Levels of Agriculture Development and Crop Diversification: A District-Wise Panel Data Analysis in West Bengal

Rukhsana and Asraful Alam

Abstract Crop diversification is an important management to augment agriculture development sustainability in India, including income-enhancing strategies for farmers and employment generation, poverty eradication, judicious use of natural resources and promoting ecological management. This study analyzed the nature, extent and association between levels of agricultural development and crop diversification across districts of West Bengal using secondary data. The Herfindahl index has been used to calculate agricultural diversification, and the level of agricultural development was developed based on a composite z-score through selected parameters of agriculture. The result shows that the diversity of crops is diversifying at a faster rate than the all-India level. However, this has happened only in a few selected areas and not in the entire state. The level of crop diversification and agriculture development found varies among districts of West Bengal. It has been found that crop diversification has a positive correlation with all selected indicators of agriculture such as irrigation, cultivators, gross sown area and levels of agricultural development as a whole, showing a strongly positive correlation with crop diversification, indicating that crop diversification has increased with an increase in the level of agricultural development. Major constraints for low crop diversification in some districts of West Bengal are lack of irrigation facilities, frequent droughts, erratic rainfall, poor asset base, lack of awareness and training, lack of credit facilities, traditional farming practices, average land holding size and per capita income. Thus, the growth of crop diversification can be improved through technical support, supply of quality input, insurance coverage and the existence of modern storage-processing centers in the low agriculture diversified regions.

Keywords Levels of agriculture development · Crop diversification · Herfindahl index · Composite z-score

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1 Introduction

In the twenty-first century, there is a need to double global food and feed production on existing agricultural lands, which is essential to achieving food and nutritional security and improving agricultural resource use efficiency; protecting biodiversity in ecosystems is needed to restore the health of the ecosystem. These are some of the major challenges facing agriculture across the world. To attain this, there must be a substantial increase in food production, while at the same time, the environmental footprint of agriculture must be significantly reduced. This can be achieved by slowing agricultural expansion, augmenting crop efficiency, closing the yield gap, changing diet and reducing waste, and together these approaches can double food production while reducing the environmental influences of agriculture (Foley et al., 2011). Presently, the agriculture sector is facing many challenges, including climate change and associated variability effects, leads to more extreme events like drought and heat stress or flood, degrading land and water, loss of agrobiodiversity and declining food quality, all adversely effecting ecosystem health and food and nutritional security. Crop yields are either stagnant or declining (Ray et al., 2012), whereas we often have observed large yield gaps between potential yields and agricultural yields, especially in the developing world (Meng et al., 2013; Edreira et al., 2017).

Diversifying crops in agriculture can improve resilience and health of ecosystems in a variety of ways (for example, pest outbreaks and pathogen transmission that are likely to worsen due to global warming). Economic inducements that encourage the production of a select few crops, campaigns to grow transgenic crops and the idea of monocultures being more productive than diverse farming systems are major barriers to promoting this diversified approach. Crop diversification can be applied at different scales in a variety of forms and allowing farmers to decide on a policy which can leads to augmented resilience and uplift to economic of farmers (Lin, 2011). Crop diversification is considered a significant way to increase agricultural income, poverty alleviation, employment generation, soil conservation and water resources, and it is an important strategy to overcome many of the emergencies faced by developing countries (Joshi et al., 2004). Mandal and Bezbaruah (2013) observed that as a food risk-coping mechanism, crop diversification has a strong positive effect on small farmers' incomes in India. Von Braun (1995) found that agricultural diversity in export vegetable production augmented rural employment by 45% in Guatemala. Similarly, Ali and Abedullah (2002) showed that diversification of crops toward high-value commodities produced significant employment in food and feeding production. Recently, Birthal et al. (2004) found that household agricultural diversity of small farmers toward high-value crops is likely to be poor in developing regions at the household level.

The Indian agriculture sector is mostly dominated by marginal and small farmers who are facing the problems of low income, low productivity and low availability of food grains (Desai et al., 2011). Over the decades, farmers have been advised to diversify their agriculture to meet the basic needs of their families through increased

income and to reduce environment challenges also (Sinha & Ahmad Nasim, 2016). Various benefits such as poverty alleviation, income generation, employment supply, food security, environmental development and agricultural sustainability can be achieved by crop diversification. Diversified cropping or new cropping systems were found to increase the value of natural resources. It has also been found that the pattern of diversification improves the agricultural income at higher levels, such as increasingly accommodating more profitable crops (Saleth & Maria, 1995; Dutta, 2012; Rukhsana, 2020). The physical and socioeconomic conditions of the area with a high level of agricultural technology and low degree of diversification should be controlled to lead to crop diversification (Raju, 2012). The purpose of this study is to determine the regional variation of crop diversification or specialization at the district level and levels of agriculture development in West Bengal and the association between crops.

The Study Area West Bengal state has been selected for the study; it lies between 21°31′ and 27°13′14″ north latitude and 85° 45′20″ and 89°53′ east longitude. It has 19 districts and 341 development blocks and is organized into 66 subdivisions. West Bengal lies in the eastern region of India with a great physical diversity and shares international borders with Bangladesh and Nepal (Fig. 1). Crop diversification is considered to be a way to increase the contribution to the production ratio of non-rice crops to achieve higher agricultural growth rates in the future. Apart from boosting development, diversification can also contribute to higher nutrition levels, poverty alleviation, employment generation and sustainable natural resource management.
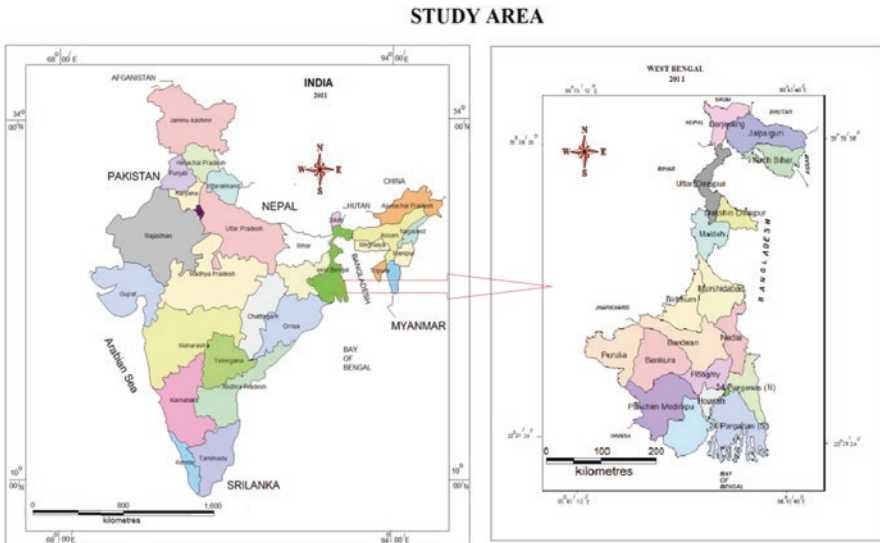
Fig. 1 Location map of West Bengal

Methodology   Crop diversification involves adding more crops to the existing agriculture system (Makate et al., 2016). The main concept of crop diversity is the addition of more crops to the existing crops, denoted horizontal crop diversity (Joshi et al., 2004). However, this type of diversification means expanding the system base, adding more crops to the existing cropping system, using techniques like multiple cropping techniques combined with other efficient management practices. It can also describe crop diversity, for instance, crop additios and adjustments, which is related to the primary concept of crop diversification, but they are only a way to optimize profit and manage the land (FAO, 2015).

Various statistical methods have been found to estimate the diversity of agriculture or crop diversification from existing literature, including maximum ratios, augive index, entropy index, modified entropy index, composite entropy index, Simpson index, and so on. Kumar et al. (2012), Benin et al. (2004), Chand (1996) and Pandey and Sharma (1996) applied said indexes in their work. Each of these tools has its own merits and limitations of data requirements, ease of estimation and interpretation. Additionally, results attained through these indexes or methods are more or less the same.

In this study the crop diversification (CDI) index has been examined to define crop diversification for particular crops of interest. This was achieved by subtracting the Herfindahl index (HI) from one which is an index of concentration and has a direct relationship with diversification of crops, where a zero value signifies specialization and greater than zero indicates crop diversification. This index formula has been used to find the crop diversification area in the selected study area. The Herfindahl index given below is computed by taking the sum of squares of acreage proportion of each crop in the total cropped area. The formula of the Herfindahl index is as follows:

$$\text{Herfindalh index}\left(\text{HI}\right) = \sum_{i-1}^{N} P_i^2$$

where N denotes the total number of crops and Pi is area proportion of the i-th crop in total cropped area. With augmented diversification, the Herfindahl index would decrease. This index takes a value of one when there is complete concentration and approaches zero when diversification is perfect. Thus, the Herfindahl index is bounded by zero and one.

The correlation coefficient has been used for the dependent variable (crop diversity) and independent variables (selected agricultural development variables of the factors affecting crop diversity), and Student's t-test technique has been applied to find the determinants which are significant at 1% and 5% levels. The correlation coefficient has been calculated based on the Karl Pearson's correlation co-efficient (r) technique, as follows:

$$r = \frac{\sum xy - \sum x \sum y / n}{\sqrt{\sum x^2 - \frac{(\sum x)^2}{N}} \sqrt{\sum y^2 - \frac{(\sum y)^2}{N}}}$$

where r is the coefficient of correlation, X, y are the two given variables, and n is the number of observations. To find the computed 't' value, Student's t-test technique is used, which is given below: where t is the calculated value of 't' in the test of significance, r is the computed value of the coefficient of correlation, and n is the number of observations.

$$\text{Index of Cropping Intensity} = \frac{\text{Index of area under crops}}{\text{Index of net area sown}} \times 100$$

Levels of agricultural development have been scrutinized using composite z-score technique, expressed as follows:

$$Z = \frac{X - \bar{X}}{SD} \tag{1}$$

where Z = standard score, X = original values of the score, $\bar{X}$ = mean of variables and SD = standard deviation of variables; the obtained Z = score of each indicator is added district wise to be known as composite Z = score(s) for each spatial unit of the study area.

$$Cs = \sum Z_{ij} \tag{2}$$

where Cs denotes composite Z-scores, and Z_{ij} indicates the sum of Z-scores of indicators j in district i.

2 Result and Discussions

Regions of Agricultural Development Sustainable development of any country depends on food. It is necessary to check the levels of agricultural development to know the facts. The districts are organized into five categories of agriculture development: high => 1.5, medium =0.5–1.5, low = −0.5 to 0.5 and very low = −1.5 to −0.5 in terms of the combined z-score (− < 1.5) in composite z-score. Agricultural development includes eight indicators including net sown area, gross sown area, total irrigated area, intensity of crop, percentage of land by size groups and fertilizer consumption in kilograms per hectare. The analysis shows that the lowest overall Z score of −2.08 has been obtained by Darjeeling, while the highest of 1.50 by Burdwan (Table 1). Figure 2 shows that a notable area of very high concentration of

agricultural development comprises two districts, Burdwan and Nadia, while a high concentration of agricultural development is founs in five districts, including Murshidabad, Birbhum, Hooghly, Pashim Medinipur and Puraba Medinipur. It is clear from this figure that the development of agriculture is found more in the southern and central part of the study area. But these districts are counted as medium and low in crop diversification except for Murshidabad and Birbhum, which contribute to higher diversification because of the higher density of population and more industrialization with cash crops. A very low concentration of agricultural development is founs in five districts: Uttar Dinajpur, Dakhin Dinajpur, Purulia, Howrah and Norton 24 Parganas; these districts are high in crop diversification except for Purulia. Actually, those districts with the highest concentration of agricultural development have low crop diversification due to industrialization and commercialization of cash crops.

The analysis reveals that the lowest composite z-score of −2.08 is achieved by Darjeeling while the highest at 1.50 is attained by the Bardhaman (Table 1).

Regions of Crops Diversification Changing agricultural patterns and practices is the result of successful implementation of the "Green Revolution Program (GRP)" and policies. In addition, the Indian agricultural sector has seen significant changes

Table 1 District-wise distribution of agricultural development (in Composite Standardized Z-Scores) in West Bengal (2011–2012)

Name of the district	GCA	NSA	CI	TIA	FC	LH	CZS	RECZS
Bardhaman	1.24	1.554	−0.277	1.534	0.768	−0.218	4.82	1.50
Cooch Behar	−0.01	−0.330	0.627	−0.422	−1.346	−9.025	−1.48	−0.45
North24 Parganas	−0.25	−0.559	0.627	−1.498	−1.036	−7.733	−2.71	−0.84
South24 Parganas	−0.25	0.672	−0.890	1.239	0.130	−2.873	0.90	0.28
Bankura	−0.05	0.386	−0.802	−1.118	0.854	0.140	−0.74	−0.22
Uttar Dinajpur	−0.21	−0.117	−0.306	0.000	0.528	−1.216	−0.11	−0.03
Dakshin Dinajpur	−1.01	−0.914	−0.656	−0.573	−0.259	−4.495	−3.42	−1.05
Darjeeling	−1.56	−1.468	−1.094	−1.177	−1.424	−9.348	−6.72	−2.08
Howrah	−1.73	−1.962	0.248	−0.368	−0.067	−3.695	−3.88	−1.20
Malda	−0.37	−0.550	0.277	0.826	0.648	−0.717	0.83	0.26
Hooghly	0.03	−0.738	1.911	−0.717	1.765	3.939	2.25	0.70
Jalpaiguri	0.14	0.440	−0.511	0.569	0.569	−1.047	1.21	0.38
Murshidabad	1.82	1.014	1.327	−1.288	−0.043	−3.596	2.83	0.88
Nadia	0.95	0.040	1.823	2.137	−0.323	−4.762	4.63	1.44
Purba Medinipur	0.02	0.002	−0.015	0.484	1.314	2.057	1.80	0.56
Paschim Medinipur	1.92	2.120	−0.073	−0.431	−1.238	−8.576	2.30	0.71
Purulia	−0.86	0.063	−1.940	−0.377	−1.609	−10.121	−4.73	−1.46
Birbhum	0.20	0.349	−0.277	0.916	0.769	−0.211	1.95	0.61
AVERAGE	0.00	0.00	0.00	−0.01	0.00	−3.42	−0.01	0.00
SD	1.00	1.00	1.00	1.04	1.00	4.17	3.23	1.00

Note: *GCA* Gross sown area, *NSA* Gross sown area, *CI* Cropping intensity, *TIA* Total irrigated area, *FC* Fertilizer consumption, *LH* land holding
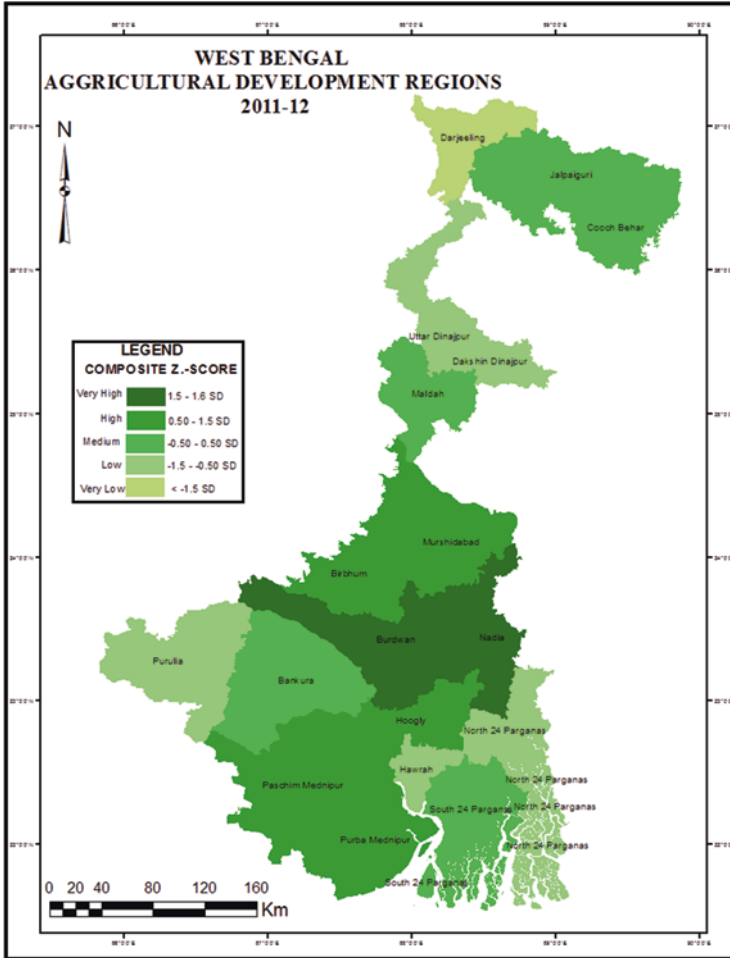
Fig. 2 Agricultural development regions

from traditional food grain farming to diversification and cultivation of commercial horticultural crops since the 1990s (Rukhsana, 2020). Furthermore, similar results have been observed in the state of West Bengal in relation to agricultural practices. Study area was graded into five categories (very high, high, medium, low and very low crop diversified regions) of crop diversification based on the Herfendahl index.

Table 2 and Fig. 3 present the scenario of crop diversification in west Bengal during 2012–13. The sample mean of the Herfindahl index is 0.057, which is found to be the highest Herfindahl index (Table 2). Crop diversification is mainly observed in the northern regions of West Bengal. Figure 2 shows that the Howrah district is the most highly diversified district followed by Dakshin Dinajpur (0.01), Birbhum (0.01) and Cooch Behar (0.01), while districts like Birbhum along with Uttar

**Table 2** Crops diversity in West Bengal at district level

Sl. No.	Name of the district	2012–2013
1	Burdwan	0.06
2	Koch Behar	0.01
3	South 24 Parganas	0.03
4	North 24 Parganas	0.02
5	Bankura	0.02
6	Dakshin Dinajpur	0.01
7	Darjeeling	0.04
8	Hawrah	0.001
9	Maldah	0.03
10	Hoogly	0.08
11	Jalpaiguri	0.03
12	Murshidabad	0.03
13	Nadia	0.25
14	Paschim Mednipur	0.17
15	Purba Mednipur	0.08
16	Uttar Dinajpur	0.02
17	Purulia	0.13
18	Birbhum	0.01
Total average	0.057	

Source: Compiled by author. Calculation is based on data from Statistical Handbook West Bengal (2012) published by Bureau of Applied Economics & Statistics Department, Kolkata, W.B Office of the Directorate of Agriculture, Government Of West Bengal

Dinajpur have made tremendous improvement in crop diversification in West Bengal. Moderate diversification has been recorded in the districts of Hoogly (0.08), Burdwan (0.08) and Purba Mednipur (0.08), which made important advancements in crops diversification during 2012–2013 due to improvement of irrigation facilities and changes in institutional holding size and accessibility to markets.

Crop diversification is influenced by many factors including development of infrastructure, consumption of fertilizer and adoption of technology like irrigation facilities, relative income, cost of resources and population size and per capita income as well as climate change. This section examines the factors influencing diversification in favor of agriculture practice or high-value crops. Several regression analyses have been performed using data for the period 2012–2013 to identify important factors affecting crop diversification. To find the relation between crop diversification and its determinants, the co-efficient of correlation (r) has been calculated, which is shown in the mentioned figures of the respective determinants. After going through crop diversification and agricultural fields, it would be valuable to study the factors affecting crop diversification in the study area. Crop diversification and the relationship between agricultural development and population are discussed in this section.
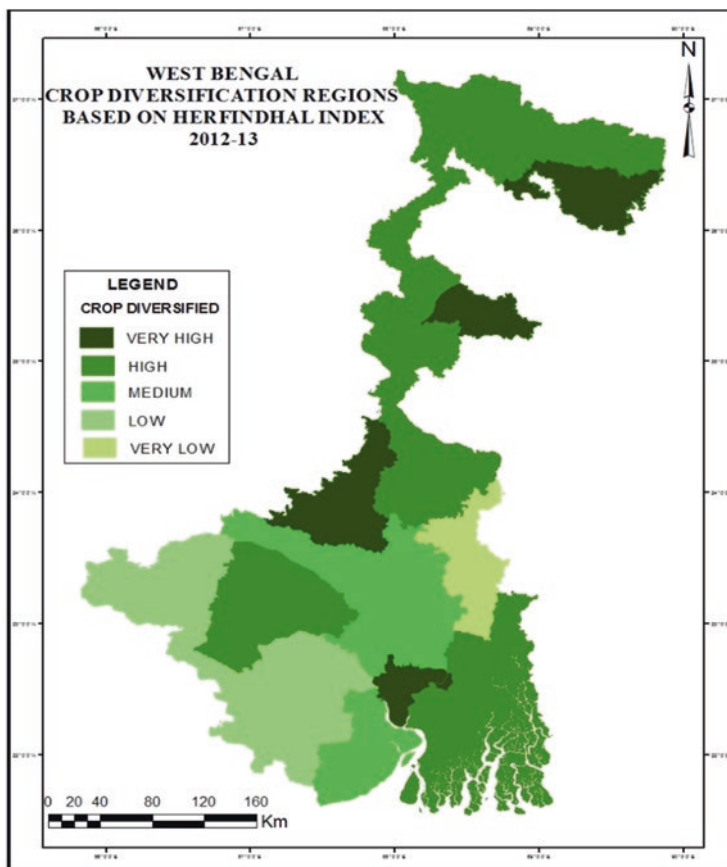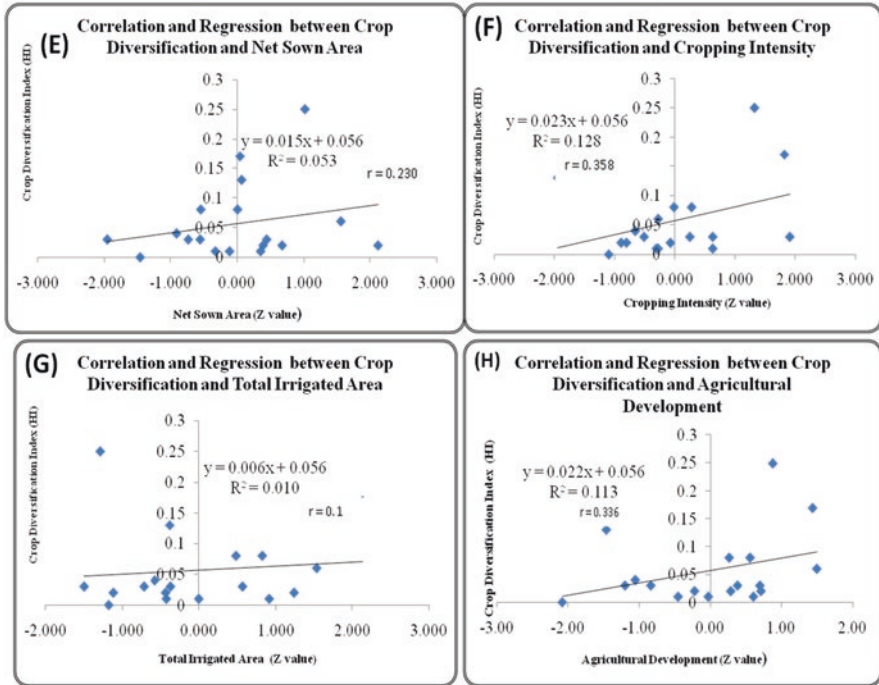
Fig. 3 Crop diversification region

Population density is the most important indicator for measuring crop diversity. The rural population, both skilled and unskilled, is pushed into agricultural land to pay for highland crop production. Population density, therefore, increases with continuous natural development in villages as the demand for food crops also increases. A high inverse relationship has been found between the two said variables. Figure 4a shows that negative correlation (r = −0.158) is indicated between population density and crop diversification. It also sheds light on the fact that as the population density increases as a result of crop diversification, it continuously decreases. It is clearly seen that there is a high positive correlation (r = 0.515) between crop diversification and work force participation (Fig. 4b). Crop diversification has increased almost equally with the increase in work force participation (Rukhsana & Alam, 2021). It is also further mentioned that with the increase of population the demand for human beings also increases and the demand for food crops for this situation also increases, as workforce participation increases for maximum production from a single filed.
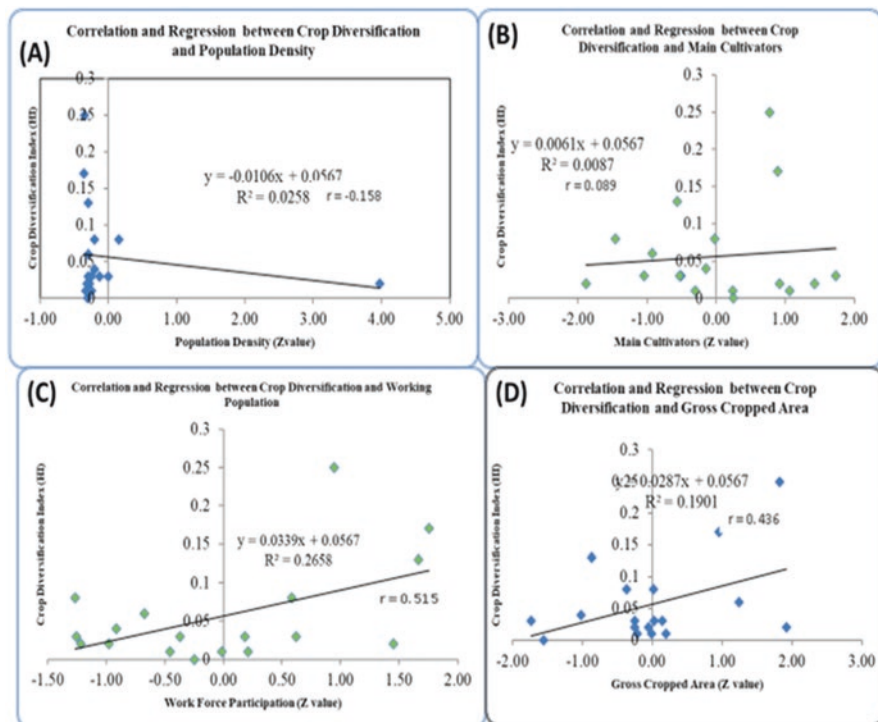
Fig. 4 Correction between crop diversification and agriculture selected determinants

Figure 4c expresses that a positive correlation (r = 0.089) has been found between crop diversification and main cultivators. It also shows that with an increasing number of main cultivators, crop diversification also increases day by day. As we know that farmers are one of the important elements for the development of the production of crops, no agricultural activities are possible without farmers. However, the growth rate of crop diversification is better than for the main farmers. In Fig. 4d, a positive correlation (r = 0.436) has been reported between 'crop diversification and gross cropped area,' indicating that crop diversification increases as well as gross crop area growth. The gross cropped area increases day by day because of the demand of the population for their daily lives. The maximum crop area results in an increase in maximum production as the result of crop diversification also increases. Most districts of West Bengal have a high density of population like Malda, Nadia and Burdwan.

Figure 5e shows the positive relationship between the variables plotted by simple linear regression (r = 0.230), which shows the corresponding increase of crop diversification with increasing net sown area. This can be attributed to the fact that land conversion in villages is a faster rate of occupational transfer as a result of the use of large-scale agricultural land for crop production in villages. The work force was previously engaged in agriculture and other forms of primary activities, but now the

Fig. 5 Correction between crop diversification and agriculture selected determinants

farmer is focusing on single crop production like jute and paddy. Some districts, including Burdwan, Medinipur, Bankura, Purulia and Birbhum, are heavily cropped. Figure 5f displays strong positive correlation (r = 0.358) between 'crop diversification and crop intensity,' indicating that crop intensity increased with an increase in crop diversity in the districts of Nadia, Hooghly, Murshidabad, and so on, because gross and net sown areas also increase. Figure 5g exhibits strong positive correlation (r = 0.1) between 'crop diversification and total irrigated area,' which showed that crop diversification increased with the increase of total irrigated area. This indicates that there is a strong correlation between similar variables, with an 85.5% confidence level with 0.25% significance. Figure 5h shows strong positive correlation (r = 0.336) between crop diversification and agricultural development, which shows an increase in crop diversification with the development of agricultural development. The relationship between crop diversification and agricultural development indicates that there is a strong correlation between the same variables, with a 90% confidence level with 0.25% significance.

Conclusion Crop diversification is an important tool for increasing income and employment generation for small and marginal farmers, especially in an agrarian state like West Bengal. This study analyzed the nature, extent and association between levels of agricultural development and crop diversification in West Bengal district-wise. The result shows that crops are diversifying at a faster rate than the

all-India level. However, this has happened only in a few selected areas and not in the entire state. The level of crop diversification and agricultural development found varies among districts of West Bengal.

The strong progress of diversity of crops has been reported for the northern portion of West Bengal including districts of Darjeeling, Cooch Behar, Jalpaiguri, Uttar Dinajpur, Dakhin Dinajpur, Burdwan and Malda. Crop diversification has been rated highest in Cooch Behar district because 80–90% of the population is engaged in the agricultural sector and dominated only by agribusiness. Major constraints on low crop diversification in some districts of West Bengal are lack of irrigation facilities, frequent droughts, erratic rainfall, poor asset base, lack of awareness and training, lack of credit facilities, traditional farming practices, average land holding size and per capita income. It has been found that crop diversification has a positive correlation with all selected indicators of agriculture such as irrigation, cultivators, gross sown area and levels of agricultural development as a whole, showing a strongly positive correlation with crop diversification, indicating that crop diversification grew with an increase in the level of agricultural development. This means using all agricultural facilities for the development of diversification in a proper way, and planning of crop diversification can be augmented and income level may be increased for small farmers.

References

Ali, M., & Abedullah, A. (2002). Economic and nutritional benefits from enhanced vegetable production and consumption in developing countries. *Journal of Crop Protection, 6*(1), 2002.

Benin, S., Smale, M., Pender, J., Gebremedhin, B., & Ehui, S. (2004). The economic determinants of cereal crop diversity on farm in Ethiopian highlands. *Agricultural Economics, III*, 197–208.

Chand, R. (1996). Diversification through high value crops in Western Himalayan Region: Evidence from Himachal Pradesh. *Indian Journal of Agricultural Economics, XXXXI*(4), 652–663.

Desai, B. M., D'souza, M., & Sharma, T. (2011). Agricultural policy strategy instruments and implementations: A review and road ahead. *Economic and Political Weekly, 56*(53), 42–50.

Dutta, S. (2012). *A Spatio temporal analysis of crop diversification in Hugli District*. Geo-Analyst.

Edreira, J. I. R., Mourtzinis, S., Conley, S. P., et al. (2017). Assessing causes of yield gaps in agricultural areas with diversity in climate and soils. *Agricultural and Forest Meteorology, 247*, 170–180.

FAO, IFAD, & WFP. (2015). *The state of food insecurity in the world*. In Meeting the 2015 International hunger targets: Taking stock of uneven progress. ROME. http://www.fao.org/3/a-i4646e.pdf. Accessed 4 Jan 2017.

Foley, J. A., Raman Kutty, N., Brauman, K. A., et al. (2011). Solutions for a cultivated planet. *Nature, 478*, 337–342.

Joshi, P. K., Gulati, A., Birthal, S. P., & Tewari, L. (2004). Agricultural diversification in South Asia: Patterns, determinants and policy implications. *Economic and Political Weekly, 39*(24), 52–53.

Kumar, A., Pramod, K., & Alakh, N. S. (2012). Crop diversification in eastern India: Status and determinants. *Indian Journal of Agricultural Economics, LXVII*(4), 600–616.

Lin, B. B. (2011). Resilience in agriculture through crop diversification: Adaptive management for environmental change. *Bioscience, 61*, 183–193.

Mandal, R., & Bezbaruah, M. P. (2013). Diversification of cropping pattern: Its determinants and role in food affected agriculture of Assam plains. *Indian Journal of Agricultural Economics, 68*(2), 169–181.

Meng, Q., Hou, P., Wu, L., et al. (2013). Understanding production potentials and yield gaps in intensive maize production in China. *Field Crops Research, 143*, 91–97.

Pandey, V. K., & Sharma, K. C. (1996). Crop diversification and self-sufficiency in food grains. *Indian Journal of Agricultural Economics, LI*(4), 644–651.

Raju, A. (2012). Patterns of crop concentration and diversification in Vizianagaram District of Andhra Pradesh. *Transactions, II*, 34.

Rukhsana. (2020, December). Micro and macro level analysis of crop diversification: Evidence from agrarian state. *Indian Journal of Economics and Development, 16*(4), 489–499.

Rukhsana, & Alam, A. (2021). Household analysis of crop diversification and socioeconomic classifications of agriculture practitioner. In Rukhsana & A. Alam (Eds.), *Agriculture, food and nutrition security*. Springer.

Saleth, & Maria, R. (1995). *Prospects, agricultural diversification in Tamil Nadu*. Institute of Economic Growth.

Sinha, D. K., & Ahmad Nasim, S. K. (2016). Shrinking net sown area: An analysis of changing land use pattern in Bihar. *Journal of Agrisearch, III*(4), 238–243.

Von Braun, J. (1995). Agricultural commercialization: Impacts on income and nutrition and implications for policy. *Food Policy, 20*(3), 1995.