I.A.S.R.I./P.R. – 07/2021
आई .ए .एस .आर .आई / .पी .आर .– 07/2021
Institute Project Code: AGEDIASRISIL201802800137
संस्थान परियोजना कोड : AGEDIASRISIL201802800137

Project report

Crop Diversification: Pattern, Determinants and its Impact on Nutritional Security in India

Rajesh T	PI: 24.01.2021 to 01.10.2021 & Co-PI: 05.09.2018 to 23.01.2021
Anuja A.R.	PI: 05.09.2018 to 23.01.2021
Harish Kumar H.V.	(Co-PI)
Mrinmoy Ray	(Co-PI)

पूर्वानुमान एवं कृषि प्रणाली प्रतिकथन प्रभाग
Division of Forecasting and Agricultural Systems Modelling

ICAR-Indian Agricultural Statistics Research Institute
Library Avenue, PUSA, New Delhi – 110 012
https://iasri.icar.gov.in/

(2021)

Contents

List of Tables

List of Figures

Preface

Crop diversification is important in the nutritional point of view. Better income prospects and higher marketable surplus can supplement the consumption of nutritious food in terms of variety as well as quantity. Earlier literature suggests the direct effect of crop diversification on food availability and nutrition. In India, diversifying towards coarse cereals improves nutritional supply, climate resilience and resource use efficiency and reduce greenhouse gas emissions without compromising calorie production. Diverse production systems focusing on horticultural crops add to food security and reduce anemia. Consumption of a well-balanced and diversified diet is a sustainable strategy to check problems associated with malnutrition. With this background, this study examined the status of crop diversification in India and its determinants, and impact of crop diversification on the district wise nutritional status in India.

We used the Simpson Index of diversification (Sd) as an indicator of crop diversification. We found that the area share of food crops is declining in the central, western, and southern regions while the area share is increasing in the northern and eastern regions. The area share of cereals and millets is declining in all regions except northern region and eastern region for the past decade and a half. The area share of pulse crops is increasing in the western and southern regions. The share of high-value crops such as fruits and vegetables has also increased in all the regions during the study period. We estimated the extent of crop diversification at the regional/state level for food crops, non-food crops and the whole crop sector. Also, we analyzed the relationship between crop diversification and nutritional status at the district level using simulation study employing bivariate copula function. We used indicators of child and adult nutrition status and compared the relative performance of districts in their nutritional outcomes using the undernutrition index as a proxy. Using hierarchical clustering, we grouped states and districts based on the index values. Results of the simulation study using bivariate copula function indicated a dominant influence of crop diversification on reducing undernutrition in India. Overall, the varying extent of crop diversification across regions implies that region-specific interventions are necessary to promote the crop diversification.

Project Team

प्रस्तावना

पोषण की दृष्टि से फसल विविधीकरण महत्वपूर्ण है। बेहतर आय की संभावनाएं और उच्च विपणन योग्य अधिशेष विविधता के साथ-साथ मात्रा के मामले में पौष्टिक भोजन की खपत को पूरक कर सकते हैं। उप-सहारा अफ्रीका में, विविध कृषि फार्म घरों में विविध आहार लेते हैं। पहले के साहित्य खाद्य उपलब्धता और पोषण पर फसल विविधीकरण के प्रत्यक्ष प्रभाव का सुझाव देते हैं। भारत में, मोटे अनाज की ओर विविधता लाने से पोषण आपूर्ति, जलवायु लचीलापन और संसाधन उपयोग दक्षता में सुधार होता है और कैलोरी उत्पादन से समझौता किए बिना ग्रीनहाउस गैस उत्सर्जन में कमी आती है। बागवानी फसलों पर केंद्रित विविध उत्पादन प्रणालियां खाद्य सुरक्षा को बढ़ाती हैं और एनीमिया को कम करती हैं। कुपोषण से जुड़ी समस्याओं की जांच के लिए एक अच्छी तरह से संतुलित और विविध आहार का सेवन एक स्थायी रणनीति है। इस पृष्ठभूमि के साथ, इस अध्ययन ने भारत में फसल विविधीकरण की स्थिति और इसके निर्धारकों, और भारत में जिलेवार पोषण स्थिति पर फसल विविधीकरण के हमने फसल विविधीकरण के संकेतक के रूप में विविधीकरण के सिम्पसन इंडेक्स (एसडी) का इस्तेमाल किया। प्रभाव की जांच की।

हमने पाया कि मध्य, पश्चिमी और दक्षिणी क्षेत्रों में खाद्य फसलों का क्षेत्रफल घट रहा है जबकि उत्तरी और पूर्वी क्षेत्रों में क्षेत्रफल का हिस्सा बढ़ रहा है। पिछले डेढ़ दशक से उत्तरी क्षेत्र और पूर्वी क्षेत्र को छोड़कर सभी क्षेत्रों में अनाज और बाजरा का क्षेत्रफल घट रहा है। दलहनी फसलों का क्षेत्रफल पश्चिमी और दक्षिणी क्षेत्रों में बढ़ रहा है। अध्ययन अवधि के दौरान सभी क्षेत्रों में फलों और सब्जियों जैसी उच्च मूल्य वाली फसलों की हिस्सेदारी में भी वृद्धि हुई है। हमने खाद्य फसलों, गैर-खाद्य फसलों और पूरे फसल क्षेत्र के लिए क्षेत्रीय/राज्य स्तर पर फसल विविधीकरण की सीमा का अनुमान लगाया। इसके अलावा, हमने द्विचर कोप्युला फ़ंक्शन को नियोजित करते हुए सिमुलेशन अध्ययन का उपयोग करके जिला स्तर पर फसल विविधीकरण और पोषण स्थिति के बीच संबंधों का विश्लेषण किया। हमने बच्चे और वयस्क पोषण की स्थिति के संकेतकों का उपयोग किया और अल्पपोषण सूचकांक का प्रॉक्सी के रूप में उपयोग करते हुए उनके पोषण परिणामों में जिलों के सापेक्ष प्रदर्शन की तुलना की। पदानुक्रमित क्लस्टरिंग का उपयोग करते हुए, हमने सूचकांक मूल्यों के आधार पर राज्यों और जिलों को समूहीकृत किया। द्विचर कोप्युला फंक्शन का उपयोग करते हुए सिमुलेशन अध्ययन के परिणामों ने भारत में अल्पपोषण को कम करने पर फसल विविधीकरण के एक प्रमुख प्रभाव का संकेत दिया। कुल मिलाकर, विभिन्न क्षेत्रों में फसल विविधीकरण की अलग-अलग सीमा का तात्पर्य है कि फसल विविधीकरण को बढ़ावा देने के लिए क्षेत्र-विशिष्ट हस्तक्षेप आवश्यक हैं।

Chapter 1: Introduction

1.1 Introduction

The employment in agriculture as a percentage of total employment in India is about 42 percent in 2019 (World Bank, 2020). The sector mainly accommodates small and marginal farmers undertaking subsistence farming. At the policy level, there is a substantial shift in focus from enhancing food production to promoting farmers' welfare and nutritional security (MoA & FW, 2016). Diversion, degradation and continuous fragmentation of agricultural landholdings along with climatic variability and associated risks highlight the need to device alternate strategies for increasing the prospects of farming as an occupation, especially for small and marginal farmers. Doubling farmers' income by 2022 is the major goal and crop diversification towards high-value crops is one of the important strategies suggested by NITI Aayog.

The Sustainable Development Goals (SDGs) have set specific targets aimed at ending poverty, protecting the planet and ensuring prosperity for all by 2030. SDG 2 stands for a global commitment to tackle undernutrition and hunger. It also recognises the need to promote sustainable agriculture for achieving food security and improved nutrition. Crop diversification can have important implications for farmers' welfare, nutritional security and sustainability in agriculture. India has tremendous potential for crop diversification and to make farming a sustainable and profitable economic activity (GoI, 2018).

Crop diversification refers to a shift from the regional dominance of one crop to the regional production of several crops. Diversification in cropping choice decreases the overall production risk by selecting a mix of crops that have a low or negative correlation in their productivity. The direction of crop diversification is also a matter of research interest. Diversification of crops enhances cropping intensity and productivity growth (Bobojonov et al., 2012). Diversification towards high-value crops such as fruits and vegetables enhance the income prospects of farmers (Joshi et al., 2006). But, at the same time, these crops are prone to higher risks (Kumar et al., 2012). Diversification towards more remunerative crops such as fruits, vegetables, plantation crops, etc. can enhance farmers' income security and risk-bearing ability (Pingali and Rosegrant, 1995; Guvele, 2001; Ryan and Spencer, 2001; Van den Berg et al., 2007; Kahan, 2008; Sharma, 2011; Chand, 2017; Anuja et al., 2020). An inverse relationship between the degree of diversification and the likelihood of being poor has been empirically established, and this is specifically true for smallholders (Barghouti et al., 2004; Birthal et al., 2015; Thapa et al., 2017; Anuja et al, 2020). Besides, crop diversification brings about sustainability and resilience in agriculture. Diversification is one of the rational ways of managing price and production risks (Pandey et al., 2007; Lin, 2011). Crop diversification also helps to reduce the vulnerability of small farmers towards climate change (McCord, 2015).

In India, the degree of diversification exhibits huge variations among different regions (Radhakrishna and Panda, 2006). Identifying pattern and degree of crop diversification are imperative in formulating region-specific agriculture development strategies. Crop diversification is also important in the nutritional point of view. Better income prospects and higher marketable surplus can supplement the consumption of nutritious food in terms of variety as well as quantity. In sub-Saharan Africa, diverse agricultural farms lead to diverse diets in households (Mugendi Njeru, 2013). Earlier literature suggests the direct effect of crop diversification on food availability and nutrition (Lin, 2011; Jones et al., 2014).

In India, diversifying towards coarse cereals improves nutritional supply, climate resilience and resource use efficiency and reduce greenhouse gas emissions without compromising calorie production (Davis et al., 2019). Diverse production systems focusing on horticultural crops add to food security and reduce anaemia (Makate et al., 2016). Consumption of a well-balanced and diversified diet is a sustainable strategy to check problems associated with malnutrition (Ecker et al., 2011).

With this background, this study examines the status of crop diversification in India and its determinants, and impact of crop diversification on the district wise nutritional status in India. This report is organised as follows. Chapter 2 describes the status and pattern of crop diversification in India, Chapter 3 covers the determinants of crop diversification in India and Chapter 4 provides the status of undernutrition in the country and analysis of the association of crop diversification with the nutritional indicators.

1.2 Motivation:

Not many studies have analyzed the recent pattern and determinants of crop diversification across different regions in India. The project is expected to generate knowledge on the trend and pattern of crop diversification and its major determinants, both sector wise and region wise. The outcomes of the project would provide feedback for framing appropriate policies interventions in the respective areas across the regions in future plans. There are not many studies assessing the impact of crop diversification on nutritional status.

This project made an attempt to address these issues. In light of the above, this study was conducted with the following objectives

OBJECTIVES

1. To examine the trend and pattern of crop diversification in India
2. To identify the determinants of crop diversification in India
3. To assess the impact of crop diversification on dietary diversity and nutritional status in India

Review of Literature

Pattern and determinants of crop diversification

The performance of Indian agricultural sector in terms of income generation and diversification has followed an unsteady path and showed huge variations between different geographical locations across the country at the disaggregated level (Radhakrishna and Panda, 2006).

The process of crop diversification in the state of Himachal Pradesh becomes evident from rising proportion of gross cropped area under fruit and vegetable crops. The cultivation of high value crops yields very high net returns and has made a significant impact on the income and employment levels of all the categories of cultivating households (Sharma, 2011).

Kumar and Gupta (2015) examined state-level trends and patterns in crop diversification towards high value crops in India for the period 1990-91 to 2011-12. The study has revealed that cropping pattern at state level is transforming from food grains to high-value crops but the transformation is not uniform across the states/regions. Cropping intensity, average annual rainfall and gross irrigated area are the major determinants of crop diversification.

A district–wise panel data analysis of pattern and determinants of crop diversification done among small holders in West Bengal show that all the districts of West Bengal and the state as a whole have exhibited a higher crop diversification over the period of time. Both the supply side and demand side variables like rural literacy rate, the percentage of urban population to total population of the district, relative earning from high-value crops (HVC) than cereals, the market density of a particular region, the percentage of small landholders and area under high yielding varieties (HYV) of food grains, magnitude of rainfall and extension of crop insurance facility found to have impact on crop diversification (Mithiya *et al.,* 2018).

Impact of crop diversification on dietary diversity and nutritional status

Immink and Alarcon (1991) have reported that crop diversification is associated with higher household income but no significant nutritional change to individual or household level. In Mali, Torheim *et al.* (2004) have found that the number of crops cultivated by a household was positively associated with adult nutrient adequacy. According to Joshi *et al.,* (2004) South Asian countries are gradually diversifying with some inter-country variation in favor of high value commodities, namely, fruits, vegetables, livestock and fisheries. Agricultural diversification is strongly influenced by price policy, infrastructure development (especially markets and roads), urbanization and technological improvements. Rain-fed areas has benefited more as a result of agricultural diversification in favor of high value crops by substituting inferior coarse cereals.

Rais, Pazderka and Vanloon (2009) established that in India, most of the subsistence farms cannot provide for the entire household's food needs from production alone, often due to small landholdings and low productivity. Therefore, they have to generate income to purchase additional food. Intrinsically, agricultural diversification and commercialization provide alternative strategies for the rural households to improve diets (Hendrick and Msaki 2009; Khandker and Mahmud 2012), the former by yielding diverse food items for own consumption and the latter by increasing income and the household's ability to purchase a diverse range of food items. The growing of different groups of food crops contribute directly to a more diversified nutritional intake.

A study by Remans *et al.* (2011) has revealed that the diversity of crops on farms to be positively associated with the diversity of nutrients in rural areas of Malawi, Mali, and Uganda. Improvement of agricultural productivity is a powerful tool to reduce under nutrition across the vast majority of the population (Gulati *et al*., 2012).In the rural highlands of Ecuador, on-farm species diversity and family-level dietary diversity were also found positively correlated (Oyarzun *et al.,* 2013).

According to Jones *et al.*, (2014) farm production diversity has the potential to influence the diversity of household diets. In Malawi, empirical analysis indicated that more diverse production systems contributed to more diverse household diets.

Pellegrini and Tasciotti (2014) in their study from RIGA database on 8 developing and transition economies found positive correlation between the number of crops cultivated, household income from crops and dietary diversity. The crop diversification enhanced crop productivity and resilience (household income, food security and nutrition) in rural smallholder farming systems of Zimbabwe (Makate *et al*. 2016).

Empirical research in Zambia revealed that the effect of protein and calorie diversification reduced wasting and underweight significantly. The effect of agricultural diversification was non-linear. Low levels of diversification (i.e., specialization) had marginal positive effects on stunting, while excessive levels of crop diversification had a negative effect on stunting (Mukuka and Kuhlgatz, 2015).

Rajendran *et al.,* (2017) established that in Maize based production systems of sub-Saharan Africa; mere increase in crop diversification does not influence dietary diversity of farm households due to the presence of interaction effect between Simpson's Index and crop income.

Chapter 2: Status of crop diversification in India

This chapter examines the spatio-temporal pattern of crop diversification in major states of India.

Data source

The study is based on the secondary data on land area statistics published by Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, Government of India. The food crops group include cereals and millets, pulses, fruits and vegetables, sugar, and condiments and spices; while non-food crops are comprised of oilseeds, fibres, drugs and narcotics, and plantation crops. The Simpson Index of Diversification (Sd) is estimated for the entire crop sector and crop sub-sectors (food crops/non-food crops) for the period 2001-02 to 2016-17. For the calculation of the index, we use the triennium average of area share of crops in five-year intervals.

Methodology

Crop diversification index

Simpson Index of crop diversification (Sd) is used to assess the degree of crop diversification. The index is estimated using the following formula,

$$sd = 1 - \sum_{i=1}^{n} p_i^2$$

where, P_i is the proportion of i^{th} crop/crop sector in the gross cropped area. The diversification index ranges between 0 and 1. Higher values indicate high degree of crop diversification.

Box 1. Categorisation of states into different regions

Northern	Eastern	Central	Western	Southern
Uttar Pradesh	Odisha	Madhya Pradesh	Rajasthan	Andhra Pradesh
Punjab	Bihar	Chhattisgarh	Maharashtra	Telangana
Haryana	West Bengal		Gujarat	Karnataka
	Assam			Tamil Nadu
				Kerala

Results and Discussion

Pattern of crop diversification

Area share of crops

The region-wise share of food crops and non-food crops in the gross cropped area (GCA) for the period TE 2001-02 and TE 2016-17 is presented in Table 1. The share of food crops was highest in the eastern region (89.31%) followed by northern region (83.34%) in TE 2016-17. On the contrary, the share of non-food crops was highest in the western region (46.80%). The share of food crops in the total cultivated area has been decreasing in general except for Punjab, Odisha, Bihar, Karnataka and Tamil Nadu.

Table 2 indicates the relative area share of crop sectors in gross cultivated area. The area share of cereals and millets has been declining in all regions except northern and eastern regions for the past 15 years. The area share of pulse crops has been increasing in the western and southern regions. The share of fruits and vegetables in the area under food crops has also increased in all the regions except northern region for the study period. Under non-food crops, area share of oilseeds in the GCA has been declining in the eastern region and southern region.

Extent of crop diversification

Figure 1, 2 and 3 depict the extent of diversification within food crops, non-food crops and total crop sector during 2001-02 to 2016-17, respectively. The extent of diversification within food crops has been low in the northern region, especially in Punjab and Haryana as more than 90 percent of the area of food crop cultivation in these states is under wheat and rice. The results also indicate a declining trend in extent of diversification during TE 2001-02 to 2016-17. Wheat, rice, sugarcane, cotton, oilseeds and pulses are the major crops cultivated in the northern region. About 74 percent of the gross cultivated area of the region is under cereals and millets cultivation in TE 2016-17. Specialisation towards paddy and wheat cultivation adversely affected the agricultural sustainability of the region by degradation of natural resources (Gill, 2016; Ghuman and Sharma, 2016). In order to ensure sustainability in agricultural production systems along with productivity and profitability, the Government of India introduced crop diversification program for Haryana, Punjab and Western Uttar Pradesh in 2013-14. The efforts of the central and state governments to promote sustainable and viable crop diversification in the region have yielded limited outcomes so far. The gradual replacement of traditionally grown nutri-cereals such as jowar and bajra has limited affordable and diversified nutrition source from the rural diet of the region (Kumar, 2017).

Table 1: Region/State-wise area share of food crops and non-food crops in respective gross cultivated area

(percent)

States/ Regions	Food crops		Non-food crops	
	TE 2001	TE 2016	TE 2001	TE 2016
Uttar Pradesh	92.12	91.20	7.88	8.80
Punjab	82.41	88.04	17.59	11.96
Haryana	73.30	70.79	26.70	29.21
Northern	82.61	83.34	17.39	16.66
Odisha	88.77	97.98	11.23	3.17
Bihar	95.53	96.36	4.47	3.64
West Bengal	84.42	83.18	15.58	16.82
Assam	81.31	79.72	18.69	20.28
Eastern	87.51	89.31	12.49	10.98
Madhya Pradesh	66.19	64.79	33.81	35.21
Chhattisgarh	94.81	94.84	5.19	5.16
Central	80.50	79.82	19.50	20.18
Rajasthan	62.31	59.28	37.69	40.72
Maharashtra	69.21	57.53	30.79	42.47
Gujarat	43.14	42.80	56.86	57.20
Western	58.22	53.20	41.78	46.80
Andhra Pradesh*	67.87	65.39	32.13	34.61
Karnataka	72.63	75.39	27.37	24.61
TN	71.72	76.46	28.28	23.54
Kerala	44.59	37.85	55.41	62.15
Southern	64.20	63.70	35.80	36.30

Note: Calculated using data from Directorate of Economics and Statistics, Ministry of Agriculture, Government of India; TE: Triennium Ending Averages; TE 2001 = 1999-2001, TE 2016 = 2014-2016; *includes Telangana

Table 2: Region/State-wise area share of crop sectors (Percent)

	Food crops										Non-food crops							
	Cereals and Millets		Pulses		Fruits and Vegetables		Sugar		Condiments and Spices		Oilseeds		Fibres		Drugs, Narcotics and Plantation Crops		Other Non-Food Crops	
States/ regions	TE 2001	TE 2016	TE 2001	TE 2016	TE 2001	TE 2016	TE 2001	TE 2016	TE 2001	TE 2016	TE 2001	TE 2016	TE 2001	TE 2016	TE 2001	TE 2016	TE 2001	TE 2016
Uttar Pradesh	69.65	70.39	10.57	8.76	3.76	3.08	7.88	8.78	0.26	0.19	3.49	4.56	0.05	0.03	0.66	1.00	3.69	3.21
Punjab	78.09	84.25	0.78	0.24	1.93	2.36	1.56	1.18	0.05	0.01	1.14	0.60	6.57	4.43	0.01	0.31	9.87	6.62
Haryana	67.24	67.18	2.61	1.12	0.99	1.07	2.39	1.45	0.08	0.07	7.69	7.84	9.42	9.64	0.05	0.03	9.54	11.59
Northern	71.66	73.94	4.65	3.37	2.22	2.17	3.94	3.80	0.13	0.09	4.10	4.34	5.35	4.70	0.24	0.45	7.70	7.14
Odisha	59.13	79.44	18.84	9.35	8.66	6.53	0.37	0.15	1.77	2.51	9.99	2.00	1.17	0.02	0.06	0.00	0.00	0.00
Bihar	80.25	80.42	8.82	6.54	5.12	6.06	1.19	3.22	0.16	0.12	1.98	1.58	1.99	1.47	0.19	0.13	0.30	0.46
West Bengal	67.02	61.57	2.60	3.09	13.46	16.99	0.25	0.19	1.09	1.33	6.27	8.28	6.75	5.73	2.21	2.51	0.35	0.30
Assam	67.31	62.70	2.86	3.59	7.17	9.02	0.71	0.78	3.25	3.62	8.46	8.29	2.30	2.09	6.72	8.99	1.22	0.92
Eastern	68.43	71.03	8.28	5.64	8.60	9.65	0.63	1.09	1.57	1.90	6.68	5.04	3.05	2.33	2.30	2.91	0.47	0.42
Madhya Pradesh	43.22	41.61	20.47	19.10	1.08	1.79	0.36	0.52	1.05	1.78	27.86	31.30	2.51	2.23	0.09	0.20	3.36	1.48
Chhattisgarh	78.43	76.93	14.07	14.56	1.92	2.55	0.13	0.53	0.26	0.27	5.06	5.05	0.09	0.06	0.00	0.00	0.03	0.05
Central	60.83	59.27	17.27	16.83	1.50	2.17	0.25	0.52	0.66	1.02	16.46	18.18	1.30	1.15	0.04	0.10	1.69	0.76
Rajasthan	45.30	37.49	13.78	17.13	0.51	0.77	0.07	0.02	2.66	3.86	15.85	18.77	2.79	1.94	0.52	1.42	18.53	18.59
Maharashtra	44.99	33.42	16.70	15.73	3.71	6.22	3.14	2.29	0.67	0.32	11.93	18.86	14.77	18.58	0.04	0.12	4.04	4.46
Gujarat	28.96	23.53	7.23	5.10	2.76	7.28	2.43	1.37	1.76	1.34	26.84	18.93	15.76	19.99	1.65	14.91	12.61	7.56
Western	39.75	31.48	12.57	12.65	2.32	4.75	1.88	1.23	1.70	1.84	18.21	18.85	11.11	13.50	0.74	5.48	11.73	10.20
Andhra Pradesh*	41.70	38.13	13.92	14.12	6.38	8.16	2.97	2.14	2.90	2.84	20.54	13.27	8.73	17.75	1.28	1.03	1.57	2.55
Karnataka	46.15	37.99	16.06	22.55	3.94	5.98	3.33	4.94	3.15	3.93	18.36	14.59	4.73	5.62	2.35	2.94	1.93	1.46
Tamil Nadu	44.64	44.91	10.83	14.89	8.31	10.09	5.23	4.45	2.72	2.12	18.42	14.33	2.74	2.81	2.11	3.71	5.01	2.68
Kerala	11.50	7.53	0.29	0.14	20.03	19.38	0.34	0.15	12.43	10.19	30.85	30.22	0.14	0.01	20.17	25.89	4.26	6.50
Southern	36.00	32.14	10.28	12.93	9.67	10.90	2.97	2.92	5.30	4.77	22.04	18.10	4.09	6.55	6.48	8.39	3.19	3.30

Note: Calculated using data from Directorate of Economics and Statistics, Ministry of Agriculture, Government of India; TE: Triennium Ending Averages; TE 2001 = 1999-2001, TE 2016 = 2014-2016; *includes Telangana

On the other hand, the southern region had exhibited higher degree of diversification within the food crops. The Sds of Andhra Pradesh, Karnataka and Tamil Nadu have increased across the study period. Cereals such as rice, maize, pulses, oilseeds, fruits and vegetables are the major crops cultivated in this region except for Kerala. Earlier studies also report diversification towards minor crops such as maize, sugarcane, pulses and coconut in southern states (Velavan and Balaji, 2012). As the area under cultivation was distributed among food crops and non-food crops, the crop sector in this region has higher degree of diversification for the period under consideration. Kerala has highest level of diversification among food crops. Oilseeds (mainly coconut) and plantation crops (mainly rubber) together account for about 56 percent of the gross cultivated area of the state.

The central region of India (Chhattisgarh and Madhya Pradesh) had a low diversification index within the non-food crop sector and the index has been declining over the study period. Whereas, the food crop sector of the region has displayed medium levels of diversification.

The eastern region of India (Odisha, Bihar, West Bengal and Assam) had medium level of diversification within food crops. About 80 percent of the gross cultivated area in Odisha and Bihar is under cereal and millets. The trend in diversification index indicates that the crop sector in the eastern region has been slowly diversifying except for Odisha. Kumar et al (2012) reported that the crop sector in the eastern region had been gradually diversifying towards high value crops. In West Bengal, crop diversification towards high-value crops such as oilseeds, fruits and vegetables has been happening during the study period. Earlier literature indicates similar trend in the direction of crop diversification in the eastern region (Haque et al., 2010).

Overall, the extent of diversification in the crop sector was low in the northern region for the past one and a half-decade. On the contrary, the western and southern regions have displayed a higher degree of crop diversification and the Sds of these regions were rising across the study period. Altogether, the crop sector in the central region of India has registered a medium level of diversification and remained stagnant during the study period.

Box 2. Classification of states based on degree of crop diversification, TE 2016-17

Category	**Range of Sd**	**Food crops**	**Non-food crops**
Low	0.00 - 0.30	Punjab and Haryana	Odisha, Madhya Pradesh and Chhattisgarh
Medium	0.31 - 0.60	Uttar Pradesh, Odisha, Bihar, West Bengal, Assam, Madhya Pradesh, Rajasthan, Maharashtra, Gujarat, Andhra Pradesh, Tamil Nadu and Chhattisgarh	Punjab, Rajasthan, Gujarat, Andhra Pradesh, Telangana, Karnataka, Tamil Nadu and Kerala
High	0.61 - 1.00	Kerala and Karnataka	Uttar Pradesh, Haryana, Bihar, West Bengal, Assam and Maharashtra

Box 2 describes the classification of major states of the country under three categories based on the degree of crop diversification as low Sd (Range 0.00 – 0.30), medium Sd (0.31-0.60), and high Sd (Range 0.61-1.00 for TE 2016-17.

Under the food crops, Punjab and Haryana had lower diversification index (below 0.30) and hence grouped under the category of Lower Sd states. The states of Uttar Pradesh, Odisha, Bihar, West Bengal, Assam, Madhya Pradesh, Rajasthan, Maharashtra, Gujarat, Andhra Pradesh, Tamil Nadu and Chhattisgarh displayed a moderate scale of crop diversification within food crops. Kerala and Karnataka recorded higher diversification index within food crops.

Odisha, Madhya Pradesh and Chhattisgarh registered lower levels of Sd under the non-food crops category. Punjab, Rajasthan, Gujarat, Andhra Pradesh, Karnataka, Tamil Nadu and Kerala recorded moderate Sds while Uttar Pradesh, Haryana, Bihar, West Bengal, Assam and Maharashtra depicted higher Sds for non-food crops.

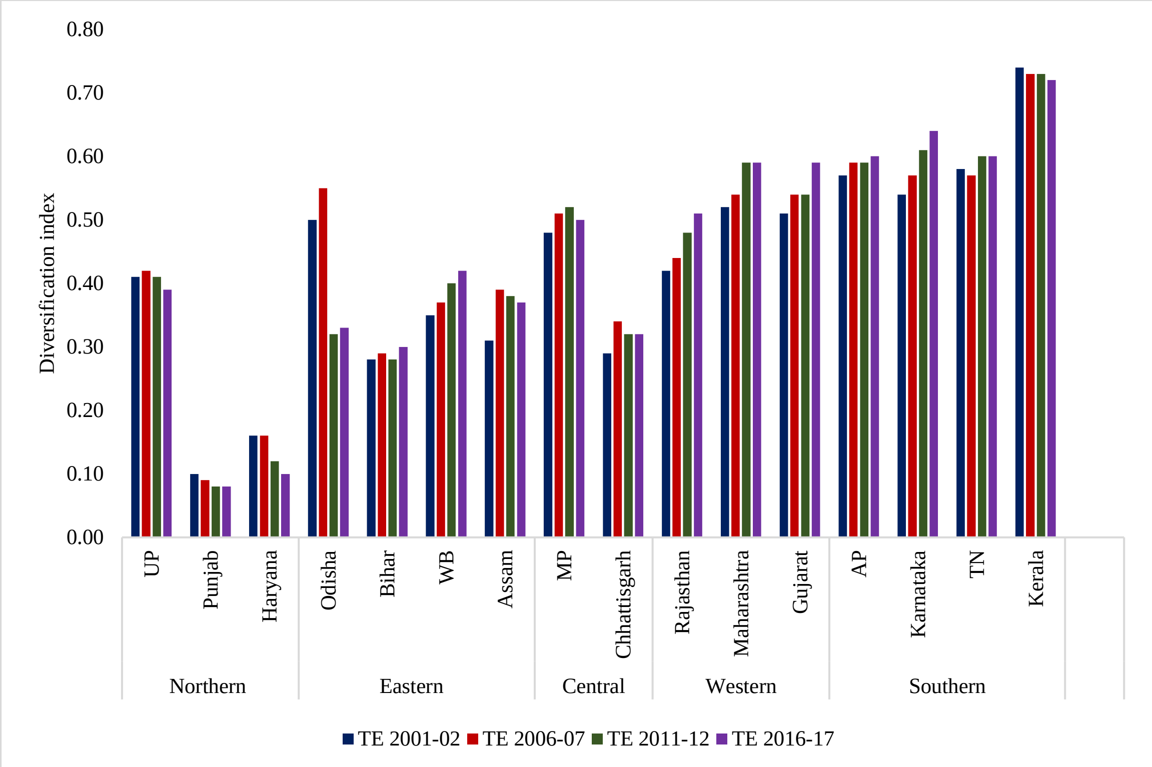


Figure 1: State-wise diversification index -Food crops

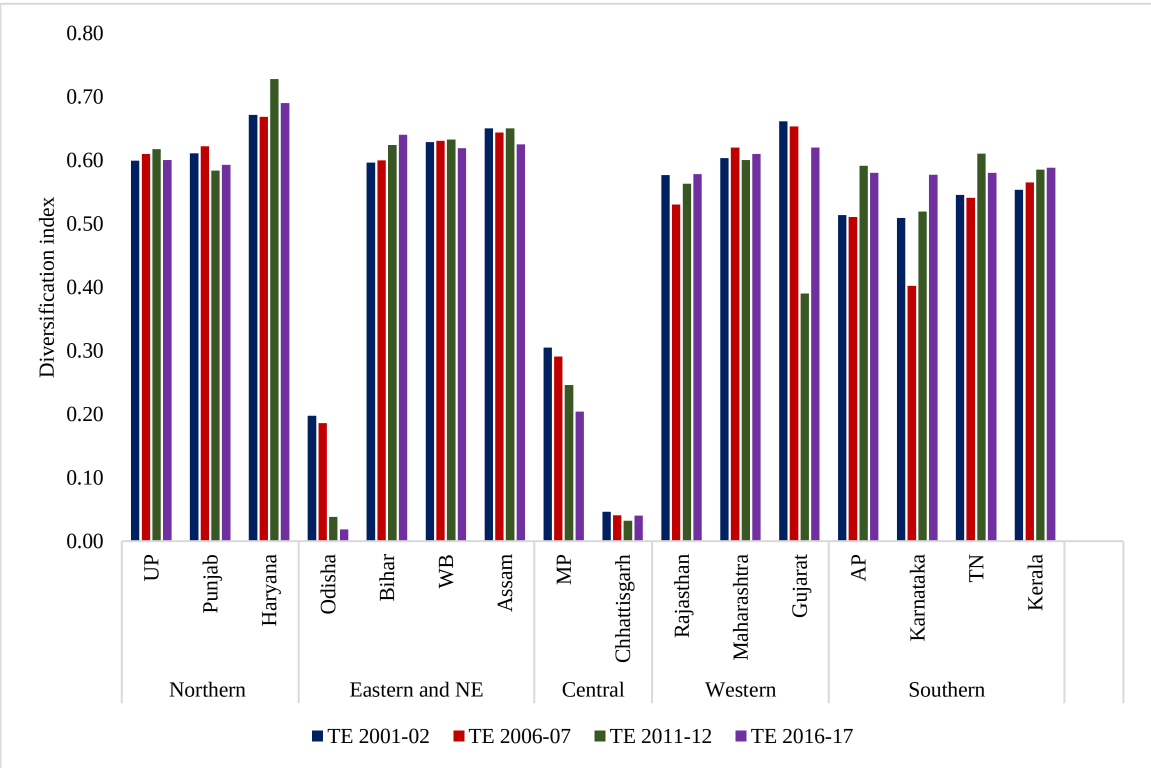


Figure 2: State-wise diversification index-Non-food crops

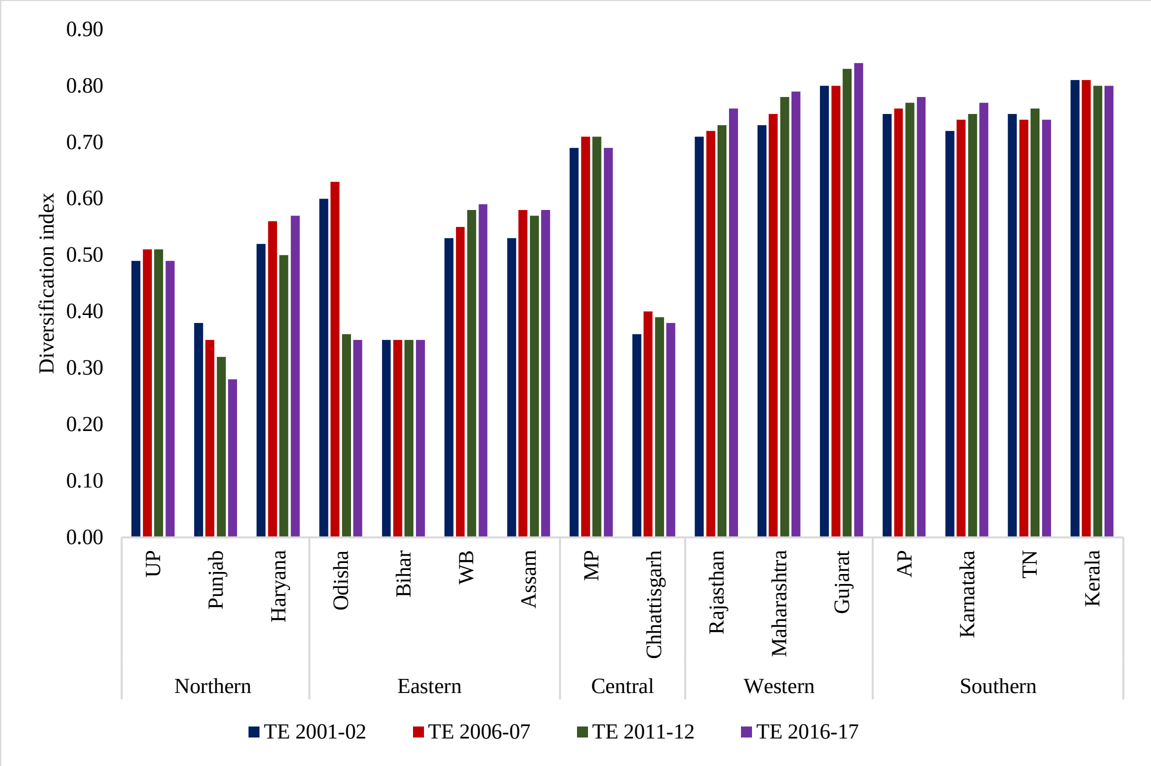


Figure 3: State-wise crop diversification index- Total crops

Conclusion

This study examined the present status and trend in crop diversification in India. We used the Simpson Index of diversification (Sd) as an indicator of crop diversification. The study relied on the crop area statistics released by the Directorate of Economics and Statistics, Government of India. We found that the area share of food crops is declining in the central, western, and southern regions while the area share is increasing in the northern and eastern regions. Between TE 2001-02 and TE 2016-17, the share of food crops was reduced by 5.02 percent, 0.68 percent and 0.50 percent in western, central and southern regions respectively. However, the share of food crops increased by 1.80 percent and 0.73 percent in eastern and northern regions. The area share of cereals and millets is declining in all regions except northern region and eastern region for the past decade and a half. The area share of pulse crops is increasing in the western and southern regions. The share of high-value crops such as fruits and vegetables has also increased in all the regions during the study period. Under non-food crops, the area share of oilseeds has been declining in the eastern and southern regions.

We estimated the extent of crop diversification at the regional/state level for food crops, non-food crops and the whole crop sector. Results indicated that the extent of diversification within food crops has been low in the northern region. In the states of Punjab and Haryana more than 90 percent of the area of food crops is under cereals, mainly rice and wheat. The diversification index has also shown a declining trend during 2001-02 to 2016-17. The extent of diversification in the overall crop sector was low in the northern regions for the past one and a half-decade. On the contrary, the western and southern regions have displayed a higher degree of crop diversification and the Sds of these regions were rising during the study period. We also categorized major agrarian states of the country based on the degree of crop diversification.

Chapter 2: Determinants of Crop diversification in India

An attempt has been made in this chapter to analyze the determinants of crop diversification at all India level using district-level data.

Data source

Data related to district wise irrigation share has been compiled from the land area statistics published by Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, Government of India. Date related to number share of marginal households, household share based on social group and house hold share based on gender has been compiled from Agricultural census (2015-16).

Methodology

Regression Model

To discern the determinants of crop diversification at all India level, regression model was used in the present study.

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon$$

for i = 1,2,3,…, *N* (Number of districts)

Where,

Y is the diversification index (dependent variable)

X_1 is the share of irrigation

X_2 is the share of marginal farm households

X_3 is the share of farmers belonging to social groups other than SC and ST

X_4 is the share of households having male as family head

$\beta_1, \beta_2, \beta_3, \beta_4$: Parameters

α is the constant

ε is the error term

Results and Discussion

Basic details of the variables considered for identifying the determinants influencing crop diversification in India is given in Table 3. From the table we can observe that on an average, around 46 percent the total cropped area is under irrigation in the sample districts.

Table 3: Details of the determinants influencing crop diversification in India

(Percentage)

Variables (n=549)		Minimum	Maximum	Average
Irrigation share		0.05	100.00	45.95
Land class: Share of number of house holdings	Marginal	2.90	99.13	63.25
	Small	0.69	51.63	18.74
	Semi-medium	0.14	48.31	11.41
	Medium	0.00	55.27	5.72
	Large	0.00	24.73	0.88
Social group (Number share)	SC	0.00	60.18	11.16
	ST	0.00	100.00	12.66
	Others	0.00	100.00	76.18
Gender	Share of male HH	55.48	99.91	88.04

Note: Calculated using data from Directorate of Economics and Statistics, Ministry of Agriculture, Government of India

Similarly, on an average, 63.25 percent of the farmers belongs to marginal category, 18.74 and 11.41 percent of the farmers belongs to small and semi-medium farmers category, respectively. It was found that 88.04 percent of the households have males as head of the family.

The determinants of crop diversification in India are given Table 4. Regression model was used in the study to assess the factors influencing crop diversification in India. The

Table 4: Determinants of crop diversification in India n=549

Dependent Variable (Diversification index)	Coefficients	Std. Err.
Irrigation share (%)	-0.17***	0.03
Share of marginal farm households (Number share)	-0.09***	0.03
Share of farmers belonging to social groups other than SC and ST	0.08**	0.04
Share of male households (number)	-0.85***	0.10
Constant	125.83	10.35

Note: Calculated using data from Directorate of Economics and Statistics, Ministry of Agriculture, Government of India

*** and ** indicates level of significance at one percent and five percent, respectively.

results revealed that variables like irrigation share, share of marginal farm households and share of households having males as heads are negatively influencing crop diversification, whereas share of farmers belonging to social groups other than SC and ST are positively influencing crop diversification in India. This implies that those districts having higher area under irrigation are less likely to move towards crop diversification. Similarly, those districts having higher share of marginal farm households and districts having higher share of households with males as family heads are less likely to move towards crop diversification. On the other hand, it was found that those districts having higher share of farmers belonging to social groups other than SC and ST are more likely to move towards crop diversification.

Conclusion

The present study examined the determinants of crop diversification in India by using regression analysis model. It was observed that irrigation share, share of marginal farm households and share of households having males as heads are negatively influencing crop diversification, whereas share of farmers belonging to social groups other than SC and ST are positively influencing crop diversification in India.

Chapter 3: Crop diversification and nutritional status

This chapter examines the relationship between the degree of crop diversification and the extent of child and adult undernutrition status in India using district-level data.

Data source

Crop diversification index

The data we use for estimation of district wise crop food crop diversification index come from the Land Use Statistics, Directorate of Economics & Statistics, Ministry of Agriculture and Farmers Welfare, Government of India. District wise diversification indices are estimated for major 21 states considering the area under food crops based on the assumption of its major impact on the nutritional status. We estimated the crop diversification index using the triennium average of food crops area ending the year 2015-16 as the recent National Family Health Survey IV (NFHS IV) data is available for the year 2015-16. District level indices are estimated due to limitations in the availability of production and consumption database at the household level. The software used for the preparation of maps was STATA 15 MP.

Normalised undernutrition index

We use data from the district fact sheets of the NFHS IV, 2015-16 for estimation of the Normalised undernutrition index. We estimated normalised indices for 558 districts across 21 states of the country.

Methodology

In this study, we explore the relationship between the extent of crop diversification and undernutrition. We used normalised undernutrition index following Gulati et al. (2012). The index gives a broad perspective on the relative status of the major Indian states in terms of undernutrition.

We used indicators of nutrition status among children (under 5 years of age) and adults (15 to 49 years) for the construction of the undernutrition index. Indicators of child undernutrition includes the percentages of underweight, wasted and stunted children under 5 years of age. Stunting, which is an indicator of the long-term impact of undernutrition, measures the growth retardation in terms of height for age. A child under the age of 5 is considered as stunted if his/her weight to height ratio falls below two standard deviations than the average for the specific age. Wasting, an indicator of current nutrition status measures the weight for height based on similar standards. Underweight estimates the weight to height ratio for a specific age and those children with the ratio below two standard deviations from the average is coming under this category.

Normalised undernutrition index

Following Gulati et al. (2012), we estimated a normalised undernutrition index combining indicators of child and adult nutrition status. The percentage of wasted, stunted and underweight children (under the age of 5 years) and the percentage of thin men and women (whose body mass index less than 18.5 kg/m^{2}) and anaemic women (in the age group of 15-49 years) is used for the construction of the index.

Normalisation of the indicators was performed using the formula

$$\text{Normalised indicator } = \frac{\text{actual values} - \text{minimum value}}{\text{maximum value} - \text{minimum value}} \quad (1)$$

Normalisations adds robustness to the calculated index values and render them scale-free (Gulati et al., 2012|). The undernutrition index is calculated as a simple average of the normalised child and adult nutrition indicators. These indices enable comparison of the performance of the districts in terms of their nutritional outcomes.

Diversification index

We estimated district wise food crop diversification index following the same methodology as described in Chapter 2.

Simulation study using bivariate copula function

We employed a simulation study using conditional distribution of undernutrition index based on the conditional value of diversification index by employing bivariate copula function (Li et al., 2015; Fan and Qian, 2016; Mazdiyasni et al., 2017; Nguyen-Huy et al., 2017).

Bivariate copulas explain the extent of dependence among two random variables. The present study estimated the conditional distribution of the undernutrition index (random variable Y), given the conditional value of diversification index (random variable X). Suppose $F_X(x)$ and $F_Y(y)$ represent marginal distribution functions of these variables. The joint distribution function of $F_{X,Y}(x, y)$ as per copula functions can be estimated as-

$$F_{X,Y}(x,y) = C\left[F_X(x), F_Y(y)\right]$$

(2)

Where, *C* stands for the bivariate copula, a cumulative distribution function for a bivariate distribution. For each set of data, we have fitted six copula families viz. Gaussian, Student t, Clayton, Gumbel, Frank, Joe. For selecting the best suited copula function for simulation of the conditional distribution, we employed minimum Akaike's information criterion (AIC) and Bayesian's information criterion (BIC) and the largest log-likelihood value. For observations x_i and y_i (i=1, 2,…, n) the Log-likelihood, AIC and BIC of a bivariate copula family *C* with parameter(s) θ is defined as-

$$\log likelihood = \sum_{i=1}^{n} \ln[\, C(F_X(x_i), F_Y(y_i)/\theta)]$$

$$AIC = -2\sum_{i=1}^{n} \ln[C\left(F_X(x_i), F_Y(y_i)/\theta\right)] + 2k$$

$$BIC = -2\sum_{i=1}^{n} \ln[C\left(F_X(x_i), F_Y(y_i)/\theta\right)] + \ln(n)k$$

Where,

k=1 for one parameter copulas and *k*=2 for two parameter copulas family.

The joint density function can be written as follows-

$$f_{X,Y}(x,y) = f_X(x) f_Y(y) C_{12}[F_X(x), F_Y(y)]$$

(3)

where,

$$C_{12}[F_X(x), F_Y(y)] = \frac{\partial}{\partial[F_X(x)]}\frac{\partial}{\partial[F_Y(y)]} C[F_X(x), F_Y(y)]$$

The conditional distribution function of *Y/X=x* can be written as follows-

$$F_{Y/X}(y/x) = C_1[F_X(x), F_Y(y)]$$

(4)

where,

$$C_1\left[F_X(x), F_Y(y\right] = \frac{\partial}{\partial[F_X(x)]} C\left[F_X(x), F_Y(y)\right]$$

By utilizing equation (4) conditional distribution of *Y* (Undernutrition index) can be simulated for given values of *X* (Diversification index). This analysis was done employing the "VineCopula" package of R software.

Cluster Analysis

Using the "cluster" package of R software, hierarchical clustering was performed for grouping the states of India based on the Undernutrition index.

Results and discussion

Undernutrition index

Figure 4 portrays the clustering of major states based on the undernutrition index. This dendrogram represents the hierarchal relationship between states under consideration using the clustering approach. From the results obtained from cluster analysis, it can be inferred that the 21 states can be grouped into three distinct groups based on the undernutrition index. The first group consists of 10 states viz. Jharkhand, Bihar, Gujarat, Madhya Pradesh, Odisha, Maharashtra, West Bengal, Uttar Pradesh, Chhattisgarh and Rajasthan. The mean value for the index is 34.27 for the first group. Jharkhand, Bihar and Madhya Pradesh fare the worst in the undernutrition index (39.17, 36.98, 36.22 respectively). States such as Assam, Andhra Pradesh, Haryana, Karnataka and Telangana constitute the second cluster with an average index value of 28.25. The third group consists of 6 states viz. Kerala, Punjab, Jammu & Kashmir, Uttrakhand, Himachal Pradesh and Tamil Nadu. The mean undernutrition index is 22.43 for the third group. Kerala ranks the best in these indicators according to the index estimated using nutrition indicators form the NFHS-IV 2015-16.

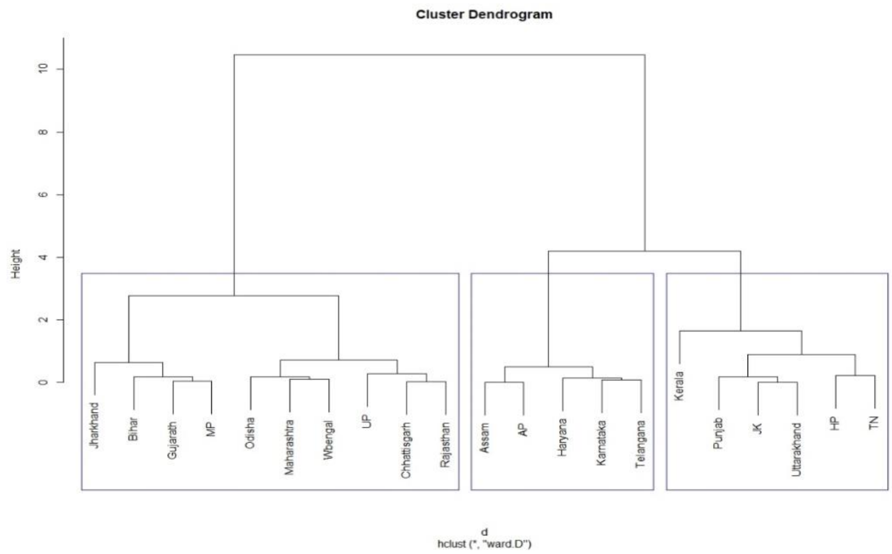


Figure 4: Cluster dendrogram of states based on undernutrition index

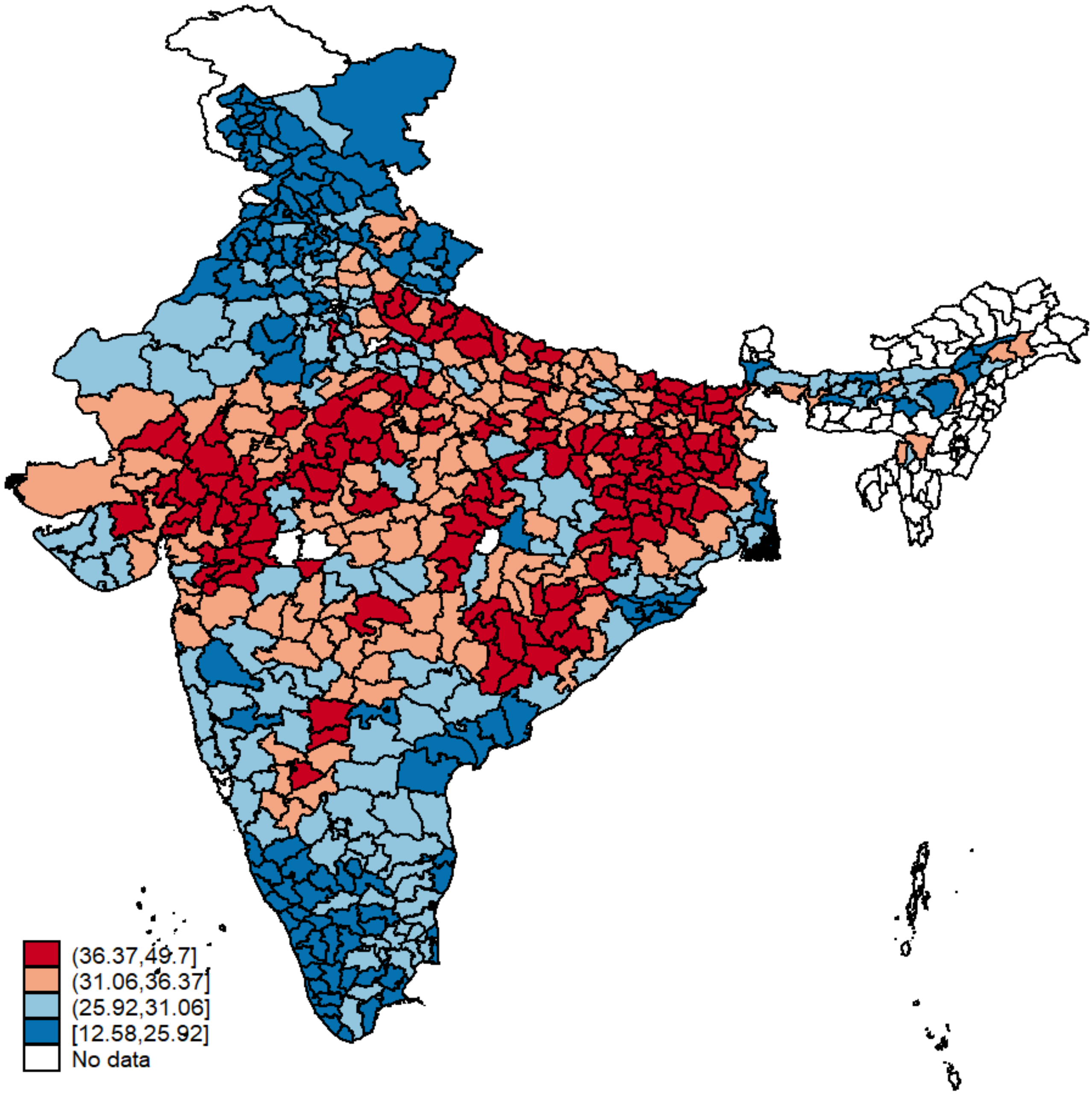


Figure 5: District wise undernutrition index, 2015-16

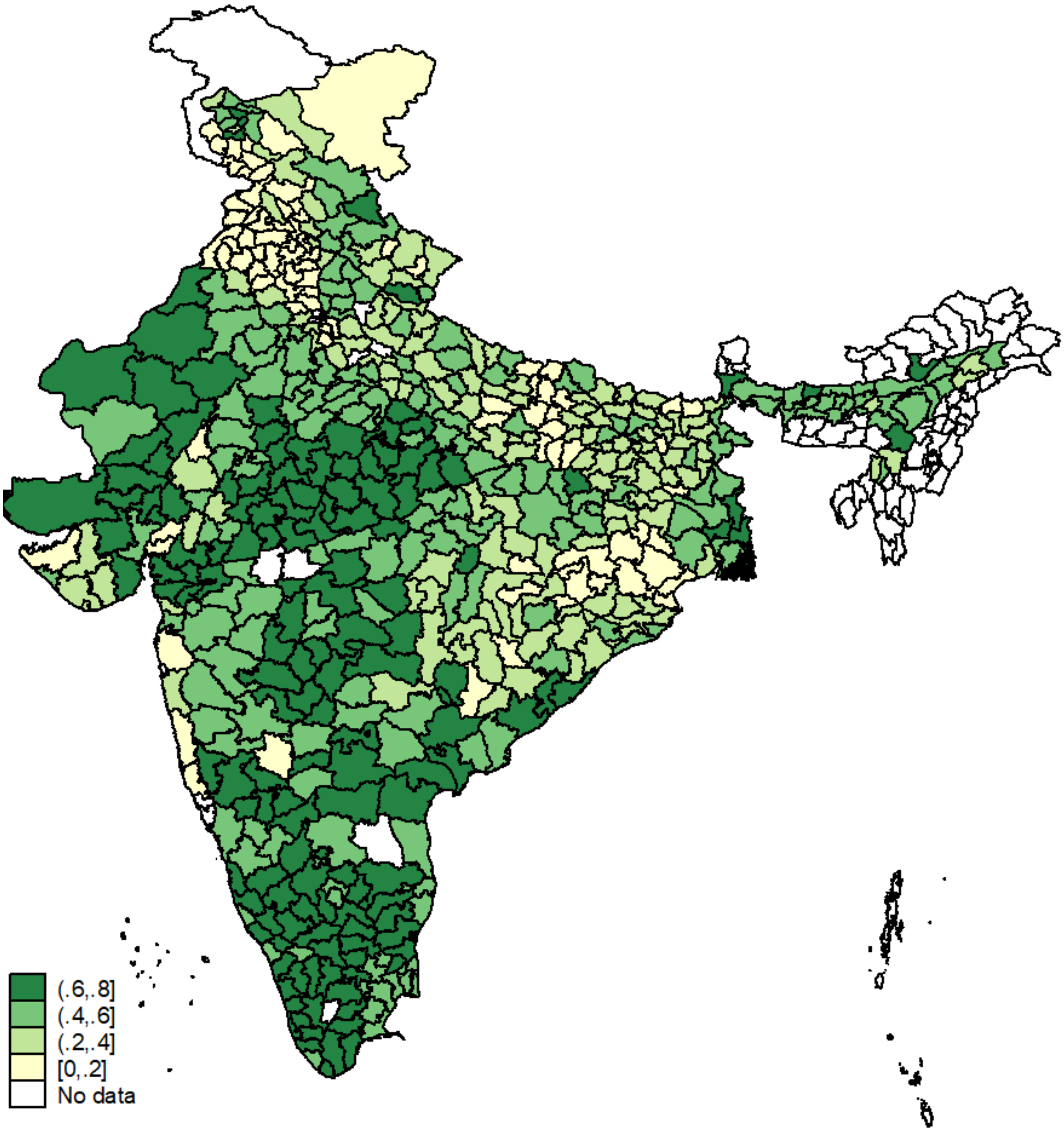


Figure 6: District wise diversification index for food crops, 2015-16

Figure 5 shows the status of undernutrition across Indian districts. Figure 6 depicts the district wise spatial variations in the extent of diversification among food crops in India. Based on the cluster analysis, the districts are grouped into 5 based on the index values of undernutrition (Table 5).

Table 5: Clusters of districts based on the undernutrition index

Group	Range	Number of districts	Percent
1	12.5 - 22.4	64	11
2	22.5 - 26.8	103	18
3	26.9 - 32.4	149	27
4	32.5 - 39.1	180	32
5	39.2 - 49.7	62	11

Of the total 558 districts considered, the first cluster has 64 districts with an average undernutrition index of 19.31. The second cluster which consists of districts with index values in the range of 22.5 to 26.8 has 103 districts with a mean index value of 24.96. The third cluster that accounts for about 27 percent of the total sample districts, has an average undernutrition index value of 29.69. The number of districts in the fourth and fifth clusters consists of 180 and 62 respectively. The average index value for the fourth cluster is 35.81. The fifth cluster with the worst performance in terms of nutrition indicators has a mean undernutrition index value of 41.88.

Bivariate copula

Table 6: Effect of crop diversification on undernutrition index using Copula method based on simulation

Copula	Gaussian Copula	Student t copula	Clayton copula	Gumbel copula	Frank copula
Parameter	-0.03*	par1: -0.04* par2: 8.14*	-0.12*	-1.05*	-0.39*
Log Likelihood	0.07	1.46	1.07	1.53	0.55
AIC	1.86	1.07	1.13	0.94	1.41
BIC	6.17	5.69	5.87	5.24	5.92

*Significant at 5 % level of significance

In this study, out of six fitted bivariate functions based on AIC, BIC and Log-Likelihood values, Gumbel copula was found best for the considered datasets. From the fitted function simulation of conditional distribution of undernutrition index for divergent values of diversification index 0.05, 0.25, 0.50, 0.75 and 0.98 were generated. Further, for each simulated

Table 7: Simulation of the conditional distribution of undernutrition index based on the conditional value of diversification index

Conditional value of diversification index	Probability of Undernutrition Index > 30	Probability of Undernutrition Index > 35
0.05	0.66	0.38
0.25	0.61	0.34
0.50	0.56	0.29
0.75	0.49	0.24
0.98	0.44	0.18

dataset probability of undernutrition index more than 30 as well as probability of undernutrition index more than 35 were computed. The probability values were represented in Table 7. From the table it can be inferred that if the value of the crop diversification index increases the probability of undernutrition reduces. About 43 percent of the districts has undernutrition index value above 30 and about 11 percent has above 40. The probability of having an undernutrition index value higher than 35 is significantly reduced at higher degree of diversification among food crops.

Our hypothesis is that the degree of crop diversification has a negative influence on the undernutrition status of respective districts. Though there are several other factors influence the nutritional outcome of a region, crop diversification can directly influence the access, variety and affordability of diverse diet (Ecker et al., 2011; Chinnadurai et al., 2016). Crop diversification is positively correlated with the household level food consumption by improving quantity and variety of food (Mango et al., 2018, Adjimoti and Kwadzo, 2018). Higher crop diversification increases resilience of households for short term agricultural shocks (Mukuka and Kuhlgatz, 2015). According to Gulati et al. (2012) indicators of the level of agricultural performance or income have a strong and significant negative relationship with indices of undernutrition among adults and children. Therefore, the results indicate that a higher degree of crop diversification among food crops could reduce the probability of undernutrition.

Conclusion

This study examined the impact of crop diversification on nutritional status at the district level. We analyzed the relationship between crop diversification and nutritional status at the district level using simulation study employing bivariate copula function. We used indicators of child and adult nutrition status and compared the relative performance of districts in their nutritional outcomes using the undernutrition index as a proxy. Using hierarchical clustering, we grouped states and districts based on the index values. Results of the simulation study using bivariate copula function indicated a dominant influence of crop diversification on reducing undernutrition in India. Overall, the varying extent of crop diversification across regions imply that region-specific interventions are necessary to promote the crop diversification. Promoting diversification among food crops can improve the nutritional outcomes of districts among other factors. These interventions need parallel efforts to address lacuna associated with resource use efficiency, sustainability, market logistics, regional demand supply gap and income demands of farmers.

Summary

In India, the degree of diversification exhibits huge variations among different regions (Radhakrishna and Panda, 2006). Identifying pattern and degree of crop diversification are imperative in formulating region-specific agriculture development strategies. Crop diversification is also important in the nutritional point of view. Better income prospects and higher marketable surplus can supplement the consumption of nutritious food in terms of variety as well as quantity. In sub-Saharan Africa, diverse agricultural farms lead to diverse diets in households (Mugendi Njeru, 2013). Earlier literature suggests the direct effect of crop diversification on food availability and nutrition (Lin, 2011; Jones et al., 2014).

In India, diversifying towards coarse cereals improves nutritional supply, climate resilience and resource use efficiency and reduce greenhouse gas emissions without compromising calorie production (Davis et al., 2019). Diverse production systems focusing on horticultural crops add to food security and reduce anaemia (Makate et al., 2016). Consumption of a well-balanced and diversified diet is a sustainable strategy to check problems associated with malnutrition (Ecker et al., 2011). With this background, this study examined the status of crop diversification in India and its determinants, and impact of crop diversification on the district wise nutritional status in India.

We used the Simpson Index of diversification (Sd) as an indicator of crop diversification. We found that the area share of food crops is declining in the central, western, and southern regions while the area share is increasing in the northern and eastern regions. The area share of cereals and millets is declining in all regions except northern region and eastern region for the past decade and a half. The area share of pulse crops is increasing in the western and southern regions. The share of high-value crops such as fruits and vegetables has also increased in all the regions during the study period. Under non-food crops, the area share of oilseeds has been declining in the eastern and southern regions. We estimated the extent of crop diversification at the regional/state level for food crops, non-food crops and the whole crop sector. Results indicated that the extent of diversification within food crops has been low in the northern region. In the states of Punjab and Haryana more than 90 percent of the area of food crops is under cereals, mainly rice and wheat. The extent of diversification in the overall crop sector was low in the northern regions for the past one and a half-decade. On the contrary, the western and southern regions have displayed a higher degree of crop diversification and the Sds of these regions were rising during the study period.

The present study examined the determinants of crop diversification in India by using regression analysis model. It was observed that irrigation share, share of marginal farm households and share of households having males as heads are negatively influencing crop diversification, whereas share of farmers belonging to social groups other than SC and ST are positively influencing crop diversification in India. Finally, we analyzed the relationship between crop diversification and nutritional status at the district level using simulation study employing bivariate copula function. We used indicators of child and adult nutrition status and compared the relative performance of districts in their nutritional outcomes using the undernutrition index as a proxy. Using hierarchical clustering, we grouped states and districts based on the index values. Results of the simulation study using bivariate copula function indicated a dominant influence of crop diversification on reducing undernutrition in India. Overall, the varying extent of crop diversification across regions implies that region-specific interventions are necessary to promote the crop diversification. Promoting diversification among food crops can improve the nutritional outcomes of districts among other factors. These interventions need parallel efforts to address lacuna associated with resource use efficiency, sustainability, market logistics, regional demand supply gap and income demands of farmers.

सारांश

भारत में, विविधीकरण की डिग्री विभिन्न क्षेत्रों (राधाकृष्ण और पांडा, **2006)** के बीच भारी भिन्नता दर्शाती है। क्षेत्र-विशिष्ट कृषि विकास रणनीतियों को तैयार करने में फसल विविधीकरण के पैटर्न और डिग्री की पहचान करना अनिवार्य है। पोषण की दृष्टि से भी फसल विविधीकरण महत्वपूर्ण है। बेहतर आय की संभावनाएं और उच्च विपणन योग्य अधिशेष विविधता के साथ-साथ मात्रा के मामले में पौष्टिक भोजन की खपत को पूरक कर सकते हैं। उप-सहारा अफ्रीका में, विविध कृषि फार्म घरों में विविध आहारों की ओर ले जाते हैं (मुगेंडी नजेरू, **2013)**। पहले का साहित्य खाद्य उपलब्धता और पोषण पर फसल विविधीकरण के प्रत्यक्ष प्रभाव का सुझाव देता है (लिन, **2011;** जोन्स एट अल।, **2014)**।

भारत में, मोटे अनाज की ओर विविधता लाने से पोषण आपूर्ति, जलवायु लचीलापन और संसाधन उपयोग दक्षता में सुधार होता है और कैलोरी उत्पादन से समझौता किए बिना ग्रीनहाउस गैस उत्सर्जन में कमी आती है (डेविस एट अल।, **2019)**। बागवानी फसलों पर ध्यान केंद्रित करने वाली विविध उत्पादन प्रणालियां खाद्य सुरक्षा को बढ़ाती हैं और एनीमिया को कम करती हैं (माकाटे एट अल।, **2016)**। एक अच्छी तरह से संतुलित और विविध आहार का सेवन कुपोषण से जुड़ी समस्याओं की जांच के लिए एक स्थायी रणनीति है (एकर एट अल।, **2011)**। इस पृष्ठभूमि के साथ, इस अध्ययन ने भारत में फसल विविधीकरण की स्थिति और इसके निर्धारकों, और भारत में जिलेवार पोषण स्थिति पर फसल विविधीकरण के प्रभाव की जांच की।

हमने फसल विविधीकरण के संकेतक के रूप में विविधीकरण के सिम्पसन इंडेक्स (एसडी) का इस्तेमाल किया। हमने पाया कि मध्य, पश्चिमी और दक्षिणी क्षेत्रों में खाद्य फसलों का क्षेत्रफल घट रहा है जबकि उत्तरी और पूर्वी क्षेत्रों में क्षेत्रफल का हिस्सा बढ़ रहा है। पिछले डेढ़ दशक से उत्तरी क्षेत्र और पूर्वी क्षेत्र को छोड़कर सभी क्षेत्रों में अनाज और बाजरा का क्षेत्रफल घट रहा है। दलहनी फसलों का क्षेत्रफल पश्चिमी और दक्षिणी क्षेत्रों में बढ़ रहा है। अध्ययन अवधि के दौरान सभी क्षेत्रों में फलों और सब्जियों जैसी उच्च मूल्य वाली फसलों की हिस्सेदारी में भी वृद्धि हुई है। गैर-खाद्य फसलों के तहत, पूर्वी और दक्षिणी क्षेत्रों में तिलहन के क्षेत्रफल में गिरावट आई है। हमने खाद्य फसलों, गैर-खाद्य फसलों और पूरे फसल क्षेत्र के लिए क्षेत्रीय/राज्य स्तर पर फसल विविधीकरण की सीमा का अनुमान

लगाया। परिणामों ने संकेत दिया कि उत्तरी क्षेत्र में खाद्य फसलों के भीतर विविधीकरण की सीमा कम रही है। पंजाब और हरियाणा राज्यों में खाद्य फसलों का **90** प्रतिशत से अधिक क्षेत्र अनाज, मुख्य रूप से चावल और गेहूं के अंतर्गत आता है। पिछले डेढ़ दशक से उत्तरी क्षेत्रों में समग्र फसल क्षेत्र में विविधीकरण की सीमा कम थी। इसके विपरीत, पश्चिमी और दक्षिणी क्षेत्रों ने उच्च स्तर की फसल विविधीकरण प्रदर्शित किया है और अध्ययन अवधि के दौरान इन क्षेत्रों के एसडी बढ़ रहे थे।

वर्तमान अध्ययन ने प्रतिगमन विश्लेषण मॉडल का उपयोग करके भारत में फसल विविधीकरण के निर्धारकों की जांच की। यह देखा गया कि सिंचाई का हिस्सा, सीमांत कृषि परिवारों का हिस्सा और पुरुषों के मुखिया वाले परिवारों का हिस्सा फसल विविधीकरण को नकारात्मक रूप से प्रभावित कर रहा है, जबकि अनुसूचित जाति और अनुसूचित जनजाति के अलावा अन्य सामाजिक समूहों से संबंधित किसानों का हिस्सा भारत में फसल विविधीकरण को सकारात्मक रूप से प्रभावित कर रहा है। अंत में, हमने द्विचर कोप्युला फ़ंक्शन को नियोजित करते हुए सिमुलेशन अध्ययन का उपयोग करके जिला स्तर पर फसल विविधीकरण और पोषण स्थिति के बीच संबंधों का विश्लेषण किया। हमने बच्चे और वयस्क पोषण की स्थिति के संकेतकों का उपयोग किया और अल्पपोषण सूचकांक का प्रॉक्सी के रूप में उपयोग करते हुए उनके पोषण संबंधी परिणामों में जिलों के सापेक्ष प्रदर्शन की तुलना की। पदानुक्रमित क्लस्टरिंग का उपयोग करते हुए, हमने सूचकांक मूल्यों के आधार पर राज्यों और जिलों को समूहीकृत किया। द्विचर कोप्युला फंक्शन का उपयोग करते हुए सिमुलेशन अध्ययन के परिणामों ने भारत में अल्पपोषण को कम करने पर फसल विविधीकरण के एक प्रमुख प्रभाव का संकेत दिया। कुल मिलाकर, विभिन्न क्षेत्रों में फसल विविधीकरण की अलग-अलग सीमा का तात्पर्य है कि फसल विविधीकरण को बढ़ावा देने के लिए क्षेत्र-विशिष्ट हस्तक्षेप आवश्यक हैं। खाद्य फसलों के बीच विविधीकरण को बढ़ावा देने से अन्य कारकों के अलावा जिलों के पोषण संबंधी परिणामों में सुधार हो सकता है। इन हस्तक्षेपों के लिए संसाधन उपयोग दक्षता, स्थिरता, बाजार रसद, क्षेत्रीय मांग आपूर्ति अंतर और किसानों की आय मांगों से जुड़ी कमियों को दूर करने के लिए समानांतर प्रयासों की आवश्यकता है।

References

Ecker, O., Mabiso, A., Kennedy, A. and Diao, X. (2011) Making Agriculture Pro-nutrition: Opportunities in Tanzania. IFPRI Discussion Paper 01124. International Food Policy Research Institute, Washington, DC.

Gulati, A., Kumar, G.A., Shreedhar, G., and Nandakumar, T. (2012) Agriculture and Malnutrition in India. *Food & Nutrition Bulletin*, **33**(1), 74-86.

Hendrick, S, L and Msaki, M.M. (2009) The impact of Smallholder Commercialization of Organic Crops on Food Consumption Patterns, Dietary Diversity and Consumption Elasticities. *Agrekon*, **48**(2), 184-199.

Immink, M.D.C. and Alarcon, J.A. (1991) House-hold Food Security, Nutrition and Crop Diversification among Smallholder Farmers in the Highlands of Guatemala. *Ecology of Food and Nutrition,* **25**(4), 1-19.

Jones, A.D., Shrinivas, A. and Bezner-Kerr, R. (2014) Farm Production Diversity is Associated with Greater Household Dietary Diversity in Malawi: Findings from Nationally Representative Data. *Food Policy*, **46**, 1-12.

Joshi, P. K., Gulati, A., Birthal, S. P. and Tewari, L. (2004) Agricultural Diversification in South Asia: Patterns, Determinants and Policy Implications. *Economic and Political Weekly*, **39**(24), 52–53.

Khandker, S.R and Mahmud, W. (2012) Seasonal Hunger and Public Policies. World Bank. Washington DC, USA.

Kumar, S. and Gupta, S. (2015) Crop Diversification towards Hgh-value Crops in India: A state level Empirical Analysis. *Agricultural Economics Research Review,* **28**(2), 339-350.

Makate, C., Wang, R., Makate, M. *et al*. (2016) *Springer Plus* 5: 1135. https://doi.org/10.1186/s40064-016-2802-4 accessed on 25.06.2018

Mithiya, D., Mandal, K. and Datta, L. (2018) Trend, Pattern and Determinants of Crop Diversification of Small holders in West Bengal: A District-wise Panel data Analysis. *Journal of Development and Agricultural Economics*, **10**(4), 110-119.

Mukuka, R. and Kuhlgatz, C. H. (2015) Child Malnutrition, Agricultural Diversification and Commercialization among Smallholders in Eastern Zambia Indaba Agricultural Policy Research Institute (IAPRI). Working Paper 90, Accessed from http://www.iapri.org.zm on 2.07.2018.

Oyarzun, P.J., Borja, R.M., Sherwood, S. and Parra, V. (2013) Making Sense of Agro-biodiversity, Diet, and Intensification of Smallholder Family Farming in the Highland Andes of Ecuador. *Ecology and Food Nutrition*, **52**(6), 515-541.

Papademetriou, M., and Dent, F. (2001) Crops diversification in the Asia-Pacific Region. FAO, Rome.

Pellegrini, L. and Tasciott, L. (2014) Crop Diversification, Dietary Diversity and Agricultural Income: Empirical Evidence from Eight Developing Countries. *Canadian Journal of Development Studies*, **35**(2),11–227.

Radhakrishna, R. and Panda, M. (2006) Macroeconomics of Poverty Reduction: India Case Study. *Macroeconomics of Poverty Reduction*, Indira Gandhi Institute of Development Research, Mumbai.

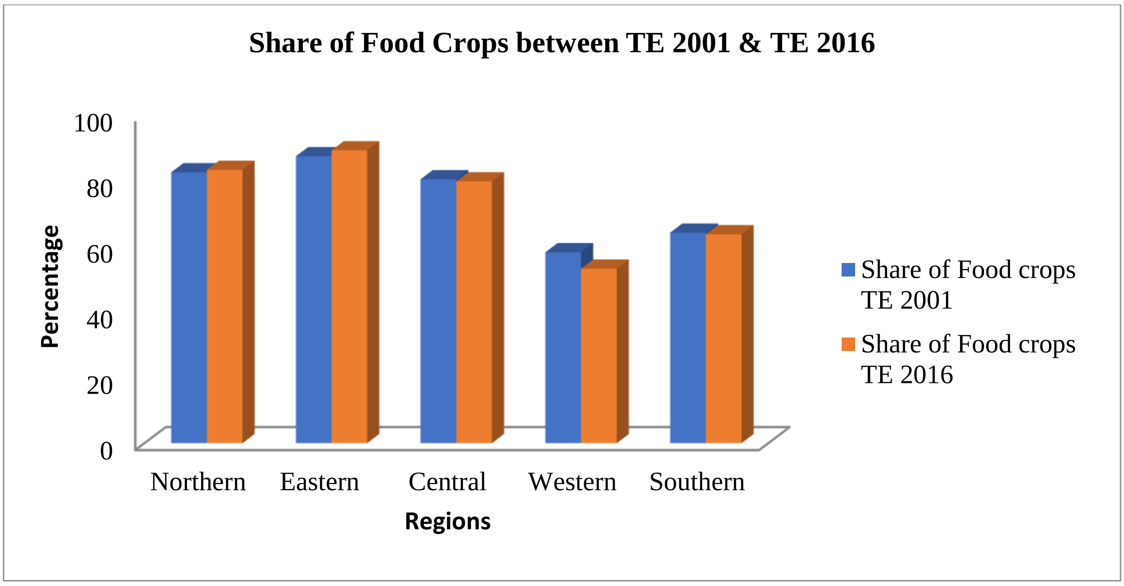
Rajendran, S., Afari-Sefa, V., Bekunda, M., Dominick, I., and Lukumay, P. J. (2014) Does Crop Diversity Contribute to Dietary Diversity? Evidence from Integration of Vegetables into Maize Based Farming Systems in Tanzania. 88th Annual Conference, April 9-11, 2014, Agricultural Economics Society.

Remans, R., Flynn, D.F.B., Diru, W., Fanzo, J., Gaynor, K., Lambrecht, I., Mudiope, J., Mutuo, P.K., Nkhoma, P., Siriri, D., Sullivan, C. and Palm, C. (2011) Assessing Nutritional Diversity of Cropping Systems in African Villages. *PLoS ONE*, **6**(6), e21235.

Sharma, H. R. (2011) Crop diversification in Himachal Pradesh; Patterns, Determinants and Challenges. *Indian Journal of Agricultural Economics*, **66**(1), 105-112.

Torheim, L.E., Ouattara, F., Diarra, M.M., Thiam, F.D., Barikmo, I., Hatloy.A. and Oshaug, A. (2004) Nutrient Adequacy and Dietary Diversity in Rural Mali Association and Determinants. *European Journal of Nutrition,* **58,** 594-604.

Annexure-I



Share of Food Crops between TE 2001 & TE 2016
100
80
60
40
20
0
Percentage
Northern
Eastern
Central
Western
Southern
Regions
Share of Food crops TE 2001
Share of Food crops TE 2016

Annexure-II

Particulars	Top Five Districts		Bottom Five Districts	
Irrigation Share (%)	Punjab	Amritsar	Tamil Nadu	The Nilgiris
	Punjab	Barnala	Assam	Dhemaji
	Punjab	Fatehgarh Sahib	Chhattisgarh	Dakshin Bastar Dantewada
	Punjab	Firozepur	Assam	Golaghat
	Punjab	Jalandhar	Assam	Tinsukia
Share of marginal farm households (Number share)	Kerala	Thiruvananthapuram	Rajasthan	Churu
	Kerala	Kollam	Punjab	Firozepur
	Kerala	Thrissur	Rajasthan	Bikaner
	Kerala	Alappuzha	Rajasthan	Jaisalmer
	Tamil Nadu	Kanniyakumari	Rajasthan	Ganganagar
Share of farmers belonging to social groups other than SC and ST	Jammu & Kashmir	Udhampur	Himachal Pradesh	Una
	Haryana	Mewat	Gujarat	Navsari
	Haryana	Jhajjar	Himachal Pradesh	Mandi
	Haryana	Karnal	Jammu & Kashmir	Samba
	Haryana	Kaithal	Jammu & Kashmir	Rajauri
Share of male households (number)	Assam	Nalbari	Andhra Pradesh	Vizianagaram
	Assam	Dhemaji	Andhra Pradesh	Visakhapatanam
	Assam	Nagaon	Kerala	Ernakulam
	Punjab	Bathinda	Andhra Pradesh	Guntur
	Punjab	Kapurthala	Karnataka	Haveri