	Sundargarh	0.64	Kalahandi	0.59	Jagatsingpur	0.63
18	Sambalpur	0.63	Cuttack	0.59	Nayagarh	0.63
19	Cuttack	0.62	Khordha	0.58	Sambalpur	0.61
20	Nabarangpur	0.62	Sundargarh	0.57	Dhenkanal	0.61
21	Jagatsingpur	0.61	Kendrapara	0.57	Jajapur	0.61
22	Khordha	0.60	Sambalpur	0.54	Mayurbhanj	0.59
23	Baudh	0.59	Baudh	0.54	Kendrapara	0.58
24	Puri	0.57	Jharsuguda	0.53	Baleshwar	0.58
25	Mayurbhanj	0.56	Puri	0.52	Khordha	0.57
26	Sonepur	0.55	Mayurbhanj	0.48	Baudh	0.57
27	Kendrapara	0.55	Baleshwar	0.45	Puri	0.53
28	Baleshwar	0.49	Sonepur	0.44	Baragarh	0.52
29	Baragarh	0.46	Baragarh	0.42	Sonepur	0.52
30	Bhadrak	0.41	Bhadrak	0.41	Bhadrak	0.46
Coefficient of Variation		0.154		0.176		0.114

Source: Authors' calculation from the Agricultural Statistics of Odisha

However, ranking of the districts has not changed much. This is explained with the help of correlation matrix of *cdi*-1993, *cdi*-2002 and *cdi*-2012 (table 4). The correlation coefficients are significant at 1% level, indicating that neither *cdi* values nor ranking of districts has changed significantly over time.

Figure 1 presents scenario of crop diversification across all the districts. On the basis of *cdi* ranking, we have attempted to examine the top ten, medium ten and bottom ten districts during 1993, 2002 and 2012. The central and southern districts have continued to remain among the top ten, while there is a fluctuation in the rank of districts in the medium and bottom classes. It may be noted here that the southern and south-coastal regions are relatively less developed in comparison to the north-coastal Odisha. Most of the southern districts fall in the KBK region, one of the most backward regions of India. This means economic development and crop diversification have not moved in tandem in Odisha.

Table 3. Result of paired t-test

Pair	Mean	SD	t-value	p-value
cdi 1993-94 – *cdi* 2002-03	0.0293	0.0090	3.2566	0.0029
cdi 2002-03 – *cdi* 2012-13	-0.0423	0.0067	-6.2639	0.0000
cdi 1993-94 – *cdi* 2012-13	-0.0130	0.0074	-1.7460	0.0914

Source: Authors' computation from Agricultural Statistics of Odisha

Table 4. Correlation coefficients

	Pearson			Spearman		
	cdi 1993	*cdi* 2002	*cdi* 2012	*cdi* 1993	*cdi* 2002	*cdi* 2012
cdi 1993	1	0.689**	0.721**	1	0.642**	0.717**
cdi 2002	0.689**	1	0.870**	0.642**	1	0.808**
cdi 2012	0.721**	0.870**	1	0.717**	0.808**	1

Source: Authors' computation**. Correlation is significant at the 0.01 level (2-tailed).

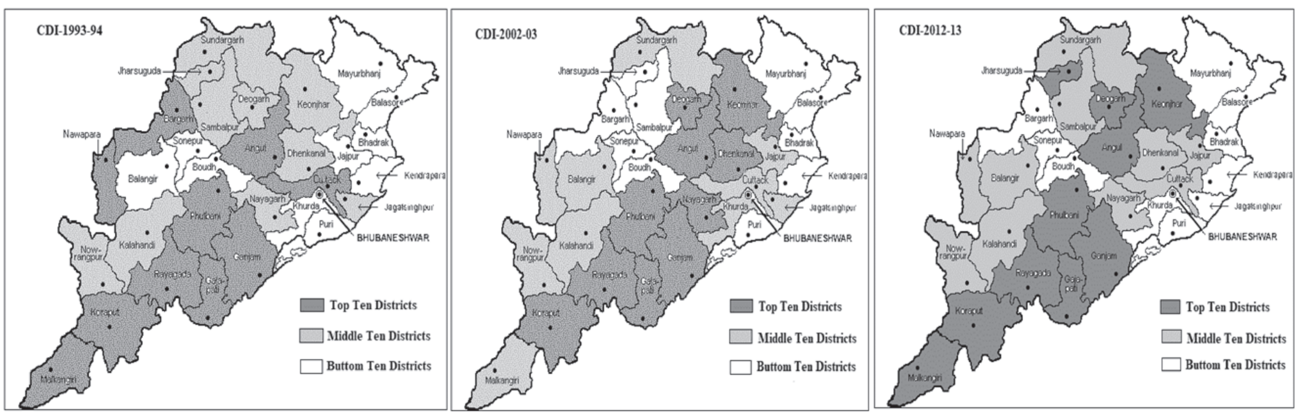

Figure 1. Cop diversification in Odisha: 1993, 2002, and 2012

3.3 Determinants of crop diversification

Table 5 presents descriptive statistics. The mean *cdi* of the panel is 0.61, but with a huge difference in its minimum and the maximum values. Likewise, we find is huge dispersion in *hyv, ci, irin* and *rrg*.

3.3.1 Test of panel unit roots

Before exploring determinants of crop diversification, an attempt has been made to detect if the determinants are free from unit roots problem or not. Considering the fact that the number of years in the balanced panel is just 20, we have used Fisher-type unit root test. Results are presented in table 6. The inverse chi-square and modified inverse chi-square p- values for all the variables are less than 0.05. Hence, there are no unit roots in any of these variables.

3.3.2 Regression results

Table 7 presents estimates based on a pooled regression model. Except rainfall (*rnfd*) and credit (*lncrdt*), coefficients of all other variables are statistically significant. However, before interpreting these, we undertake some important diagnostic tests.

3.3.3 Diagnostic checks

To detect if the panel has heteroscedasticity and non-normality problems, we have conducted Cameron & Trivedi's decomposition of IM-test and the results are presented in table 8. The null hypotheses of no heteroscedasticity and skewness in the data-set are rejected. But the model does not suffer from multicollinearity problem as understood by the variance inflating factor in table 9. The tolerance coefficient

Table 5. Descriptive statistics

SN	Variable	Description	Mean	SD	Min	Max
1	*cdi*	Crop diversification index	0.610	0.097	0.32	0.83
2	*hyv*	High yielding varieties	39.33	12.12	2.5	71.5
3	*ci*	Cropping intensity	155.55	24.11	16	231
4	*irin*	Irrigation intensity	30.41	14.08	3.2	71.72
5	*rrg*	Rural road density	28.33	10.38	9.69	69.41
6	*rnfd*	Rainfall dummy	-2.81	22.50	-64.9	77.8
7	*lnddp*	Agricultural income	8.35	0.52	7.12	9.75
8	*lncrdt*	Agricultural credit	6.91	1.46	2.18	10.25

Source: Authors' computed from secondary data

Table 6. Fisher-type unit root test with trend

Fisher-type	Statistic	Inverse chi-squared (60)(p)	Statistic	Inverse normal (p)	Statistic	Inverse logit t (154)/(p)	Statistic	Modified inv. chi-squared(p)
cdi	87.113	0.0127	-2.8048	0.0025	-2.6927	0.0039	2.475	0.0067
hyv	126.263	0.0000	-5.5335	0.0000	-5.4166	0.0000	6.049	0.0000
ci	89.072	0.0088	-2.1357	0.0164	-2.4799	0.0071	2.654	0.0040
irin	160.086	0.0000	-5.5337	0.0000	-6.3147	0.0000	9.137	0.0000
rrg	196.787	0.0000	-7.0740	0.0000	-8.6759	0.0000	12.487	0.0000
rnfd	761.133	0.0000	-23.809	0.0000	-38.429	0.0000	64.004	0.0000
lnddp	113.140	0.0000	-4.4397	0.0000	-4.547	0.0000	4.851	0.0000
lncrdt	98.534	0.0013	-3.3268	0.0004	-3.422	0.0004	3.518	0.0002

Source: Authors' computation

Table 7. OLS pooled regression

Variable	Coefficient	SE	t-value	p-value
hyv	-0.005065	0.000259	-19.53	0.000
ci	0.000542	0.000115	4.70	0.000
irin	-0.001291	0.000241	-5.36	0.000
rrg	0.000939	0.000234	4.01	0.000
rnfd	0.000106	0.000105	1.01	0.312
lnddp	0.047494	0.005615	8.46	0.000
lncrdt	-0.003539	0.002215	-1.60	0.111
Constant	0.366109	0.043218	8.47	0.000

No. of observations= 600, $F(7, 592) = 175.01$
Prob > F = 0.0000, R^2=0.6742, Adj R^2=0.6703
Root MSE=0.05561

Source: Authors' computation

Table 8. Cameron & Trivedi's decomposition of IM-test

Source	χ^2	df	p-value
Heteroscedasticity	185.12	35	0.0000
Skewness	20.49	7	0.0046
Kurtosis	0.11	1	0.7402
Total	205.72	43	0.0000

Source: Authors' computation

Table 9. Variance inflation factor(VIF) for independent variables

Variable	VIF	TOL (1/VIF)
irin	2.23	0.448180
lncrdt	2.01	0.496789
hyv	1.91	0.523073
lnddp	1.67	0.600375
ci	1.50	0.668030
rrg	1.15	0.872576
rnfd	1.08	0.922276
Mean VIF	1.65	

Source: Authors' computation

(TOL) is above 0.3 indicating the fact that multi-collinearity is not an issue in this panel.

3.3.4 FE/RE regressions

Since pooled regression suffers from the problem of heteroscedasticity, as it is usually prone to, we estimate fixed effects/ random effects models. The results are presented in table 10.

Whether FE or RE model is to be considered for further analysis is scrutinized through Hausman test and the results are presented in table 11. The null hypothesis that RE model is more appropriate is rejected as p=0.00.

However, the FE model also requires some diagnostic checks. We have checked heteroscedasticity by using the modified Wald test and cross-sectional dependence by using the Pesaran CD test.

The modified Wald test shows that there is heteroscedasticity, and the Pesaran test shows that there is cross-sectional dependence in the panel. Therefore, as a remedy, we estimate pooled OLS with Driscoll-

Table 10. Results of fixed effects and random effects models

Variable	Fixed effect			Random effect		
	Coefficient	Test statistic	p-value	Coefficient	Test statistic	p-value
hyv	-0.00021	-10.87	0.000	-0.002290	-11.96	0.000
ci	0.00024	3.09	0.002	0.000226	2.86	0.004
irin	0.00018	1.04	0.296	-3.48e-06	-0.02	0.984
rrg	-0.00051	-1.73	0.084	-0.000298	-1.03	0.302
rnfd	0.00007	1.21	0.228	0.000082	1.46	0.144
lnddp	0.02801	6.01	0.000	0.030505	6.50	0.000
lncrdt	-0.00140	-0.95	0.342	-0.001579	-1.06	0.291
Constant	0.43893	15.08	0.000	0.430293	13.88	0.000
No. of observations		600			600	
No. of groups		30			30	
R^2: Within		0.3422			0.3392	
Between		0.6741			0.7374	
Overall		0.5238			0.5928	
F(7, 563)		41.83 (p=0.0000)		χ^2(7)	312.77 (p=0.000)	
corr(u_i, Xb)		0.5571			0 0(assumed)	
sigma_u		0.0761			0.0486	
sigma_e		0.0253			0.0253	
ρ		0.9003			0 .7866	

Group variable: states, No. of groups =30, observations per group = 20

Source: Authors' calculation

Table 11. Results of Hausman test

Variable	Coefficients		Difference	$\sqrt{diag(V\_b - V\_B)}$
	b (FE)	β (RE)	b-β	SE
hyv	-0.002061	-0.002290	0.000229	
ci	0.000240	0.000226	0.000014	
irin	0.000181	-3.48e-06	0.000185	0.000049
rrg	-0.000507	-0.000298	-0.000208	
rnfd	0.000066	0.000082	0.000016	
lnddp	0.028009	0.030505	-0.002497	
lncrdt	-0.001397	-0.001579	0.000183	

Source: Authors' computation
Note: H_0= difference in coefficients not systematic
χ^2 (computed)= 73.79, p-value 0.000

Table 12. Diagnostic checks for FE model

SN	Null hypothesis	Test	Test statistic	p-value	Decision
1	No group wise heteroscedasticity in fixed effect regression model.	Modified Wald test	χ^2 =423.19	0.000	Heteroscedasticity is present.
2	No cross sectional independence in the panel.	Pesaran CD test	Pesaran= 14.2 Average absolute vale of the off diagonal elements=0.285	0.000	There is cross sectional dependence in the panel.

Source: Authors' computation

Kraay[2] standard errors and the robustness of these results is cross-checked against the results from a Panel-Correlated Standard Errors (PCSE) regression (table 13 &14).

3.3.5 Results of pooled regression with Driscoll-Kraay standard errors

The Driscoll-Kraay standard errors are well calibrated when cross-sectional dependence is present. We observe that the results of pooled OLS regression with Driscoll-Kraay standard errors and the PCSE regressions are consistent with each other.

All the variables, except rainfall and credit are significant. The coefficients of high yielding variety seeds and irrigation intensity are negative meaning that these lead to crop concentration, whereas the determinants like cropping intensity, rural loads, and agricultural income lead to crop diversification.

3.4 Discussion

The observation of Nayak and Kumar (2016) that high yielding varieties (*hyv)* leads to crop concentration is confirmed in the present paper. Likewise, irrigation is also found leading to crop concentration. Usually,

[2] Driscoll and Kraay (1998) propose a nonparametric covariance matrix estimator which produces heteroscedasticity consistent standard errors that are robust to very general forms of spatial and temporal dependence. Driscoll & Kraay's covariance matrix estimator equals the heteroscedasticity and autocorrelation consistent covariance matrix estimator of Newey and West (1987) applied to the time series of cross-sectional averages. Loosely speaking, Driscoll & Kraay's methodology applies a Newey-West type correction to the sequence of cross-sectional averages of the moment conditions. Adjusting the standard error estimates in this way guarantees that the covariance matrix estimator is consistent, independently of the cross-sectional dimension N.

Table 13. Pooled OLS regression with Driscoll-Kraay standard errors

Variable	Coefficient	Test statistic	p-value
hyv	-0.005065	-7.63	0.000
ci	0.000542	2.99	0.006
irin	-0.001291	-2.56	0.016
rrg	0.000940	3.63	0.001
rnfd	0.000106	1.11	0.278
lnddp	0.047494	6.01	0.000
lncrdt	-0.003539	-1.34	0.190
Constant	0.366109	6.21	0.000
No. of observations		600	
No. of groups		30	
F(7,29)		1850.00	
R^2		0.6742	
Root MSE		0.0556	
p-value		0.0000	
Maximum lag		2	

Source: Authors' computation
Note: Group variable: district, Time variable: year, Panels: correlated (balanced), No. of groups= 30, observations per group= 18

Table 14. Results of panel-corrected standard error regression

Variable	Coefficient	Test statistic	p-value
hyv	-0.005065	-13.54	0.000
ci	0.000542	3.82	0.000
irin	-0.001291	-4.61	0.000
rrg	0.000940	5.59	0.000
rnfd	0.000106	1.01	0.314
ln ddp	0.047494	9.49	0.000
ln crdt	-0.003539	-1.86	0.062
Constant	0.366109	9.75	0.000
No. of observations		600	
No. of groups		30	
Estimated covariance		465	
Estimated autocorrelations		0	
Estimated coefficients		8	
R^2		0.6742	
Wald (7)		1120.04	
p-value		0.0000	

Source: Authors' computation
Note: Group variable: district, Time variable: year, Panels: correlated (balanced)

higher irrigation intensity leads to higher cropping intensity. Interestingly, the present paper finds that (*cdi)* is positively influenced by cropping intensity but negatively by irrigation intensity. A look at the correlation matrix gives us some more information in this context (table 15). It is observed that *cdi* is positively correlated to *ci* but negatively correlated to *irin*. However, *irin* and *ci* are positively correlated. This lack of transitivity might be looking paradoxical but it has a possible explanation. Although irrigation intensity is associated with increasing cropping intensity, it is observed that crop diversification is higher in the districts having lower irrigation intensity. This means, higher cropping intensity is confined to monocropping in coastal Odisha where irrigation intensity is relatively higher, whereas it is associated with multicropping practice in rainfed districts of western and southern Odisha. However, the finding of this paper supports the view of Kumar and Gupta (2015b) that cropping intensity has significant positive impact on crop diversification as farmers have inclination to rotate the crops for maintaining soil fertility through nutrient recycle.

Table 15 also gives another interesting observation that there exists a very high degree of correlation (0.629) between *irin* and *hyv*. High yielding paddy in turn is a factor leading to crop concentration (refer tables 13-15). Being high yielding and supported by the minimum support prices (MSP) the paddy becomes an assured crop against all types of risks. The farmer is usually a risk averter. For him, risk arising from both the price and yield variations in alternative crops might be acting as the crucial exogenous variables that discourage to undertake alternative crops. Another very closely related problem might be the lack of proper marketing arrangements for other crops. Although the paper has not studied the role of factors like support prices, risks and marketing bottlenecks in choosing alternative crops, insights can be drawn from the work of Haque (2010), which shows that market facilities are essential for crop diversification. However, major portion of the more diversified KBK region is rainfed. So, high yielding crops which use water intensively are scarcely grown in this region. Therefore, *hyv* is observed as a factor contributing to crop concentration rather than diversification.

Similarly, there are various irrigation systems in Odisha, depending upon how the water is distributed to crops. More canal irrigation in comparison to minor (lift and flow) irrigation promotes monocropping of paddy. A recent study by Mukherjee and Chattopadhya (2017) observes that canal irrigation leads to crop concentration. However, Ashok and Balasubramanian (2006) had a contrary view that irrigation intensity has a positive influence on crop diversification. To address the continuing debate, there is a need to examine the impact of different types of irrigation systems on crop diversification, which is beyond the scope of this paper.

Credit and insurance promote agro-processing, and access to information and communications technology (ICT) leads to crop diversification (Cummings Jr. et al. 2007). The present study, however, observes that credit has a negative effect . In Odisha, cooperative societies normally provide agricultural credit for *kharif* crop primarily on the basis of land ownership status. So, small and marginal farmers get less credit. As Basantray and Nancharaiah (2017) have observed that crop diversification is inversely correlated with farm

Table 15. Correlation matrix for the panel

Variable	*cdi*	*hyv*	*ci*	*irin*	*rrg*	*lnddp*	*lncrdt*
cdi	1	-0.756**	0.141**	-0.538**	0.187**	0.245**	-0.061
hyv	-0.756	1	-0.041	0.629**	-0.027	0.028	0.135**
ci	0.141	-0.041	1	0.330**	-0.003	0.258**	0.348**
irin	-0.538**	0.629**	0.330**	1	-0.151**	0.124**	0.358**
rrg	0.187**	-0.027	-0.003	-0.151**	1	0.204**	0.164**
lnddp	0.245**	0.028	0.258**	0.124**	0.204**	1	0.415**
lncrdt	-0.061	0.135**	0.348**	0.358**	0.164**	0.415**	1

Source: Authors' computation

Note: **signifies significant at 1 percent level, *signifies significant at 5 percent level.

size, the structure of the present credit disbursal is obvious to cause crop concentration.

Rural road density per hectare of gross cropped area (*rrg*) and per capita district domestic product from agriculture (*ddp*) are found to have significant positive impact on crop diversification. Some previous studies had also observed significant positive impact of road density on crop diversification (Rao et al. 2004; Cummings Jr et al. 2007; Shamdasani 2016). On the contrary, some studies have also observed significant negative influence of road density on diversification (Ashok & Balasubramanian 2006; Singh et al. 2006). Our findings corroborate the former viewpoint. Farmers having access to improved rural road infrastructure are usually better poised to exploit the market benefits.

Similarly, per capita district domestic product from agriculture is also found to be a positive factor for diversification. In the present paper, we have considered *lnddp* in lieu of *ddp* with a view to avoid unit roots in data. Higher *ddp* enhances capacity to save and invest. This raises risk taking capacity of farmers (Joshi et al. 2004; Rao et al. 2004; Gulati et al. 2005; Dube & Guveya 2016). However, contrary to these we observe that *ddp* is higher for relatively backward districts indicating the phenomenon that crop diversification may be distress-driven, as in the absence of alternative employment avenues farmers in underdeveloped regions may resort to multiple farming for sustenance.

As regards the impact of deviation of rainfall on crop diversification, the coefficient of the dummy is positive but not significant. This supports the conventional wisdom that the districts having proneness to drought or flood take recourse to crop diversification to some extent.

4 Conclusion and implications

On the basis of the analysis, the paper offers the following conclusions:

That, there has been a sluggish rise in crop diversification in Odisha. The years 1993-2002 witnessed a reduction in the extent of diversification, whereas during 2002-2012, there has been an improvement in crop diversification index, on an average. But for the entire span of 1993 to 2012, although there has been an increase in crop diversification, the increase is not significant.

That, a regional divide in crop diversification is observable between the southern districts (mostly the KBK districts) vis-à-vis other districts. Except for a few coastal districts like Jajpur and Jagatsingpur, all other coastal districts have low crop diversification. Conversely, many of the KBK districts, except for Nabarangpur, Sonepur and Nuapada, have high crop diversification.

That, all the determinants of diversification like seed quality, irrigation intensity, cropping intensity, rural road density, agricultural income and credit are significant, except for rainfall. High yielding variety seeds of paddy, irrigation intensity and credit lead to crop concentration, whereas cropping intensity, rural roads and district domestic product from agriculture per capita lead to crop diversification.

That, capacity of farmers as proxied by district domestic product for agricultural income per capita is a positive contributor to crop diversification. However, it is observed that *ddp* is higher for relatively backward districts. This may be understood as the distress phenomenon, i.e., in the absence of alternative employment avenues farmers of underdeveloped regions may resort to multiple farming for sustenance.

That, road density, a factor which indicates the status of rural infrastructure, has positive impact on crop diversification. As rural roads ensure rural connectivity, it fastens the input reach to farm lands and supply of agricultural products to the nearby markets.

That, cropping intensity has significant positive impact on crop diversification as farmers have inclination to rotate the crops for maintaining soil fertility through nutrient recycle.

That, high yielding variety paddy, irrigation intensity and credit do have significant but negative impact on crop diversification. HYV paddy, being more productive and supported by the minimum support prices which are almost revised upward periodically, becomes an assured crop against all types of risks and uncertainty. Therefore, it is an obvious choice for the farmers across the state. However, the major portion of KBK region is rain fed. So HYV crops which use water intensively are scarcely grown in this region. Similarly, there is more canal irrigation found in the state in comparison to minor (lift and flow) irrigation per gross copped area, which leads to concentration rather than crop diversification. Credit is also a factor leading to crop concentration.

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. An attempt as such was made in Puri sadar block and Semiliguda block of Koraput in 1988 by which cropping intensity as well as cropping pattern had undergone significant change. However, there is a need to adopt such planning across the state holistically. As the study indicates that canal irrigation leads to crop concentration in coastal Odisha, attempts may be made to incentivise farmers to grow alternative crops in place of paddy in marginal lands and horticulture in high lands, which will also make water use efficient. While emphasis needs to be on provision of improved basic infrastructure like rural roads, power, transportation and marketing, and supply of adequate post-harvest technologies, a knowledge-based farming calls for wider interaction between the researchers, extension personnel, agricultural institutions and farmers.

Acknowledgement

The authors thankfully acknowledge the editorial comments and suggestions of the anonymous referees.

References

Aheibam, M., Singh, R., Feroze, S. M., Singh, N. U., Singh, R. J., & Singh, A. K. (2017). Identifying the determinants and extent of crop diversification at household level: an evidence from Ukhrul district, Manipur. Economic Affairs, 62(1), 89-95.

Ashok, K. R., & Balasubramanian, R. (2006). Role of infrastructure in productivity and diversification of agriculture. A research report, South Asia Network of Economic Research Institutes, Islamabad.

Basantaray, A. K., & Nancharaiah, G. (2017). Relationship between crop diversification and farm income in Odisha- an empirical analysis. Agricultural Economics Research Review, 30 (Conference Number), 45-58.

Basavaraja, N. D., Gajananab, T. M., & Satishkumar, M. (2016). Crop diversification in Gadag district of Karnataka. Agricultural Economics Research Review, 29(1), 151-158.

Birthal, P. S., Jha, A. K., Joshi, P. K., & Singh, D. K. (2006). Agricultural diversification in north-eastern region of India: implication for growth and equity. Indian Journal of Agricultural Economics, 61(3), 328-340.

Birthal, P. S., Joshi, P. K., Roy, D., & Thorat, A. (2013). Diversification in Indian agriculture towards high-value crops: role of small holders. Canadian Journal of Agricultural Economics, 6, 61–91.

Birthal, P. S., Roy, D., & Negi, D. S. (2015). Assessing the impact of crop diversification on farm poverty in India. World Development, 72, 70–92.

Birthal, P. S., Negi, D. S., Jha, A. K., & Singh, D. (2014). Income sources of farm households in India: determinants, distributional consequences and policy implications. Agricultural Economics Research Review, 27(1), 37-48.

Chand, R., & Pal, S. (2003). Policy and technological options to deal with India’s food surpluses and shortages. Current Science, 84 (3), 388-398.

Cummings Jr., R., Joshi, P. K., Gulati, A., & Ganguly, K. (2007). Agricultural diversification towards high value commodities: a study in food surplus states in India with focus on Andhra Pradesh and Punjab. International Food Policy Research Institute, New Delhi.

Driscoll, J. C., & Kraay, A. C. (1998). Consistent covariance matrix estimation with spatially dependent panel data. Review of Economics and Statistics, 80, 549–560.

Dube, L., & Guveya, E. (2016). Factors influencing smallholder crop diversification: a case study of Manicaland and Masvingo provinces in Zimbabwe. International Journal of Regional Development, 3(2), 1-25.

Government of Odisha (2015). Odisha agriculture statistics 2013-14. Directorate of Agriculture and Food Production, Bhubaneswar.

Gulati, A., Minot, N., Delgado, C., & Bora, S. (2005). Growth in high-value agriculture in Asia & the emergence of vertical links with farmers. In: Paper presented at the Symposium ‘towards high-value agriculture & vertical coordination: implications for agribusiness & smallholders’. National Agricultural Science Centre, New Delhi.

Haque, T. (2010). Constraints and potentials of diversified agricultural development in eastern council for social development and others. Project report, Planning Commission, Government of India, New Delhi.

Joshi, P. K., Birthal, P. S., & Minot, N. (2006). Sources of agricultural growth in India: role of diversification towards high value crops. Discussion Paper 98, Markets, Trade and Institutions Division, International Food Policy Research Institute, Washington, DC.

Joshi, P. K., Gulati, A., & Cummings Jr., R. (2007). Agricultural diversification and smallholders in south Asia. Academic Foundation, New Delhi.

Joshi, P. K., Gulati, A., & Birthal, P. S. (2007). Agricultural diversification in India- status, nature & pattern. In: Agricultural diversification and smallholders in South Asia (P. K. Joshi, A. Gulati, & R. Cummings Jr., eds.). Academic Foundation, New Delhi.

Joshi, P. K., Gulati, A., Birthal, P. S., & Tewari, L. (2004). Agriculture diversification in South Asia: patterns, determinants and policy implications. Economic and Political Weekly, 39(18), 2457-2467.

Kumar, A., Kumar, P., & Sharma, A. N. (2012). Crop diversification in Eastern India: status and determinants. Indian Journal of Agricultural Economics, 67(4), 600-616.

Kumar, S., & Gupta, S. (2015a). Crop diversification in India: emerging trends determinants and policy implications. International Journal of Current Research, 7(6), 17188-17195.

Kumar, S., & Gupta, S. (2015b). Crop diversification towards high-value crops in India: a state level empirical analysis. Agricultural Economics Research Review, 28(2), 339-350.

Mukherjee, S., & Chattopadhyay, S. (2017). Crop diversification in West Bengal: a district level analysis for the period 1980-81 to 2011-12. Journal of Rural Development, 36(4), 501-529.

Nayak, C. R., & Kumar, C. R. (2018). Crop diversification in Odisha: an empirical assessment. In: Agrarian distress and farmer's suicide in India (M. Swain & C.R. Nayak, eds.). S. K. Book Agency, New Delhi, 164-178.

Nayak, C. R., & Kumar, C. R. (2016). Role of rural infrastructure in crop diversification: a district level analysis of Odisha. Orissa Economic Journal, 47(1), 201-212.

Nayak, C. R. (2015). Crop diversification and land productivity in Odisha: role of rural infrastructure. PRAGATI: Journal of Indian Economy, 2(2), 1-18.

Nayak, D. K. (2016). Changing cropping pattern, agricultural diversification and productivity in Odisha-a district-wise study. Agricultural Economics Research Review, 29(1), 93-104.

Newey, W. K., & West, K. D. (1987). A simple, positive semi-definite, heteroscedasticity and autocorrelation consistent covariance matrix. Econometrica, 55, 703–708.

Panda, R. K. (2015). Trend and pattern of crop diversification in Odisha. In: Diversification of agriculture in Eastern India (M. Ghosh, D. Sarkar & B.C. Roy, eds.). Indian studies in Business and Economics, Springer.

Pingali, P. L., & Rosegrant, M. W. (1995). Agricultural commercialization and diversification: process and policies. Food Policy, 20(3), 171-186.

Raju, B. Y. (2005). Commodity study on diversification of Indian agriculture. Occasional Paper (36), Department of Economic Analysis and Research, National Bank for Agriculture and Rural Development, Mumbai.

Rao, P., Birthal, P. S., Joshi, P. K., & Kar, D. (2004). Agricultural diversification in India and role of urbanisation. Discussion paper 77, Markets, Trade and Institutions Division, International Food Policy Research Institute, Washington, DC.

Reddy, A. A. (2013). Agricultural productivity growth in Orissa, India: crop diversification to pulses, oilseeds and other high value crops. African Journal of Agricultural Research, 8(19), 2272-2284.

Shamdasan, Y. (2016). Rural road infrastructure & agricultural production: Evidence from India. Retrieved from https://sites.tufts.edu/neudc2017/files/2017/10/paper_27.pdf.

Singh, K. M., Ahmad, N., Sinha, D. K., Singh, R. K. P., & Mishra, R. R. (2018). Diversification and its determinants: search for an alternative income and agricultural development in Eastern India. International Journal of Current Microbiology and Applied Sciences, 7(2), 695-702.

Singh, N. P., Kumar, R., & Singh, R. P. (2006). Diversification of Indian agriculture: composition, determinants and trade implications. Agricultural Economics Research Review, 19 (Conference No.), 23-36.

Von Braun, J. (1995). Agricultural commercialization: impacts on income and nutrition and implications for policy. Food Policy, 20(3), 187-202.

Vyas, V.S. (2006). Diversification in agriculture: concept, rationale and approaches. In: Indian agriculture in the new millennium (N. A. Mujumdar & U. Kapila, eds.). Academic Foundation, New Delhi.

Received: May 2018; Accepted: December 2018