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Understanding the Linkages between Crop Diversity and Household Dietary Diversity in the Semi-Arid Regions of India

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Abstract

Agriculture is fundamental to achieving nutrition goals; it provides the food, energy, and nutrients essential for human health and well-being. This paper has examined crop diversity and dietary diversity in six villages using the ICRISAT Village Level Studies (VLS) data from the Telangana and Maharashtra states of India. The study has used the data of cultivating households for constructing the crop diversity index while dietary diversity data is from the special purpose nutritional surveys conducted by ICRISAT in the six villages. The study has revealed that the cropping pattern is not uniform across the six study villages with dominance of mono cropping in Telangana villages and of mixed cropping in Maharashtra villages. The analysis has indicated a positive and significant correlation between crop diversity and household dietary diversity at the bivariate level. In multiple linear regression model, controlling for the other covariates, crop diversity has not shown a significant association with household dietary diversity. However, other covariates have shown strong association with dietary diversity. The regression results have revealed that households which cultivated minimum one food crop in a single cropping year have a significant and positive relationship with dietary diversity. From the study it can be inferred that crop diversity alone does not affect the household dietary diversity in the semi-arid tropics. Enhancing the evidence base and future research, especially in the fragile environment of semi-arid tropics, is highly recommended.

Key words: Crop diversity, household dietary diversity, semi-arid tropics, farm linkages, Telangana, Maharashtra

JEL Classification: Q19

Introduction

Agriculture affects health and nutrition in very tangible ways. It can provide increased income, food security, and gender equity and can also increase the quantity and quality of food available to poor households. Agriculture is a source of livelihood for a sizable portion of the world's rural population. Increased agricultural productivity raises household income, enabling households to achieve dietary diversity and good nutrition, as well as preventing malnutrition (Hawkes and Ruel, 2006). Malnutrition is recognized as a major issue among low-income households in developing countries (FAO, 2012). An emerging line of research is to tackle this problem through the channel of agriculture. Among the different pathways (identified by Gillespie *et al*., 2012; Hawkes and Ruel, 2008 among many others) through which agriculture and nutrition are interlinked, one of the most direct ones is as source of food.

India makes for an interesting case study to explore this relationship because of (i) a significant rural population (approximately 68%), (ii) poor nutrition status, and (iii) agriculture still remains as one of the most dominating sectors in terms of livelihood

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generation in the economy. Therefore, a causal link between crop diversity and dietary diversity can potentially help in recognizing crop diversification as a strategy to promote dietary diversity among households. Dietary diversity has been long known by nutritionists as a key element of high quality diet as it allows for the consumption of a wider variety of food groups (Chatterjee, 2016). Ruel (2003) summarized that dietary diversity is a promising measurement tool and the existing literature confirms association across dietary diversity, dietary quality, nutrient adequacy and food security, though they recommend future research in order to operationalize it further.

The research on associating crop diversity to dietary diversity pattern is increasingly gaining prominence for the past few years. However, conclusions from studies exploring the link between farm diversity and dietary diversity have been far from uniform. Studies like Pellegrini and Tasciotti, 2014; Jones *et al*., 2014; Kumar *et al*., 2015; Bhagowalia *et al*., 2012, among many others have concluded in favour of impact of farm diversification, while some others like Sibhatu *et al*. (2015) and Rajendran *et al*. (2014) did not find any significant role of the same. Against this background, this paper tries to empirically understand the link between agriculture and nutrition, and exploits the relationship between crop diversity and dietary diversity at the household level in the semi-arid tropics of India. The objective of this study is to ascertain whether an increased diversity of crops in farmers' fields directly or indirectly leads to more diverse diets for the households. This paper has examined crop diversity and dietary diversity in six villages using the ICRISAT Village Level Studies (VLS) data from the states of Telangana and Maharashtra in India. Two villages are from Mahbubnagar district in Telangana and two each are from Solapur and Akola districts in Maharashtra. While the villages are located in the disadvantaged agro-climatic regions of the semi-arid tropics, they are also located in two rapidly growing states of India.

Data and Methodology

This study is primarily based on VLS dataset for the year 2013-2014 generated by International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). This dataset has been collected by ICRISAT's resident field investigators who lived in the villages (Walker and Ryan, 1990; Rao *et al*., 2009). Out of the six studied villages of Indian semi-arid tropics, two are from Telangana (Aurepalle and Dokur) and four are from Maharashtra (Shirapur and Kalman under Solapur district, and Kanzara and Kinkhed under Akola district). Aurepalle and Dokur have erratic rainfall and red soil with heterogeneous soil quality (Table 1). On the other hand, Shirapur and Kalman

Table 1. Soil, rainfall and crop characteristics of study regions

Characteristics	Mahbubnagar district (Aurepalle and Dokur)	Solapur district (Shirapur and Kalman)	Akola district (Kanzara and Kinkhed)
Soil	Red soils; marked soil heterogeneity	Deep black soils in lowlands; shallow lighter colour soils in uplands	Black soils; fairly homogeneous
Rainfall	Rainfall unassured; pronounced rainfall uncertainty at sowing	Rainfall unassured; frequent crop failures	Rainfall assured
Major crops (1975-1977)	Kharif or rainy season was the main crop-growing season. The major crops were: Paddy, castor and local *kharif*-sorghum	Main crop growing season was *rabi* or post-rainy season. *Rabi*-sorghum was the major crop	Main crop growing season was *kharif* season. Upland cotton, mung bean and hybrid sorghum were major crops
Major crops in recent years	Kharif-season crops: Paddy, cotton, castor, and *kharif*-sorghum *Rabi*-season crops: Groundnut and sunflower	Sugarcane is the major crop. *Kharif*-season crops: Pigeon pea, onion *Rabi*-season crop: Sorghum	Cotton is the major crop. *Kharif*-season crops: Pigeon pea, kharif- sorghum, soybean. *Rabi*-season crop: Wheat

Source: Deb *et al*. (2015)

Table 2. Categories of food groups

Sl.No.	Food group (Total 16)	HDDS food groups (Total 12 groups)
1	Cereals	Cereals
2	White roots and tubers	White tubers and roots
3	Vitamin-A rich vegetables and tubers	Vegetables
4	Dark green leafy vegetables	
5	Other vegetables	
6	Vitamin-A rich fruits	Fruits
7	Other fruits	
8	Organ meat	Meat
9	Flesh meats	
10	Eggs	Eggs
11	Fish and seafood	Fish and other seafood
12	Legumes, nuts and seeds	Legumes, nuts and seeds
13	Milk and milk products	Milk and milk products
14	Oils and fats	Oils and fats
15	Sweets	Sweets
16	Spices, condiments, beverages	Spices, condiments and beverages

Source: FAO (2013)

have deep black soils in lowlands and shallower lighter colour soils in uplands. Rainfall is erratic in Shirapur and Kalman also. In Kanzara and Kinkhed, soils are black and of homogeneous quality, and rainfall is assured (Deb *et al*., 2014).

The current study has mostly utilized the data of households involved in crop cultivation for constructing the crop diversity index and crop count, while dietary diversity data are from the special nutritional surveys conducted by ICRISAT in these six villages. The number of cultivating households selected for study was 289 comprising 65 from Mahabubnagar, 93 from Akola and 131 from Solapur districts.

Dietary Diversity Measurement

The study verified the hypothesis that increased diversity of crops in farmers' fields leads to an increased diversity of diets among households. Accordingly, several studies have constructed dietary diversity scores (Kant *et al*., 1993; Drewnowski *et al*., 1997; Jones *et al*., 2014). Dietary diversity is a qualitative measure of food consumption that reflects household's access to a variety of foods, and is also a proxy for the nutritional adequacy of individual's diets (Ruel, 2003; Kennedy *et al*., 2007). The present study estimated the household dietary diversity score (HDDS) based on FAO guidelines (FAO, 2013). The dietary diversity scores described in these guidelines consist of a simple count of food groups that a household or an individual has consumed over the preceding 24 hours recall period and HDDS is calculated for 12 food groups listed in the Table 2.

It is to be mentioned that Individual dietary diversity scores aim to reflect nutrient adequacy, whereas the HDDS is a snapshot of the economic ability of a household to access a variety of foods (FAO, 2013). Results from previous studies have showed that, an increase in dietary diversity is associated with socioeconomic status and household food security measured in terms of household energy availability (Jones *et al*., 2014; Lo, *et al*., 2012; Thorne-Lyman *et al*., 2009; Faber *et al*., 2009; Migotto *et al*., 2006; Ohiokpehai, 2003; Hoddinot and Yohannes, 2002;) and monthly per capita caloric availability from non-staples for all households (Hoddinot and Yohannes, 2002) and household expenditure (Thorne-Lyman *et al*., 2009).

Crop Diversity Measurement

The study has explored two different measurements of variables, viz. crop count and Simpson's Index (Simpson, 1949), also called crop diversity index to measure crop diversity in agricultural seasons (combine rainy, post-rainy and annual seasons' crops). The crop count was constructed based on the sums of the total number of different crops cultivated by the households in a crop year (i.e., July, 2013 to June, 2014) considering the earlier specified seasons. Whereas, Simpson's Index is measured with area share including food and non-food crops in the cropping pattern described in Equation (1):

$$\text{Simpson's Index (Crop Diversity Index)} = 1 - \sum_{i=1}^{k} p_i^2 \quad \ldots(1)$$

where, p_i is the share of cultivated area for the i^{th} crop in the total cultivated area of a farm household.

Analytical Framework

This paper has examined the effect of crop diversity on dietary diversity of farming households by estimating the model defined in Equation (2) through multiple linear regression analysis using cross-section data. The aim of using multiple linear regression model was to control other covariates like, individual and household characteristics, land ownership, regional effects, expenditure on food and non-food items while the estimate net effect of crop diversity on dietary diversity was calculated.

Yi = f (individual characteristics, household characteristics, agricultural characteristics, farm diversity, regional dummies) …(2)

where, Yi is a Household dietary diversity score (HDDS) and i=1,…..N (Number of households). The individual characteristics included gender, level of education and age of household-head. The household characteristics included monthly per capita expenditure on food and non-food items, and household size (No. of people). In addition, the variable dependency ratio was also explored. Agricultural characteristics included net cultivated area. Crop diversity index included two types of measurement variables, namely crop count and Simpson's Index. Finally, regional dummies were also included in the model.

Results and Discussion

Cropping Pattern, Dietary Diversity and Crop Diversity

The cropping pattern was not uniform across the six study villages. The sole cropping is very common in Telangana villages unlike in Maharashtra villages where mixed cropping is practised. In Aurepalle, only six crops were grown in an agricultural year (July 2013-June 2014), the major one was cotton, followed by paddy (in irrigated conditions). Consequently, Dokur invested in nine crops out of which paddy was the major crop in the irrigated conditions. In Solapur region, Kalman ranked high in diversification of crops by growing 23 crops in a single cropping year with several subsistence crops (food crops), viz. sorghum, pigeon pea and onion, followed by Shirapur with 16 crops, the major being sugarcane, sorghum, sorghum fodder and maize. In Akola region, both Kanzara and Kinkhed villages had mostly grown soybean, pigeon pea and wheat among the 15 and 8 crops that were grown in a single cropping year (Deb *et al*., 2014).

The crop count, which is one of the measures of crop diversity, is presented in Figure 1 for the three selected districts. It is evident that most of the sample households grew more than one crop in Akola (91%) and Solapur (90%) districts but mono-cropping was still prevalent. The mixed cropping was much significant in these regions. In Mahabubnagar region more than 50 per cent sample households were engaged in mono cropping under irrigated conditions. No clear trend of "crop monopoly" was apparent, but there was a strong evidence that the practice of intercropping had declined (Palacios, 2012).

Table 3 shows that dietary diversity and crop diversity by various covariates. The overall dietary diversity shows that on an average there were eight types of food groups that a household consumed over the preceding 24-hour recall period at the time of survey. Among the regions, Akola showed higher dietary diversity compared to the overall mean of all the three regions and all of them are significantly different from the overall mean value. The crop diversity index, was highest in Solapur (0.47), followed by Akola (0.44) and Mahabubnagar (0.16) regions. Solapur farmers cultivated more numbers of crops (3.24) vis-à-vis to other two regions. In Mahabubnagar district, even though crop diversity index was found low, the household dietary diversity existed. The results indicate that there is no uniform relation between dietary diversity score and crop diversity score (includes crop diversity index and crop count).

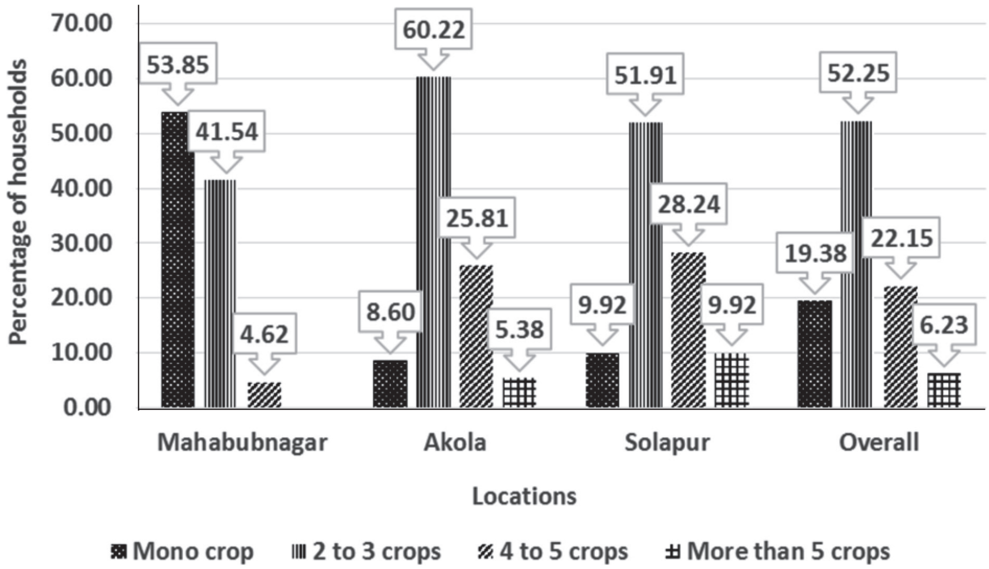

Figure 1. Crop count of households in selected districts
Source: ICRISAT VDSA dataset

Table 3. Region-wise dietary diversity, crop diversity index and crop count

Region	HDD score	Crop diversity index	Crop count
Mahabubnagar	7.43***	0.16***	1.63***
Akola	8.60***	0.44***	2.97
Solapur	7.74***	0.47***	3.24***
Over all	7.95	0.39	2.79

Source: ICRISAT VDSA dataset
Note: *** p<0.01

Table 4. Correlation matrix between household dietary diversity (HDDS) and crop diversity

Variable	HDD score	Crop diversity index	Crop count
HDD score	1		
Crop diversity index	0.2444***	1	
Crop count	0.1886***	0.8119***	1

Source: ICRISAT VDSA dataset
Note: *** p<0.01

Relationship between Dietary Diversity and Crop Diversity: Bivariate and Multivariate Analysis

To understand the effect of crop diversity on dietary diversity, the correlation among dietary and crop diversity was estimated. The dietary diversity score positively and strongly correlates with crop count as well as crop diversity index (Table 4). With a measured correlation matrix of 0.8119, it was observed that crop count and crop diversity index were strongly correlated with each other.

Bivariate regression was run to test the relationship between dietary diversity and crop diversity in two different measures (Table 5). The results of the bivariate regression indicated that dietary diversity was significantly and positively influenced by both crop count and crop diversity index. As crop diversity score refers to the number of crops and also distribution of area cultivated under various crops, it indicates that dietary diversity can be increased by increasing the number of crops as well as even distribution of area under those crops.

The Pearson-correlation matrix showed that dietary diversity score correlated significantly with crop diversity score (crop diversity index and crop count). We also examined the relationship between farm and dietary diversity by using a bivariate model. The

Table 5. Bivariate regression between household dietary diversity score (HDDS) and crop diversity

Variable	Model - 1	Model - 2
	Dependent variable = HDDS	
Crop count	0.100***	
Crop diversity index		0.799***
Constant	7.665***	7.633***
Number of observations	289	289
R square	0.036	0.060

Source: ICRISAT VDSA dataset
Note: *** p<0.01

bivariate model showed similar results. But, the bivariate model did not control other covariates and hence we measured the effect of farm diversity on dietary diversity by controlling for other possible confounding factors such as individual characteristics, household characteristics and factor endowments, etc. (Srinivasulu *et al*., 2014).

Finally, a multiple linear regression model was carried out to control the effect of other covariates on household's dietary diversity in order to capture the net effect of crop diversity (Table 6). For this purpose, two different models were considered to estimate the effect of crop diversity on dietary diversity. The model-1 examined the effect of crop count on dietary diversity by controlling other covariates. In model-2, the independent variable, viz. crop count was replaced with crop diversity index. There are other covariates which included individual characteristics, household characteristics and factor endowments. The variables such as number of people living in the household, monthly per capita expenditure on food and household total operated area were included to control the model.

After controlling for the other covariates, crop diversity did not have a significant association with dietary diversity. However, other covariates showed strong association with dietary diversity (Srinivasulu *et al*., 2014). The regression results showed that 'households which cultivated minimum one food crop in a single cropping year' have a significant and positive relationship with dietary diversity. Household size, expenditure on food and education of household-head have an important roles in increasing the household

Table 6. Multiple linear regression functions: The effect of crop diversity on dietary diversity

Variable	Model - 1	Model - 2
	Dependent variable = HDDS	
Crop counts	-0.0303	
Crop diversity index		0.0012
Is household cultivating any food crop (Yes=1 and No=0)	0.2745***	0.2474**
Household size (No.)	0.1112***	0.1076***
Dependency ratio	0.0275	0.0336
Education of household-head (Literate = 1 and Illiterate = 0)	0.1934**	0.1921**
Age of the household-head (years)	-0.0039	-0.0035
Household operated area (ha)	0.0062	0.0018
Per-capita food expenditure ('000 ₹)	0.0264**	0.0247**
Per-capita non-food expenditure ('000 ₹)	0.0013	0.0014
Sex of the household-head (Male=1 and Female=0)	-0.0639	-0.0728
Akola region	0.8955***	0.8706***
Solapur region	0.0887	0.0531
Constant	6.6303***	6.6278***
Number of observations	289	289
R square	0.467	0.465
Adjusted R square	0.444	0.442

Source: ICRISAT VDSA dataset
Note: *** p<0.01, ** p<0.05, * p<0.1

dietary diversity. With regard to three agro-ecological regions, Akola households have depicted better dietary diversity than Mahabubnagar households with a positive significant coefficient in both the models.

Discussion

This paper has attempted to explore the nature of relationship between agriculture and nutrition based on crop production (crop diversity) and nutrition intake (dietary diversity). The correlation and bivariate regression results from this study have shown that the diversity in farmer's field leads to more diverse diets in the households. The small magnitude of the relationship may be related to the temporal scales of the survey questions, since dietary diversity index is 24-hour retrospective, while crop diversity index reflects crops grown in the past one year. However, the crop diversity does not affect dietary diversity in the study regions when other social and economic covariates are controlled in the multiple linear regression models. This clearly indicates that, except crop diversity, there are other variables that have strong effect on dietary diversity in farm households in the study regions. The cultivation of food crops, number of persons in household, education level of household-head and food consumption expenditure have been found to be the most important factors to have a positive significant impact on the dietary diversity.

Conclusions

The present study has estimated the effects of crop diversity based ICRISAT VLS dataset of household surveys conducted in the semi-arid regions of two states of Telangana and Maharashtra. The descriptive analysis has revealed that agriculture is still practised by the vast majority of households in the semi-arid region, and the highest share of agricultural land is allocated to staple foods, namely rice, sorghum, and wheat, depending on the region and availability of irrigation facilities. Some, commercial crops like cotton and sugarcane are also produced.

While estimates of the crop diversity and crop count do show a small effect of changes on dietary diversity, this specification is not well identified. However, the result of this statistical test has revealed a potentially important behavioural relationship to be investigated in future research. The small effect of crop diversity on dietary diversity is probably due to the weak relationship between dietary diversity data (24-hour data) and crop data (yearly data) used for identification.

The study has inferred that crop diversity alone does not affect dietary diversity in the semi-arid tropics. As farmers do not change crops frequently across agricultural seasons in general, an area of potential research could be to investigate first when farmers choose to diversify production into foods not normally consumed in local diets that meet macro or micronutrient needs of the population. This would yield insights into the design of agricultural interventions which could be expected to have larger nutritional effects (Dillon *et al*., 2015). The most suitable policy mix to improve nutrition in crop farming households will vary from case to case (Sibhatu *et al*., 2015). As agriculture is still the most important source of food, livelihood and employment, especially in the fragile environment of semi-arid regions, there is a need to understand the linkages between agricultural growth and improved nutrition. This calls for more evidence and research as there is a void in data to establish these linkages.

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