Agricultural Economics Research Review
Vol. 29 (Conference Number) 2016 pp 15-29
DOI: 10.5958/0974-0279.2016.00030.6

Agricultural Diversity, Dietary Diversity and Nutritional Intake: An Evidence on Inter-linkages from Village Level Studies in Eastern India

Anjani Kumar[a]*, Sunil Saroj[a], R.K.P. Singh[b] and Shiv Jee[c]

[a]International Food Policy Research Institute (IFPRI), South Asia Office, New Delhi - 110 012
[b]Formerly at Rajendra Agricultural University, Pusa, Bihar
[c]Independent Researcher, Patna, Bihar

Abstract

The linkage between agriculture and nutrition is complex and often debated in the policy discourse in India. The enigma of fastest growing economy and yet the largest home of under- and mal-nourished population takes away the sheen from the glory of economic achievements of India. In this context, the study has examined the food consumption patterns, assessed the relationship between agricultural production and dietary diversity, and analysed the impact of dietary diversity on nutritional intake. The study is based on a household level panel data from 12 villages of Bihar, Jharkhand and Odisha in eastern India. The study has shown that agricultural production diversity is a major determinant of dietary diversity which in turn has a strong effect on calorie and protein intake. The study has suggested that efforts to promote agricultural diversification will be helpful to enhance food and nutrition security in the country. Agricultural programmes and policies oriented towards reducing under-nutrition should promote diversity in agricultural production rather than emphasizing on increasing production through focusing on selected staple crops as has been observed in several states of India. The huge fertilizer subsidies and government procurement schemes limited to a few crops provide little incentives for farmers to diversity their production portfolio.

Key words: Agricultural production, dietary diversity, nutrition, Eastern India, Village Level Studies

JEL Classification: Q12, Q18, I15

Introduction

Agriculture continues to be an important source of livelihood for the majority of rural population in developing countries like India. Agriculture can influence nutrition through many pathways, which include increased food intake from own production, increased incomes from diversification towards high-value crops (HVCs), livestock rearing and reduced real food prices (World Bank, 2007; Gillespie and Kadiyala, 2012; Viswanathan *et al*., 2015; Slavchevska, 2015). However, the evidence on the link between agriculture and nutrition has been vague. The incidence of under-nutrition is severe and wide spread among the farming households. This evidence is more explicit when the households or regions with agricultural predominance are compared with non-agricultural regions (Dahiya and Viswanathan, 2015). The countries and regions that experienced faster economic growth caused by structural transformation from farm to non-farm activities with a corresponding shift in the pattern of employment, have been able to reduce undernutrition at a much faster rate. The studies also show that sustained agricultural growth reduced poverty and

* Author for correspondence
Email: anjani.kumar@cgiar.org

undernutrition at a higher rate than that by other sectors (De Janvry and Sadoulet, 2001; Webb and Block, 2011).

India is facing a paradoxical situation. It is witnessing one of the highest economic growths with a much slower decline in undernutrition. Despite importance and potential of agriculture in improving nutrition of the farming households, the existing understanding about linkages between agriculture and nutrition is extremely weak in India. In the rural India (particularly in less- developed regions), food intake is closely tied to on-farm agricultural production. But, the paucity of unit-level data that combine information on both nutrition and agriculture constraints the meaningful analysis at the national level. Nevertheless, the greater emphasis being laid on the evidence-based policy making, empirical understanding of the linkages between agriculture and nutrition becomes crucial (Malhotra, 2014). This study is a contribution in this direction and focuses on the selected rural pockets of eastern India. It attempts to connect agricultural production diversity to dietary diversity at the household level and then links dietary diversity to calorie- and protein-intake. More specifically, the current study examines the food consumption patterns, agricultural production and dietary diversity based on the household level panel data from 12 villages with a view to exploring the heterogeneity in food habits, and assessing the relationship between quality of food intake and agricultural production portfolio. The impact of dietary diversity on nutritional intake has also been examined.

Data and Methodology

Data

This study has used the panel data for 2010-11 to 2014-15, which is a part of the high-frequency panel data collected through the Village Level Studies (VLS)[1] of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). These data are comprehensive records on household, individual, and plot levels collected from the selected villages on a continuous basis for five years. During data collection, the resident investigators interviewed the participating households several times year after year so as to capture the dynamics of households characteristics, including expenditure, income, consumption, investment and farming practices. In the present context, the data pertained to 12 villages in eastern India (Arap and Bhagakole villages in Patna district; Susari and Inai villages in Darbhanga district; Dubaliya and Hesapiri villages in Ranchi district; Dumariya and Durgapur villages in Dumka district of Jharkhand state; Sogar and Chandrasekhapur villages in Dhenkanal district; and Ainlatunga and Bilaikani villages in Bolangir district of Odisha state). The socio-economic and demographic characteristics of the households in these villages are depicted in Appendix I. From each village, 40 households were selected (480 households from 12 villages) and were monitored on a sustained basis. The selected households were categorized into various farm-size classes based on the size of land they possessed. First, all the households in a village possessing land area less than or equal to 0.2 ha were classified as 'labour' households. All the remaining households were categorized into tercile groups, each containing a third of the population. The sample households thus selected represented the village population. In this analysis, we have classified the households into the following categories: labour (<0.2 ha), marginal (<1 ha), small (1-2 ha), medium (2-4 ha) and large (>4 ha).

Methodology

The paper has specifically examined the food consumption pattern, agricultural production diversity, dietary diversity, the relationship between agricultural production diversity and dietary diversity, and the impact of dietary diversity on nutritional intake of the sample households in the selected villages using the VLS data collected during the agricultural years 2010-

[1] The VLS are longitudinal surveys initiated by ICRISAT in 1975 in 10 Indian villages. The surveys continued for the next 10 years, before formally closing in 1985 in response to budgetary pressure. The surveys were re-opened in 2002 in the initial six villages, starting with low frequency rounds and with higher frequency interviews since 2005-06. Subsequently in 2010, the coverage was enhanced by including 12 villages in the eastern India with funding from the Bill and Melinda Gates Foundation. The study in eastern India was conducted in partnership with the Indian Council of Agricultural Research. The VLS data however cannot be treated as representative data for districts, states or the agro-climatic region within which the villages are located due to the relatively small sample coverage.

11 to 2014-15 (July, 2010 to June, 2015). The information on area allocated to different crops, allied activities undertaken and production realized was recorded by the resident investigators from the sample household on a regular basis. The quantity of food commodities consumed by the respondent households was recorded based on a 30-day recall period[2]. The recall was administered to the heads of households at monthly intervals during the above period.

The questionnaires used for the survey were quite exhaustive and covered almost all types of food commodities generally consumed by the rural inhabitants in India. They not only included foods prepared and consumed within the household, but also those that were consumed outside (e.g. at restaurants, social functions and children's mid-day meal programmes) including processed food commodities, beverages and intoxicants. Various aspects related to food intake such as shares of various food commodities in total expenditure, per-capita intake and share of home-produced items in total consumption of each food group and the contribution of the Public Distribution System[3] (PDS) to household supply of cereals were probed. Further, diversity in the consumption basket of sample households was estimated using the Simpson Index of Dietary Diversity (SIDD) given in Equation (1):

$$\text{SIDD} = 1 - \sum_{i=1}^{n} P_i^2 \qquad \ldots.(1)$$

where, P_i is the proportion of the i^{th} food item in total monthly consumption of all food commodities by the members of household. The monthly estimates were subsequently averaged to get the final SIDD estimate for the year under consideration. The Simpson index ranges between 0 and 1, where the value moves towards 0 in case of complete specialization. Separate scores of SIDD were obtained for households belonging to each village.

Similarly, the agriculture production diversity (AgPD) index was estimated by Equation (2):

$$\text{AgPD} = 1 - \sum_{i=1}^{n} P_i^2 \qquad \ldots.(2)$$

where, P_i is the share of cultivated area of the i^{th} crop in the total cultivated area. The larger the values of this index, the larger is the diversity in crop production.

The paper has examined the hypothesis that agricultural production diversity influences the household dietary diversity and dietary diversity in turn influences the nutritional intake. We estimated the following three multiple panel regressions for examining these relationships:

$$SIDD_{it} = \alpha + \beta AgPD_{it} + \gamma E_{it} + u_i \qquad \ldots.(3)$$

$$CI_{it} = \alpha + \beta SIDD_{it} + \gamma E_{it} + u_i \qquad \ldots.(4)$$

$$PI_{it} = \alpha + \beta SIDD_{it} + \gamma E_{it} + u_i \qquad \ldots.(5)$$

In Equations (3), (4) and (5), $SIDD_{it}$ (ranging from 0 to 1) denotes the dependent variable representing dietary score of the households, CI_{it} denotes the dependent variable representing calorie intake, and PI_{it} denotes the dependent variable representing protein intake of the households. Among the set of explanatory variables, $AgPD_{it}$ in Equation (3) represents the agricultural production index (ranging from 0 to 1) of the household. E_i is a vector of explanatory variables on socio-economic and demographic characteristics of the household such as age, education of household-head, gender, household size, caste affiliation, food habits (vegetarian or non-vegetarian), per-capita total expenditure, household assets value, access to PDS, share of home-produced food, non-farm sources of income, farm-size, milk producing households, market distance from home, dependency ratio, and share of food consumption. The 'u_i' is the error-term and is assumed to be normally distributed. All the variables, except agricultural production diversity index, dietary diversity index and dummies, were converted to log before estimating the model.

The policy makers in the country are more interested to have information on factors affecting the

[2] A recall period of 30 days is generally considered too long, particularly for studies related to dietary diversity. However, under VLS programme, the sample households were sensitized to keep a record of their day-today consumption on a regular basis with help of their female members. Unless migrated, these households remained in the VLS records as regular data suppliers as long as the programme continued in the region. The resident nature of investigators also helped in checking discrepancies in the data, so minimizing sampling bias.

[3] PDS is one of the most important government programmes for distribution of subsidized food grains across the weaker section of the population to ensure household food security in India.

prevalence of deficiency in nutritional intake. We, therefore, estimated two binary panel logistic regressions to know the variables that affect the probability of being deficient in calorie and protein intake. Specifically, the multivariate logistic regression is given by Equation (6):

$$Y = \ln\left[\frac{p}{1-p}\right] = \beta_0 + \sum \beta_i X_i \qquad (6)$$

where, p represents the probability of a household being deficient in calorie and protein intake and β_s are the regression coefficients estimated by the maximum likelihood method. The X_s represent the explanatory variables and include several socio-economic and demographic characteristics of the farm households as mentioned above.

Results and Discussion

Food Consumption and Expenditure Patterns

The expenditure patterns of the sample households across farm-size groups are presented in Table 1. Significant variations were observed in the level of expenditure made by the sample households across different states as well as farm-size class. In Bihar, the average monthly per-capita consumption expenditure for sample households was ₹ 713 which was lower than that of Odisha (₹ 1022) and substantially higher than that of Jharkhand (₹ 417). Though the expenditure pattern of sample households did not entirely match their farm-size, the general trend revealed a positive association between expenditure and farm-size. The large farm households invariably spent substantially higher amounts on their consumption as compared to other households.

The share of food expenditure in total expenditure was above 50 per cent in Bihar (50.6%) and Odisha (57.3%) but little less in Jharkhand (47.4%). With a few exceptions, the share of food expenditure in total consumption expenditure depicted an inverse relationship with farm-size.

Table 2 shows the average consumption of various food commodities among the sample households in the selected states of eastern India. Cereals were the main source of dietary nutrients across all the categories of sample households, with rice and wheat being the main staples. The average cereals consumption by sample households did not reveal any significant variation across states. The average per-capita cereal consumption varied from 13.08 kg/month in Odisha to 14.20 kg/month in Jharkhand. The average cereal consumption for the sample households in these states was higher than the all-India rural average of 11.22 kg/capita/month for the year 2011-12 (Parappurathu *et al*., 2015). The average per-capita consumption of pulses was found to be 0.68 kg/month with 0.88 kg/month in Odisha and 0.48 kg/month in Jharkhand. The rural national average of pulse consumption in 2011-12 was 0.78 kg/capita/month (Parappurathu *et al*., 2015). The level of consumption of pulses among

Table 1. Average monthly per-capita expenditure across farm-size groups in sample households in eastern India, 2010-11 to 2014-15

(₹ /capita/month)
QE 2014-15

State	Labour households	Farm-size				
		Marginal	Small	Medium	Large	All
Bihar	476	657	802	1090	1949	713
	(50.3)	(51.5)	(55.1)	(54.0)	(34.3)	(50.6)
Jharkhand	464	396	414	374	1638	417
	(37.6)	(49.3)	(49.3)	(49.9)	(37.8)	(47.4)
Odisha	951	969	1093	1107	1322	1022
	(58.8)	(59.4)	(56.8)	(53.8)	(45.4)	(57.3)
Eastern India	640	642	799	894	1626	717
	(52.6)	(54.2)	(55.1)	(53.4)	(38.8)	(53.1)

Note: Figures within the parentheses indicate the share of food expenditure in total consumption expenditure
Source: Authors' calculations based on VDSA survey, 2010-11 to 2014-15

Table 2. Consumption of various food commodities across sample households of eastern India, 2010-11 to 2014-15

(kg/capita/month)

Food commodity	Bihar	Jharkhand	Odisha	Eastern India
Cereals	13.82	14.20	13.08	13.72
Pulses	0.68	0.48	0.88	0.68
Edible oils	0.52	0.48	0.55	0.52
Fresh fruits	0.91	0.35	0.95	0.74
Vegetables	7.75	7.14	6.61	7.22
Milk	6.95	1.05	1.31	3.29
Meat, fish and eggs	0.15	0.29	0.64	0.35
Sugar	0.71	0.35	0.60	0.56
Spices	0.22	0.20	0.30	0.24
Dry fruits	0.17	0.01	0.05	0.08

Source: Authors' calculations based on VDSA survey, 2010-11 to 2014-15

sample households in Jharkhand was substantially lower; only 60 per cent of the national rural average.

The per-capita consumption of edible oil in the sample households in eastern India was 0.52 kg/month against the national rural average per-capita consumption of 0.67 kg/month (Parappurathu *et al*., 2015). The edible oil consumption varied from 0.48 kg/month in Jharkhand to 0.55 kg in Odisha. The vegetable consumption was robust among the selected sample households in eastern India with an average of 7.22 kg/capita/month, which varied from 6.61 kg/capita/month in Jharkhand to 7.75 kg/capita/month in Bihar.

The villages of Bihar are far ahead of their counterparts from Jharkhand and Odisha in terms of milk consumption. The per-capita monthly consumption of milk in Bihar was 6.95 kg which was more than 6-times of that in Odisha (1.31 kg) and Jharkhand (1.05 kg). The average consumption of non-vegetarian food depicted a picture contrast of milk consumption pattern. The average level of non-vegetarian food consumption in Jharkhand (0.29 kg/capita/month) and Odisha (0.64 kg/capita/month) was substantially higher than their counterparts in Bihar. The food consumption pattern revealed the dominant dependence of household members on cereals and vegetables (and milk in Bihar) for meeting their energy and nutrient requirements. Evidently, the consumption of fruits, milk (with the exception of Bihar) and non-vegetarian food commodities was much lower in eastern India than all-India average. The variations in consumption pattern may be attributed to the nature of work, caste and religious affiliations (Parappurathu *et al*., 2015).

Status of Self-sufficiency and Contribution of PDS in Food Consumption

The level of self-sufficiency of sample households in food commodities consumed by them is presented in Table 3. In general, the sample households in eastern India showed a sufficiency level from as low as 6.7 per cent in non-vegetarian food to 65.4 per cent in milk, though with variations across states. The sample households of Bihar were relatively more self-sufficient in most of the food commodities they consumed, except the non-vegetarian foods. The share of home-produced food in cereals consumption in Bihar was above 70.7 per cent — much higher than in Jharkhand (44.7%) and Odisha (42%). In the case of pulses, 34.8 per cent of pulse consumption in Bihar was contributed by home production, while the share of home-produced pulses in Jharkhand and Odisha was only 14.2 per cent and 15.8 per cent, respectively. Except non-vegetarian food commodities, similar patterns are discernible for most of the food commodities in eastern India.

Table 4 shows the share of cereals purchased from PDS in total cereals consumed by sample households in eastern India. In the sample households, the food requirement beyond that produced at home was obtained from either the open market or the Public Distribution System (PDS). The PDS contributed about 34 per cent of the cereals consumption in Odisha,

Table 3. Share of home-produced food commodities consumed by sample households in eastern India, 2010-11 to 2014-15

(in per cent)

Food commodity	Bihar	Jharkhand	Odisha	Eastern India
Cereals	70.7	44.7	42.0	53.5
Pulses	34.8	14.2	15.8	22.6
Edible oils	27.5	1.2	1.2	10.9
Fresh fruits	26.8	27.2	23.5	25.8
Vegetables	21.9	21.5	15.1	19.8
Milk	68.8	51.7	56.4	65.4
Meat, fish and eggs	0.4	10.1	7.1	6.7

Source: Authors' calculations based on VDSA survey, 2010-11 to 2014-15

Table 4. Share of cereals purchased from PDS in total cereals consumed by sample households in eastern India, 2010-11 to 2014-15

(in per cent)

State	Labour households	Farm-size				
		Marginal	Small	Medium	Large	All
Bihar	22.3	6.4	4.0	0.0	0.1	8.1
Jharkhand	29.5	25.4	25.2	22.5	6.9	25.3
Odisha	35.8	35.9	31.4	34.5	24.6	34.0
Eastern India	28.0	21.9	19.4	18.4	10.8	21.5

Source: Authors' calculations based on VDSA survey, 2010-11 to 2014-15

followed by Jharkhand (25.3%) and Bihar (8.1%). Inter-state disparities in PDS dependence can be attributed to a number of factors such as difference in performance of PDS delivery services in the states, socio-economic profile of households and food habits (Parappurathu *et al.,* 2015; Kumar *et al.,* 2016). The dependence of household on cereals consumption showed a negative relationship with the farm-size. This may be attributed to the fact that large-size farm households are able to produce large quantity of foodgrains and thus their dependence on other sources would be less. Further, it also indicates the inclusive focus of social safety net programmes like PDS.

Dietary Diversity

The dietary diversity is a good indicator for assessing nutritional adequacy (Jones *et al*., 2014). The dietary diversity of foods is positively associated with energy and nutrients intake (Kant, 2004; Rose *et al*., 2002; Tarini *et al*., 1999). It is also found to be positively correlated with the three pillars of food security, viz. availability, access and utilization (Bernal and Lorenzana, 2003; Styen *et al*., 2006; Hillbrunner and Egan, 2008). Therefore, estimating household dietary diversity can be an alternative and easier pathway to understand household-level food and nutrition security (Taruvinga *et al*., 2013; Thorne-Lyman *et al*., 2010; Headey and Ecker, 2013). An estimate of dietary diversity score is presented in Table 5. The dietary diversity varied from 0.65 in Jharkhand to 0.78 in Bihar with an average of 0.72 for the sample households of eastern India. There is not much variation in dietary scores among different categories of farm sizes and it did not reveal any consistent pattern with farm-size. Surprisingly, the labour households had the highest dietary diversity scores in all the three states as compared to the farming households. This could be attributed to the labour households' dependence on markets and other sources for food consumption and therefore, more liberty to choose from wider choices.

Table 5. Simpson Index of Dietary Diversity for sample households across farm-size classes in eastern India, 2010-11 to 2014-15

State	Labour households	Farm-size				
		Marginal	Small	Medium	Large	All
Bihar	0.84	0.77	0.79	0.72	0.77	0.78
Jharkhand	0.77	0.72	0.74	0.75	0.63	0.73
Odisha	0.67	0.64	0.65	0.65	0.65	0.65
Eastern India	0.76	0.71	0.72	0.7	0.71	0.72

Source: Authors' calculations based on VDSA survey, 2010-11 to 2014-15

Table 6. Estimated scores of Simpson Index of Crop Production Diversity for sample households across farm-size classes in eastern India, 2010-11 to 2014-15

State	Labour households	Farm-size				
		Marginal	Small	Medium	Large	All
Bihar	0.40	0.57	0.57	0.55	0.57	0.56
Jharkhand	0.00	0.22	0.21	0.16	0.33	0.21
Odisha	0.25	0.24	0.29	0.32	0.32	0.27
Eastern India	0.32	0.34	0.36	0.33	0.43	0.34

Source: Authors' calculations based on VDSA survey, 2010-11 to 2014-15

Production Diversity

The average level of agricultural diversification was found to be low among sample households in eastern India. The level of crop diversification was relatively higher in Bihar (0.56) than in Jharkhand (0.21) and Odisha (0.27). Further, the level of crop diversification has not depicted any explicit relationship with farm-size. It seems the choice of crop cultivation was dictated more by the agro-climatic conditions of the regions rather than by individual choices or resource endowments of the farm households.

Patterns of Calorie and Protein Intake

The dietary profile of sample households in terms of their calorie and protein intake is presented in Tables 7 and 8, respectively. This shows that intake of calorie and protein varied significantly across different farm-sizes of households. On an average, this shows a positive relationship with farm-size. However, the relationship between farm-size and nutritional intake does not show any pattern in Jharkhand and Odisha. Though, the calorie intake does not exhibit substantial variation across states, it is relatively higher in Bihar.

The average level of protein intake among sample households was 61 g/capita/day; which is comparable with the national rural average of 60.7 g/capita/day (GoI, 2014). A similar picture emerges from the protein consumption pattern (Table 8). The average level of nutrition consumption masks the severity and magnitude of under- and mal-nutrition among farming households in these states. A careful perusal of the incidence of calorie and protein deficiencies indicates that 63.2 per cent of the farming population under study is deficit in calorie intake and 70.6 per cent is deficit in protein intake.

Determinants of Dietary Diversity: Role of Agricultural Production Diversity

The results on relationship between household dietary diversity and household production diversity are presented in Table 9. A perusal of Table 9 reveals that household dietary diversity is positively and significantly associated with the production diversity. It is expected in a context where markets have not yet been able to function efficiently and the majority of households rely on own production to satisfy their basic food needs (Kumar *et al*., 2015). The household-size

Table 7. Calorie intake and incidence of calorie deficiency for sample households across farm-size classes in eastern India, 2010-11 to 2014-15

State	Labour households	Farm-size				
		Marginal	Small	Medium	Large	All
Calorie intake (kcal/capita/day)						
Bihar	2185	2366	2605	2942	3070	2425
Jharkhand	2166	2289	2282	2210	3082	2276
Odisha	2379	2362	2498	2402	2385	2399
Eastern India	2248	2336	2463	2497	2761	2368
Incidence of calorie deficiency (%)						
Bihar	75.6	65.5	47.3	21.9	24.6	58.8
Jharkhand	82.5	68.7	74.2	77.0	28.3	71.4
Odisha	60.8	61.8	55.7	67.3	67.6	61.4
Eastern India	72.9	65.7	58.0	51.5	41.8	63.2

Source: Authors' calculations based on VDSA survey, 2010-11 to 2014-15

Table 8. Protein intake for sample households across farm-size classes in eastern India, 2010-11 to 2014-15

State	Labour households	Farm-size				
		Marginal	Small	Medium	Large	All
Protein intake (g/capita/day)						
Bihar	61	66	73	82	85	68
Jharkhand	52	54	54	52	82	54
Odisha	60	59	63	62	62	61
Eastern India	58	60	63	65	74	61
Incidence of protein deficiency (%)						
Bihar	73.0	63.6	44.6	18.7	17.4	56.3
Jharkhand	90.0	83.7	84.4	88.7	28.3	84.3
Odisha	80.7	78.0	72.7	81.7	75.3	77.7
Eastern India	78.7	74.0	65.8	58.3	41.2	70.6

Source: Authors' calculations based on VDSA survey, 2010-11 to 2014-15

has been found to have a positive and significant effect on household dietary diversity. Due to economies of scale, a larger household is expected to consume a more varied diet (Lee, 1989; Das, 2014). The households having older heads have depicted a lower dietary diversity as revealed from the negative and significant coefficient associated with this variable. However, the education of household-head has been observed to have significant and positive effect. Educated people are more concerned about nutritionally balanced diet and positive relationship between dietary diversity and education has been observed in some earlier studies also (Moon *et al*., 2002; Variyam *et al*., 1998; Parappurathu *et al*., 2015).

The levels of annual per-capita expenditure and of food expenditure by the households have shown a strong influence on the level of dietary diversity. However, the share of food expenditure in total consumption expenditure has not shown any effect on dietary diversity. The access to PDS turned out to be a major determinant of dietary diversity. The access to subsidized food through PDS saves households' budgetary resources for food and thus enables the

Table 9. Multiple regression results of determinants of household dietary diversity

Dependent variable: Dietary diversity index (range 0 to 1)

Variables	Coefficient	Std. error
Agricultural production index (Range 0 to 1)	0.059***	(0.017)
Socio-demographic variables		
log (age of the household-head) (in years)	-0.039**	(0.017)
Gender of household-head (male = 1, female=0)	-0.018	(0.018)
Education of household-head (secondary & above = 1, otherwise =0)	0.012	(0.014)
Caste affiliation (SC/ST = 1, others =0)	0.008	(0.010)
log (household size) (No.)	0.038***	(0.011)
Vegetarian dummy (did not consume any non-vegetarian food = 1, otherwise = 0)	0.003	(0.013)
Non-farm source of income (atleast one member employed in non-farm sector = 1, otherwise =0)	0.008	(0.009)
Variables of ownership of productive assets		
Landless (Yes = 1, otherwise =0)	0.044	(0.029)
Marginal farm-size (Yes = 1, otherwise = 0)	0.007	(0.026)
Small farm-size (Yes = 1, otherwise = 0)	0.004	(0.027)
Medium farm-size (Yes = 1, otherwise = 0)	-0.001	(0.028)
Large farm-size (Yes = 1, otherwise = 0)	-	
Milk-producing household (Yes = 1, otherwise = 0)	0.029***	(0.009)
Economic variables		
log (annual per-capita total expenditure) (in ₹)	0.041***	(0.007)
log (share of food expenditure to total expenditure)	0.001	(0.010)
log (household assets value) (in ₹)	-0.001	(0.002)
Other variables		
Access to PDS (Yes = 1, otherwise = 0)	0.014	(0.009)
log (share of home produced food) (%)	-0.004	(0.004)
log (market distance from home) (km)	0.026***	(0.006)
log (dependency ratio)	-0.002	(0.014)
Constant	1.106***	(0.129)
Observations (No.)	2,033	
Number of groups	488	
Wald $chi^2(20)$	122.51	

households to purchase additional food commodities from the market. The milk-producing households have shown a higher dietary diversity. The milk production can influence household food consumption in two ways: (i) by enhancing the availability of milk for self-consumption and (ii) by increasing cash income which helps in purchase of additional food commodities from the market. No significant difference has been observed across social groups, farm-size categories and households asset values. The women are reported to devote more attention to consumption of a nutritious diet (Dewan *et al*., 2011). However, we have not found any effect of gender on dietary diversity.

Determinants of Calorie and Protein Intake: Role of Dietary Diversity

We further examined whether dietary diversity had an impact on nutritional intake. The results on the effect of household dietary diversity on calorie and protein intake are presented in Table 10. Our results show that dietary diversity is positively and significantly associated with the level of calorie and protein intake

Table 10. Multiple regression results of determinants of household nutritional intake

Variables	Dependent variable			
	log (per-capita calorie per day)		log (per-capita protein per day)	
	Coeffi-cient	Std. error	Coeffi-cient	Std. error
Dietary diversity index (Range 0 to 1)	0.069***	(0.022)	0.144***	(0.024)
Socio-demographic variables				
log (age of the household-head) (in years)	0.002	(0.022)	0.008	(0.024)
Gender of the household-head (male = 1, female=0)	-0.062***	(0.021)	-0.057**	(0.022)
Education of household-head (secondary & above = 1, otherwise =0)	0.008	(0.017)	0.015	(0.018)
Caste affiliation (SC/ST = 1, others =0)	-0.027**	(0.011)	0.009	(0.012)
log (household size) (No.)	-0.086***	(0.013)	-0.063***	(0.014)
Vegetarian dummy (did not consume any non-vegetarian food = 1, otherwise = 0)	0.054***	(0.014)	0.086***	(0.015)
Non-farm source of income (atleast one member employed in non-farm sector = 1, otherwise =0)	0.014	(0.009)	0.012	(0.010)
Variables of ownership of productive assets				
Landless (Yes = 1, otherwise =0)	0.014	(0.034)	0.021	(0.037)
Marginal farm-size (Yes = 1, otherwise = 0)	0.029	(0.031)	0.036	(0.034)
Small farm-size (Yes = 1, otherwise = 0)	0.029	(0.032)	0.031	(0.034)
Medium farm-size (Yes = 1, otherwise = 0)	0.012	(0.033)	0.019	(0.035)
Large farm-size (Yes = 1, otherwise = 0)	-		-	
Milk producing household (Yes = 1, otherwise = 0)	-0.035***	(0.009)	-0.012	(0.010)
Economic variables				
log (annual per-capita total expenditure) (in ₹)	0.241***	(0.008)	0.278***	(0.008)
log (share of food expenditure to total expenditure)	0.226***	(0.010)	0.221***	(0.011)
log (household assets value) (in ₹)	0.011***	(0.002)	0.007***	(0.002)
Other variables				
Access to PDS (Yes = 1, otherwise = 0)	-0.018*	(0.010)	-0.054***	(0.011)
log (share of home produced food)	0.002	(0.004)	-0.006	(0.005)
log (market distance from home)	-0.037***	(0.007)	-0.038***	(0.007)
log (dependency ratio)	-0.030*	(0.015)	-0.019	(0.016)
Constant	4.964***	(0.149)	0.862***	(0.161)
Observations (No.)	2,033		2,033	
Number of groups	488		488	
Wald chi^2 (20)	1484.80		1624.63	

by the household members and thus we may say that dietary diversity ensures better nutritional intake. The other variables which have shown significant effect on the intake of calories include gender of household-head, caste, household size, farm size, monthly per-capita expenditure, share of food expenditure in consumption expenditure, dependency ratio, etc. The households headed by a male have depicted the probability of consuming lesser amount of calories as compared to female-headed households. The SC households have been observed consuming lesser calories than their counterparts in other castes. The calorie-intake has depicted an inverse relationship with the household size. The vegetarian households have

been found to consume more calories. The households producing milk have been observed to consume lesser amount of calories. The economic variables represented by annual per-capita expenditure, share of expenditure on food, and household asset value have shown a positive and significant effect on calorie intake. The distance from market and dependency ratio has revealed a significant negative influence on calorie intake.

Determinants of Calorie and Protein Deficiency

The determinants of calorie and protein deficiency are presented in Tables 11 and 12, respectively. A perusal of these tables shows that household dietary diversity plays an important role in reducing calorie and protein deficiencies. The effect of dietary diversity is more apparent on incidence of protein deficiency than calorie deficiency. One unit increase in dietary diversity would reduce the deficiencies in intake of

Table 11. Determinants of calorie deficiency

Dependent variable: Calorie deficiency

Variables	Logit Model		Marginal Effect	
	Coeffi-cient	Std. error	dy/dx	Std. error
Dietary diversity index (Range 0 to 1)	-1.080**	(0.499)	-0.109**	(0.050)
Socio-demographic variables				
log (age of the household-head) (in years)	-0.770*	(0.435)	-0.077*	(0.043)
Gender of the household head (male = 1, female=0)	0.904**	(0.446)	0.091**	(0.044)
Education of household head (secondary & above = 1, otherwise =0)	-0.051	(0.330)	-0.005	(0.033)
Caste affiliation (SC/ST = 1, others =0)	0.862***	(0.266)	0.086***	(0.026)
log (household size) (No.)	1.854***	(0.288)	0.187***	(0.026)
Vegetarian dummy (did not consume any non-vegetarian food = 1, otherwise = 0)	-1.645***	(0.319)	-0.166***	(0.032)
Non-farm source of income (atleast one member employed in non-farm sector = 1, otherwise =0)	-0.208	(0.216)	-0.020	(0.021)
Variables of ownership of productive assets				
Landless (Yes = 1, otherwise =0)	-0.806	(0.681)	-0.081	(0.068)
Marginal farm-size (Yes = 1, otherwise = 0)	-1.015*	(0.612)	-0.102*	(0.061)
Small farm-size (Yes = 1, otherwise = 0)	-0.623	(0.624)	-0.062	(0.062)
Medium farm-size (Yes = 1, otherwise = 0)	-0.955	(0.664)	-0.096	(0.066)
Large farm-size (Yes = 1, otherwise = 0)	-		-	
Milk producing household (Yes = 1, otherwise = 0)	0.324	(0.215)	0.032	(0.021)
Economic variables				
log (annual per-capita total expenditure) (in ₹)	-3.690***	(0.294)	-0.372***	(0.015)
log (share of food expenditure to total expenditure)	-3.681***	(0.338)	-0.371***	(0.024)
log (household assets value) (in ₹)	-0.204***	(0.050)	-0.020***	(0.004)
Other variables				
Access to PDS (Yes = 1, otherwise = 0)	0.844***	(0.234)	0.085***	(0.023)
log (share of home produced food)	0.075	(0.107)	0.007	(0.010)
log (market distance from home)	1.175***	(0.167)	0.118***	(0.016)
log (dependency ratio)	0.323	(0.354)	0.0326	(0.035)
Constant	45.89***	(4.300)		
ln sig2u	1.035***	(0.203)		
Observations (No.)	2,033			
Number of groups	488			

Table 12. Determinants of protein deficiency

Dependent variable: Protein deficiency

Variables	Logit Model		Marginal Effect	
	Coeffi-cient	Std. error	dy/dx	Std. error
Dietary diversity index (Range 0 to 1)	-2.549***	(0.547)	-0.234***	(0.049)
Socio-demographic variables				
log (age of the household-head) (in years)	-0.788*	(0.458)	-0.072*	(0.042)
Gender of the household-head (male = 1, female=0)	0.855*	(0.485)	0.078*	(0.044)
Education of household head (secondary & above = 1, otherwise =0)	-0.316	(0.335)	-0.029	(0.030)
Caste affiliation (SC/ST = 1, others =0)	-0.129	(0.292)	-0.011	(0.026)
log (household size) (No.)	0.875***	(0.284)	0.080***	(0.025)
Vegetarian dummy (did not consume any non-vegetarian food = 1, otherwise = 0)	-2.363***	(0.325)	-0.217***	(0.028)
Non-farm source of income (atleast one member employed in non-farm sector = 1, otherwise =0)	-0.158	(0.228)	-0.014	(0.021)
Variables of ownership of productive assets				
Landless (Yes = 1, otherwise =0)	-0.656	(0.695)	-0.060	(0.063)
Marginal farm-size (Yes = 1, otherwise = 0)	-0.628	(0.621)	-0.057	(0.057)
Small farm-size (Yes = 1, otherwise = 0)	-0.152	(0.631)	-0.014	(0.057)
Medium farm-size (Yes = 1, otherwise = 0)	-0.025	(0.671)	-0.0023	(0.061)
Large farm-size (Yes = 1, otherwise = 0)	-		-	
Milk-producing household (Yes = 1, otherwise = 0)	-0.460**	(0.226)	-0.042**	(0.020)
Economic variables				
log (annual per-capita total expenditure) (in ₹)	-4.196***	(0.367)	-0.386***	(0.017)
log (share of food expenditure to total expenditure)	-3.726***	(0.398)	-0.343***	(0.026)
log (household assets value) (in ₹)	-0.099*	(0.051)	-0.0091*	(0.004)
Other variables				
Access to PDS (Yes = 1, otherwise = 0)	1.198***	(0.248)	0.110***	(0.022)
log (share of home produced food)	0.348***	(0.109)	0.031***	(0.009)
log (market distance from home)	1.158***	(0.195)	0.106***	(0.017)
log (dependency ratio)	0.309	(0.367)	0.028	(0.033)
Constant	53.43***	(5.370)		
ln sig2u	0.998***	(0.230)		
Observations (No.)	2,033			
Number of groups	488			

Note: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

calorie and protein by 11 per cent and 23 per cent, respectively. Besides dietary diversity, various socio-economic characteristics of households also influence the incidence of deficiencies in intake of calorie and protein. The households headed by an elder person have shown lower probability of being deficient in calorie and protein intake. The households belonging to SC/ST castes have revealed a higher probability of being deficient in calorie and protein intake. The economic variables represented by monthly per-capita expenditure, household asset value and share of food expenditure in consumption expenditure have been found to play a significant role in reducing calorie and protein deficiency among the sample households. The

market distance has shown a positive relationship with nutritional deficiency, as expected. No significant effect of education on indices of calorie and protein deficiency has been observed. This may be due to a positive correlation between income and level of education. Further, the households producing milk have lesser probability of being deficient in protein intake. Again being vegetarians do not put the households in a disadvantageous position in terms of calorie and protein intake among sample agricultural households in eastern India.

Conclusions and Policy Implications

This study has contributed to better understanding of the relationships between agricultural production diversity and dietary diversity. The regression results based on the panel data of 480 households from three states, viz. Bihar, Jharkhand and Odisha in eastern India for 5 years, have shown that agricultural production diversity is a major determinant of dietary diversity. The dietary diversity in turn has a strong effect on calorie and protein intake. From a policy perspective, the findings suggest that efforts to promote agricultural diversification will be helpful to enhance food and nutrition security in the country. Agricultural programmes and policies oriented towards reducing under-nutrition should promote diversity in agricultural production rather than emphasizing on increasing production through focusing on selected staple crops, as is usually observed in several states of India. The huge fertilizer subsidies and government procurement programme, limited the production to a few crops, provide little incentives for farmers to diversity their production portfolio. Often the linkages between agriculture and nutrition seem too difficult to be pursued. This study would help in shaping the agenda of agricultural development conducive for enhancing nutrition among the farming households. Though our results have clearly shown an association between agricultural production portfolios with diet quality, in-depth research is needed to explicitly identify the precise nutritional benefits (e.g. in terms of stunting, wasting, obesity, BMI etc.) of household level composition of agricultural activities.

References

Bernal, R.J. and Lorenzana, A.P. (2003) Dietary diversity and associated factors among beneficiaries of 77 child care centers: Central regional. *Venezuela*, **53**: 52-81.

Dahiya, S. and Viswanathan, B. (2015) Women's malnutrition in India: The role of economic and social status' margin. *The Journal of Applied Economic Research*, **9**(3): 1-27.

Das, M. (2014) *Measures, Spatial Profile and Determinants of Dietary Diversity: Evidence from India*. Working paper 2014-045. Indira Gandhi Institute of Development Research (IGIDR).

De Janvry, A. and Sadoulet, E. (2001) Agricultural growth and poverty reduction: Additional evidence. *The World Bank Research Observer*, **25**(1): 1-20.

Dewan, A., Lisa, C.S. and Tauhhidur, R. (2011) Determinants of dietary quality: Evidence from Bangladesh. *World Development,* **39**(12): 2221-2231.

Gillespie, S. and Kadiyala, S. (2012) Exploring the agriculture–nutrition disconnect in India. In: *Reshaping Agriculture for Nutrition and Health*, Eds: S. Fan, and R. Pandya-Lorch. International Food Policy Research Institute (IFPRI), Washington DC. pp 173-181.

GoI (Government of India) (2014) *Nutritional Intake in India 2011-12*. NSS 68th round. Ministry of Statistics and Programme Implementation. National Sample Survey Organisation (NSSO), New Delhi.

Headey, D. and Ecker, O. (2013) Rethinking the measurement of food security: From first principles to best practice. *Food Security*, **5**(3): 327–343.

Hillbrunner, C. and Egan, R. (2008) Seasonality, household food security and nutritional status in Dinajpur, Bangladesh. *Food and Nutrition Bulletin*, **29**(3): 221–231.

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**(2014): 1–12.

Kant, A. K. (2004) Dietary patterns and health outcomes. *Journal of American Dietetic Association*, **104**: 615–635.

Kumar, A., Parappurathu, S., Babu, S. and Betne, R. (2016) Public distribution system in Bihar, India: Implication for food security. *Journal of Agricultural & Food Information*.

Kumar, N., Harris, J. and Rawat, R. (2015) If they grow it, will they eat and grow? Evidence from Zambia on agricultural diversity and child undernutrition. *The Journal of Development Studies*, **51**(8): 1060-1077.

Lee, Jonq-Ying and Brown, M.G. (1989) Consumer demand for food diversity. *Southern Journal of Agricultural Economics*, **21**(2): 47-53.

Malhotra, R. (2014) *India Public Policy Report 2014: Tackling, Poverty, Hunger and Malnutrition*. Oxford University Press, New Delhi.

Moon, W., Wojciech J.F., Larry R.B., Anna V.R., Pavlina P., Jordan J. and Manjeet S.C. (2002) Demand for food variety in an emerging market economy. *Applied Economics*, **34**(5): 573-581.

Parappurathu S., Kumar, A., Bantilan, M.C.S. and Joshi, P.K. (2015) Food consumption patterns and dietary diversity in eastern India: Evidence from village level studies (VLS). *Food Security*, **7**(5): 1031-1042.

Rose, D., Meershoek, S., Ismael, C. and Mc Ewan, M. (2002) Evaluation of a rapid field tool for assessing household diet quality in Mozambique. *Food and Nutrition Bulletin*, **23**:181–189.

Slavchevska, V. (2015) Gender differences in agricultural productivity: The case of Tanzania. *Agricultural Economics*, **46**(3): 335–355.

Styen, P. N., Nel, H. J., Nantel, G., Kennedy, G. and Labadarios, D. (2006) Food variety and dietary diversity scores in children: Are they good indicators of dietary adequacy? *Public Health Nutrition*, **9**(5): 644–650.

Tarini, A., Bakari, S. and Delisle, H. (1999) The overall nutritional quality of the diet is reflected in the growth of Nigerian children. *Sante*, **9**: 23–31.

Taruvinga, A., Muchenje, V. and Mushunje, A. (2013) Determinants of rural household dietary diversity: The case of Amatole and Nyandeni districts, South Africa. *International Journal of Development and Sustainability*, **2**(4): In Press.

Thorne-Lyman, A. L., Valpiani, N., Sun, K., Semba, R. D., Klotz, C. L., Kraemer, K., Akhter, N., de Pee, S., Moench-Pfanner, R., Sari, M. and Bloem, M.W. (2010) Household dietary diversity and food expenditures are closely linked in rural Bangladesh: Increasing the risk of malnutrition due to the financial crisis. *The Journal of Nutrition*, **140**: 182S–188S.

Variyam J.N., Blaylock, J., Smallwood, D. and Basiotis, P.P. (1998) *USDA's Healthy Eating Index and Nutrition Information*. Economic Research Service/USDA. Washington DC.

Viswanathan, B., David, G., Vepa, S. and Bhavani, R.V. (2015) Dietary Diversity and Women's BMI among Farm Households in Rural India. *Lansa Working Paper Series*, **2015** (03).

Webb, P. and Block, S. (2011) Support for agriculture during economic transformation: Impacts on poverty and undernutrition. *Proceedings of the National Academy of Sciences*, **109**(31): 12309-12314.

World Bank (2007) *From Agriculture to Nutrition: Pathways, Synergies and Outcomes*. Agriculture and Rural Development Department, Washington DC.

Appendix I

Particulars	Bihar	Jharkhand	Odisha	Eastern India
Socio-demographic variables				
Age (years)	51.8	47.4	48.8	49.4
Male-headed households (%)	94.6	90.6	98.2	94.5
Family size (No.)	7.2	5.4	5.1	5.9
Vegetarian household (%)	37.5	0.5	1.1	13.6
Employed in non-farm sector (%)	74.7	62.2	53.9	63.8
Milk producing household (%)	54.1	21.9	33.3	36.9
Education level of the household-head (%)				
Illiterate	22.5	44.8	21.1	29.3
Primary	10.7	20.5	39.9	23.5
Middle	43.0	29.1	31.4	34.7
Secondary	7.7	4.0	5.2	5.7
Higher secondary & above	16.2	1.5	2.4	6.9
Social structure by caste (%)				
Schedule castes	42.0	4.1	25.9	24.5
Schedule tribes	45.0	34.2	51.8	43.7
Other backward castes	13.0	6.9	14.9	11.6
General castes	0.0	54.7	7.5	20.1
Variables of ownership of productive assets (%)				
Labour	20.6	12.4	18.4	17.3
Marginal	55.1	62.9	45.1	54.3
Small	14.1	16.2	21.0	17.0
Medium	6.8	7.5	11.7	8.6
Large	3.3	1.1	3.8	2.8
Economic variables				
Per-capita total expenditure, (₹ /year)	8682.1	5137.3	12399.6	8757.1
Share of food expenditure to total expenditure (%)	56.2	49.0	61.6	55.7
Household assets value (₹)	50445.5	34673.1	14132.0	33944.4
Other variables				
Dietary diversity index (Range 0 to 1)	0.8	0.7	0.7	0.7
Agricultural production index (Range 0 to 1)	0.4	0.2	0.2	0.3
Per-capita calorie intake (kcal/day)	2425.1	2275.5	2399.0	2368.2
Per-capita protein intake (g/day)	68.0	54.1	60.6	61.1
Access of households to PDS (%)	34.4	66.8	91.3	63.5
Share of home produced food (%)	47.8	34.1	28.1	36.9
Market distance (km)	7.8	8.4	5.8	7.3
Dependency ratio	68.8	61.5	59.4	63.4
Calorie deficiency household (%)	58.8	71.4	61.4	63.2
Protein deficiency household (%)	56.3	84.3	77.7	70.6