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ORIGINAL RESEARCH ARTICLE

Does adoption of agroforestry increase farm production and dietary diversity in the hills of Nepal?

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ABSTRACT

There are few studies on the influence of agroforestry intervention in the farming and food system. We thus conducted this study to assess farm production diversity and household dietary diversity in the coffee-based agroforestry in Deusa village, Solukhumbu district, Nepal. This study collected data through questionnaire survey, food diary checklist for 24 hours diet recall, transect walk, focus group discussions, and key informant interviews. We compared farm production diversity and household dietary diversity scores between two agroforestry types - traditional and coffee-based. We used Pearson's Chi-Square and Fisher's Exact tests to assess the association between agroforestry type and 16 food groups wise consumption. Results showed that the farm production diversity is positively associated with the household dietary diversity. Among 16 food groups, households under coffee-based agroforestry system were more likely to consume dark green leafy vegetables (Chi square- 5.385; df=1; $p<0.05$), and descriptive statistics showed relatively higher consumption for most of the other food groups. It indicates that agroforestry intervention can be beneficial to improve farm production diversity and household dietary diversity in the longer run. Thus, agroforestry promotion is not only important in enhancing biodiversity and farm income but also equally vital in improving food and nutrition security for smallholders.

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INTRODUCTION

The promotion, farming, market and policy developments of both modern agroforestry systems and export oriented cash crop production reveal changing paradigms in addressing the issues of food security (Achterbosch *et al.*, 2014). There is a growing evidence that agroforestry can be one viable solution to solve the issues of both food insecurity and sustainability (Carson, 1992; Neupane *et al.*, 2002). Knowledge about agroforestry system is still developing and the science of agroforestry and its potential livelihood benefits are slowly being considered (McNeely and Schroth, 2006). Government and private organizations are promoting the system in recent years as it is perceived to be favorable in increasing agricultural revenue and household income. Unlike the traditional agroforestry, they introduced newer crop and tree species to the farms previously practicing traditional agroforestry as a part of integrated crop-livestock agriculture (Neupane *et al.*, 2002). One example is the promotion of inclusion of tree crops and cash crops in the mid hills of Nepal.

Inclusion of coffee in the farms of study area Deusa, is a new intervention. Coffee-based agroforestry system is promoted after 2012, while orange and fruit trees were included in their orchards in the past. Since 2012, few organizations have been assisting farmers in adopting the coffee-based agroforestry through the provision of technical know-how, materials support, extension and training together with the application of improved agriculture, livestock and forestry practices. Traditionally, farmers in Deusa practiced the conventional agroforestry, classified as "traditional agroforestry system" in this

paper, through the years to meet the subsistence needs for food, fuel wood, fodder and other means of integrated farming (Pandit *et al.*, 2019). This system incorporates cereal, legumes, tubers and other traditionally grown crops along with locally available fodder and timber trees. Whereas, the improved system, the coffee-based agroforestry system, has introduced new varieties of crops and new species of trees to the local farmers with more focus on coffee. At present, many farmers in the area are incorporating coffee plants on their farm. The ones with mature coffee plants are already receiving the benefits from sale and many new farmers have started the initial harvest. This context shows that there is some sort of transition in farming system as reported in other parts of Nepal by prior studies. The transition is visible in terms of new agriculture intervention, land use conversion, addition of new crops and trees, and abandonment of traditional crops (Kc and Race, 2020; Paudel *et al.*, 2020; Subedi *et al.*, 2021). In the context of agroforestry, the forthcoming transition from traditional agroforestry to coffee-based agroforestry could enhance growing trees, cash income, and perhaps orient more on the market-based food economy. Such that, there is an obvious influence in the household diet consumption pattern, food constituents and their whereabouts. The positive or negative outcome of coffee-based agroforestry system in farm production diversity and household diet diversity is thus vital to understand the changing food security scenario of rural farms.

Household dietary diversity is the distribution of consumption shares among food groups over a specified duration (Akerele and Shittu, 2017). It is a validated approach for measuring household food access (Swindale and Bilinsky, 2006). Farm production diversity is the classification of crops grown in the farm into different food groups used in the dietary diversity score (Jones *et al.*, 2014; Sibhatu *et al.*, 2015). It signifies the access of a household to food items and may influence the dietary diversity of households. Improved agroforestry, such as coffee-based system could provide sound ecological foundation for higher species diversity, crop productivity and economic returns (Amatya and Newman, 1993). Prior studies have also highlighted agroforestry system as a critical tool to enhance biodiversity (Jose, 2012), hence it is expected to improve farm production diversity. Other literature suggests diversified diet among cash crops growing farmers (Sharma and Pudasaini, 2020). While coffee-based agroforestry in Deusa incorporates coffee as a cash crop, there are limited studies on farm production diversity, household dietary diversity, and their relationship in agroforestry intervention.

This study provides context specific and scientific study of farm production diversity and household dietary diversity among traditional and coffee-based agroforestry systems in Deusa. It adds to the very limited literature available to address the issue, especially in the context of Nepali hill farming, and is unique in terms of the comparison between old and new agroforestry systems. The assessment of the impact of intervention through scientific research is important to inform future decisions of expanding or creating new projects that deal with the hill farmers and farming. The main concept of this research is that adoption of coffee-based agroforestry system could bring changes in farm production diversity and household dietary diversity through changes in crop species and tree species in the farm, as illustrated in the conceptual framework (Figure 1). The specific objectives of the study are: to assess the relationship between farm production diversity and household dietary diversity in smallholder farms of Deusa and to analyze if adoption of coffee-based agroforestry increases farm production diversity and household dietary diversity.

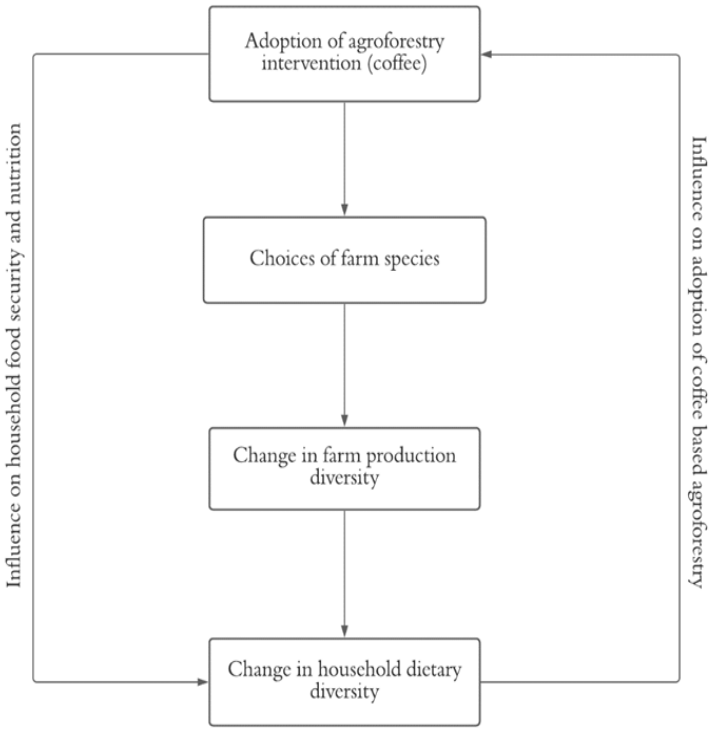

Figure 1. *Conceptual framework.*

MATERIALS AND METHODS

Study area

We conducted the study in Deusa Village of Solukhumbu district, falling under Ward (the smallest administrative unit) no. 7 and Ward no. 8 of Thulung Dudhkoshi Rural Municipality (Figure 2). It lies in the eastern mid hill of Nepal at Latitude 27° 27' 22" N, Longitude 86° 42' 3" E and elevation 1668 masl. The climate in the area ranges from subtropical to temperate. The agricultural terraces in sloppy hills, fodder and trees species mostly distantly located houses with orange or other fruit trees, and some patches of forests at the edge of the cropland plots and nearby water bodies characterized it. After 2012, Deusa Agroforestry Resource Center (DAFRC) in collaboration with The Glacier Trust and EcoHimal Nepal is promoting coffee-based agroforestry and promoting diversity of tree crops, shrubs, fodder species and providing support to the coffee farmers. The DAFRC intervention is mainly through training/capacity building and resource support to farmers in Deusa to integrate traditional methods with improved technologies in order to adapt to the climatic uncertainties (Peart and Phillips, 2018).

Sampling

Initially, we conducted two focus group discussions, a key informant interview, and one informal discussion. During this informal discussion, we got information about study area and population, and research problem to be addressed. We identified 16 village clusters in the study area (Figure 3). Using the sample size formula given by Daniel and Cross (1999), we estimated 84 households for survey, and we proportionately divided these households into village clusters (as shown in Figure 3).

$SS= [Z^2 * (p) * (1-p)]/d^2$ (Daniel and Cross, 1999)

Where,

Z = Z value (e.g., 1.96 for 95% confidence level), p = expected prevalence or proportion (0.5), and d = precision or margin of error (0.1).

Data collection

We collected data during January 2020 using following tools.

i) **Questionnaire:** The major field instrument of this research was survey questionnaire and checklist, among others. We developed the survey questionnaire after reviewing "Household Food Economy Approach" (Boudreau, 1998), and "Agro biodiversity Research Compendium" (PAR, 2018) along with other relevant literatures.

ii) **Food diary checklist:** For the food diary data, a detailed checklist on consumption of 16 categories of food was prepared according to FAO's "Guidelines for Measuring Household and Individual Dietary Diversity" (FAO, 2010). The 16 food categories included were cereals, white tubers and roots, vitamin A rich vegetables and tubers, dark green leafy vegetables, other vegetables, vitamin A rich fruits, other fruits, organ meat, flesh meat, eggs, fish and seafood, legumes/nuts and seeds, milk and milk products, oils and fats, sweets, and spices/condiments/beverages. We collected the data by 24 hours diet recall method.

iii) **Focus group discussion (FGD):** We conducted two FGDs to identify the farming and food system related issues in the local context that have started with time and with the agroforestry intervention. We conducted two rounds of FGDs. The first round of FGD involved 10 DAFRC members and beneficiaries that included of team of experienced local farmers. Whereas the second round of FGD involved around 35 local farmers associated with Sirjanshil Farmer's Group and New Star Club, which included the team of almost equal numbers of male and female participants, including the young farmers. FGDs were intended to explore on farming system changes, work of DAFRC, pros and cons of adopting coffee-based system.

iv) **Key informant interview (KII):** We conducted two rounds of KII interviews during the study duration; one before starting the household survey and the other at almost the end of the household survey. We conducted the first round of KII with a local farmer and DAFRC staff who works closely with the local farmers and makes frequent visits in the village. The aim of the first KII was to identify the number of settlement clusters, their names (also the routes and distance for the logistics) and the number of households (HN) in the respective clusters. We estimated the proportion of sample to be allocated proportionately. We conducted the second KII with two informants (Informants: DAFRC staff and an experienced local farmer) to validate some data obtained from the survey.

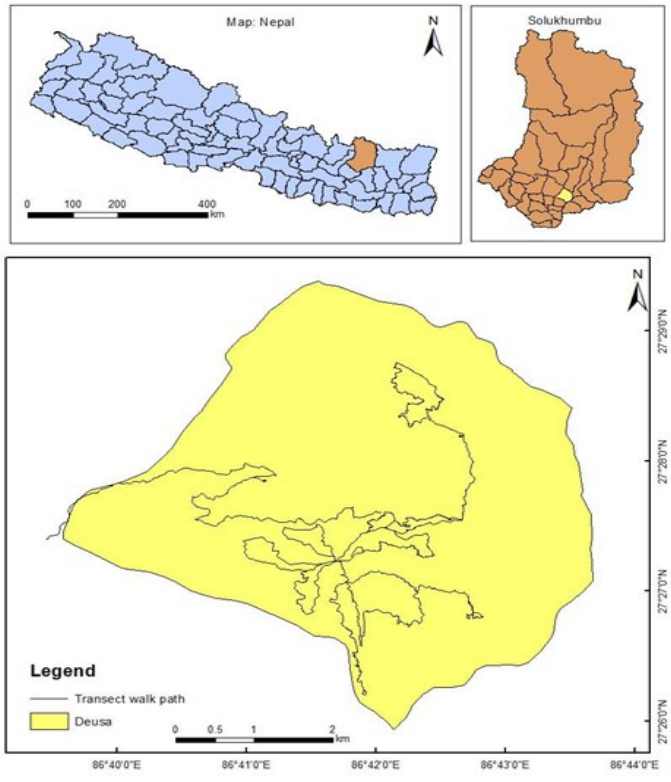

Figure 2. *Map of study area.*

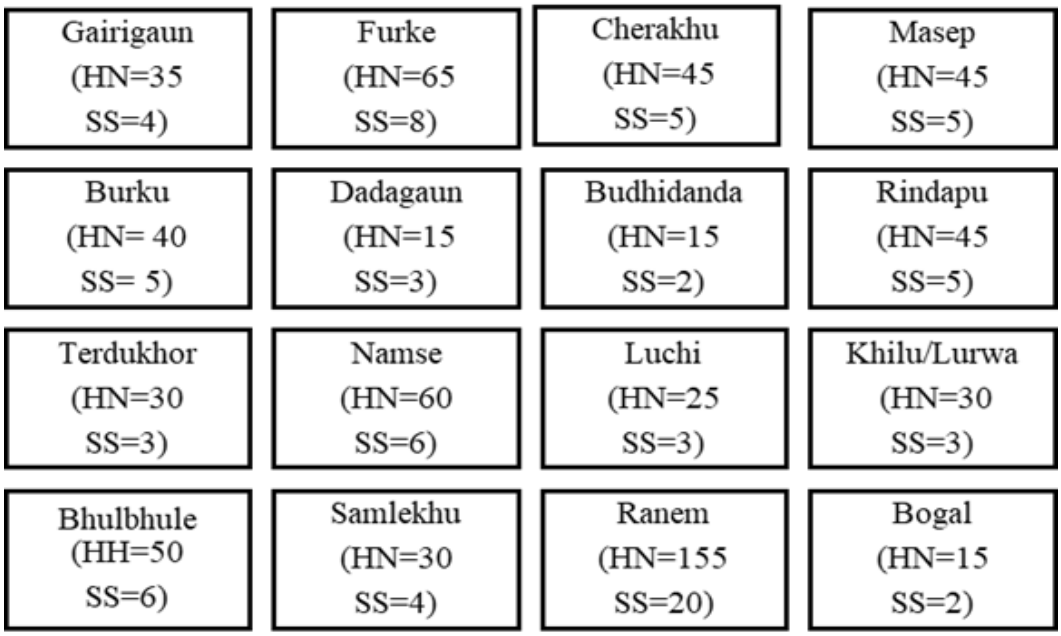

Figure 3. *Cluster wise household and sample distribution.*

v) **Transect walk:** The first author did the transect walk along the farm routes, including the route from a settlement to other. It was done to understand the local agroforestry system setting, and for the detailed free listing of the species under the system. Figure 2 shows the transect walk path in the study area.

Data analysis

We used MS Excel sheet for data entry, followed by coding/ categorization of responses and cleaning of the data, checking for missing data and outliers and crosschecking with the help of filled up questionnaires. We calculated farm production diversity score and household dietary diversity score.

i) **Production diversity score:** We asked the respondent to list out the detailed crops grown in their farm for the last one year. Based on the data, we categorized the list of crops and livestocks grown and reared in the farm into the 16 food groups. Even though some studies use simple crop and livestock species count from the farm, we in this study used the same count of food groups used in the dietary diversity score in estimating the production diversity indicator to better account for the dietary perspective (Huluka *et al.*, 2019; Jones *et al.*, 2014; Koppmair *et al.*, 2017; Sibhatu *et al.*, 2015). In this type of classification, the farms producing more crop species under the same food category would have lower production diversity than those producing crop species falling under a variety of food categories (Koppmair *et al.*, 2017).

ii) **Dietary diversity score:** We define household dietary diversity as the total number of food groups consumed by a household over 24 hours (Swindale and Bilinsky, 2006). There are two indicators of dietary diversity used in research; namely the food variety score and dietary diversity score (Swindale and Bilinsky, 2006; FAO, 2010). As food variety score is just a simple count of different food items consumed during the specified recall period, studies emphasize more on dietary diversity score, which is the number of food groups consumed by the household during the recall period (Sibhatu *et al.*, 2015). Therefore, consumption of food items falling under different food groups within the 24 hours recall period was accounted for dietary diversity scores. As there is not a single international consensus on which food groups to include in the calculation, this study has used FAO classification of 16 food groups (FAO, 2010).

For statistical data analysis, we used simple linear regression, t-test, Chi-square and Fisher's exact tests in SPSS.

i) **Simple linear regression:** We ran the simple linear regression in SPSS to find out if the farm production diversity is a factor influencing household dietary diversity. The equation for simple linear regression is:

$$Y=mX+C \quad (i)$$

Where,

Y= Household dietary diversity, m= Regression coefficient, X= Farm production diversity, and C= Constant

ii) **Independent samples t-test:** We also conducted an independent samples t-test to observe the difference between farm production diversity score and dietary diversity score between traditional and coffee-based agroforestry system.

iii) **Pearson's Chi-square and Fisher's exact test:** We also used Pearson's Chi-square test to observe association of agroforestry type with particular food group consumption. Wherever we saw violations of the assumptions for Chi-square test (cell value less than 5), we applied Fisher's exact test instead.

RESULTS AND DISCUSSION

Farm and household characteristics in Deusa

The average household size was 4.3 family members, average age of the household heads was 52.3 years with farmers age ranging from as young as 25 years old to as old as 77 years old. The major cereal crops grown in the area make up maize, millet, wheat and paddy. The farms also grow legumes and seed of different crop varieties namely black gram, rice beans, black-eyed beans, horse gram, beans and soybeans, tubers including potato, sweet potato and yams, and small fruit orchard. Vegetable garden is also common in the farms. Average weighted household livestock unit of the farms was 2.19. Own farm production was sufficient for 7.18 months. Rice is the staple, with 90.5% households supplementing the farm produced cereals with packaged rice from market. Among those households who purchase packaged rice from market, average rice pack consumption was approximately 26 kg per month and average cost for 30 kg of rice NPR. 2000. 66% of the households practiced traditional agroforestry and remaining 34% had adopted coffee-based agroforestry (Figure 4).

Relationship between farm production diversity and household dietary diversity

Tables 1 and 2 show 16 food groups used in the calculation of farm production diversity and household dietary diversity scores, along with the frequency tabulation of the response. The food group wise response shows that farms included all other food groups except fish and seafood, and sweets. However, the diet dominantly included the cereals and oil/fat. The consumption frequency order from high to low was in the order of cereals, oil/fat, legumes/nuts/seeds, white tubers and roots, spices/condiments and beverages, dark green leafy vegetables, vitamin A rich vegetables and tubers, other vegetables, flesh meat among others. Four food groups were missing from the 24 hours diet of every respondent household, namely vitamin A rich fruits, organ meat, fish and seafood, and sweets. An average production diversity score for smallholder farms in Deusa is 13.20 and the average dietary diversity score is 5.57. The farm production diversity and household dietary diversity showed a significant correlation, r = 0.357; $p<0.05$. Further, simple regression analysis showed that household dietary diversity significantly depends on the farm production diversity. Higher the farm diversity, higher is the diversified food intake. In the study area, we can predict the household dietary intake using following relationship (details in Table 3).

Household Dietary Diversity = 0.339 x Farm Production Diversity + 1.095

Table 1. Food group frequency among crops grown over a year.

S.N.	Crops under different food groups	No (N/%)	Yes (N/%)
1	Cereal	1 (1%)	83 (99%)
2	White tubers and roots	1 (1%)	83 (99%)
3	Vitamin A rich vegetables and tubers	1 (1%)	83 (99%)
4	Dark green leafy vegetables	1 (1%)	83 (99%)
5	Other vegetables	1 (1%)	83 (99%)
6	Vitamin A rich fruit	16 (19%)	68 (81%)
7	Other fruits	9 (11%)	75 (89%)
8	Organ meat	3 (4%)	81 (96%)
9	Flesh meat	3 (4%)	81 (96%)
10	Eggs	11 (13%)	73 (87%)
11	Fish and seafood	84 (100%)	0 (0%)
12	Legumes/nuts/seeds	4 (5%)	80 (95%)
13	Milk and milk products	8 (10%)	76 (90%)
14	Oil/fat	8 (10%)	76 (90%)
15	Sweets	84 (100%)	0 (0%)
16	Spices/condiments and beverages	0 (0%)	84 (100%)

Table 2. Food group frequency in household diet consumed within 24 hours.

S.N.	Crops under different food groups	No (N/%)	Yes (N/%)
1	Cereal	1 (1%)	83(99%)
2	White tubers and roots	25 (30%)	59(70%)
3	Vitamin A rich vegetables and tubers	46 (55%)	38(45%)
4	Dark green leafy vegetables+	39 (46%)	45 (54%)
5	Other vegetables	69 (82%)	15 (18%)
6	Vitamin A rich fruit	84 (100%)	0 (0%)
7	Other fruits	83 (99%)	1 (1%)
8	Organ meat	84 (100%)	0 (0%)
9	Flesh meat	70 (83%)	14 (17%)
10	Eggs	82 (98%)	2 (2%)
11	Fish and seafood	84 (100%)	0 (0%)
12	Legumes/nuts/seeds	20 (24%)	64 (76%)
13	Milk and milk products	78 (93%)	6 (7%)
14	Oil/fat	1 (1%)	83 (99%)
15	Sweets	84 (100%)	0 (0%)
16	Spices/condiments and beverages	26 (31%)	58 (69%)

+Significant difference between two agroforestry groups (Chi square- 5.385; df=1; p<0.05).

Table 3. Regression for household dietary diversity.

Variables	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	T	Sig.
(Constant)	1.095	1.3		0.842	0.402
Farm production diversity score	0.339	0.098	0.357	3.459	0.001

R^2=0.127 Adjusted R^2=0.117; F test=11.967; p>0.05; N=84.

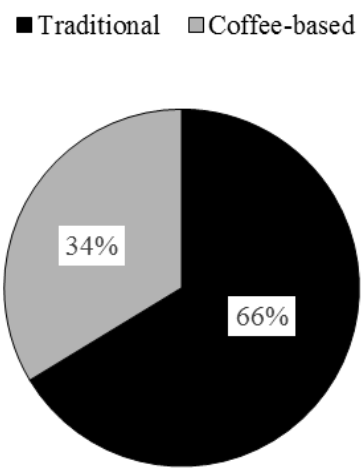

Figure 4. *Households under two agroforestry types.*

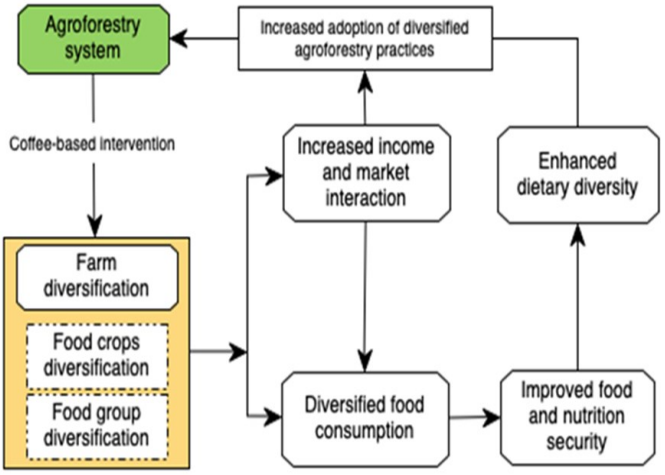

Figure 5. *Multiple factors determine crops and diets relationship.*

We expect that more diverse farm production systems may substantially stimulate consumption of varied diets (Akerele and Shittu, 2017). The regression results show a significant positive association between farm production diversity and dietary diversity as comparable to past studies (Jones *et al.*, 2014; Sibhatu *et al.*, 2015; Huluka *et al.*, 2019). The moderate positive association observed between farm production diversity and household dietary diversity shows multiple other determinants of household dietary choice (Sharma and Pudasaini, 2020). Changed or added crops, improved market opportunities and other farm level changes could have played together in determining the diversity of the crops and the diets in the study area (Figure 5). It was beyond this research scope to analyze market opportunities, seasonality and other socioeconomic factors that have complementing relationship with farm production diversity in determining household dietary diversity (Bellon *et al.*, 2016). The condition is also likely as the cash crop producers gain more income from sales and possible transition of food consumption from mostly cereal based to other food groups (Sharma and Pudasaini, 2020). However, this is a complicated decision of an individual household as other factors also govern the food choice such as taste, physical appearance, prices, and purchase of processed food (Sharma and Pudasaini, 2020). Socioeconomic factors such as household decision-making power and ethnicity also have an influence in the household dietary diversity (Ng'endo *et al.*, 2016). Therefore, farm production diversity is one factor enhancing household dietary diversity but not the only determinant (Figure 5).

Comparing between two measures of farm production diversity score, we found that the score developed using food groups count has an influence on diet diversity but that of crops count does not. Hence, we recommend to account for the number of food groups rather than a simple count of crop species in the calculation of farm production diversity score. Several past studies on farm production and dietary diversity of the smallholders (Huluka *et al.*, 2019; Jones *et al.*, 2014; Koppmair *et al.*, 2017; Sibhatu *et al.*, 2015) also recommend similar approach.

Farm production and dietary diversity among agroforestry types

Neither the farm production diversity score nor the dietary diversity score was found statistically different between traditional agroforestry and coffee-based agroforestry system at the 95% confidence level (Table 4). However, we found production diversity score different between the agroforestry systems only at the 90% confidence level. Descriptive statistics show more diverse farms and diets in coffee-based system even though it was not statistically significant at the 95% confidence level. Farms under coffee-based agroforestry system have larger orchards nearby that include fruits and fodder trees incorporated as shade trees for coffee, which was observed during the transect walk along the settlements and farms. At the same time the key informants also mentioned that most of the farms under coffee-based system cultivate the regular cereal, legumes and vegetables as well, as done by those under traditional agroforestry. So, the introduction of coffee and its shade trees has made an addition to the existing diversity of the farms. This might have enhanced the farm production diversity among coffee-based agroforestry system and slowly enhancing the dietary diversity as well. Our finding possibly implies the improved dietary diversity among the coffee-based agroforestry farmers in the long run. The transition of a farming system from traditional to coffee-based agroforestry is very clear in Deusa. As the traditional farms are undergoing transition, these results rather indicate future changes because not all the farms have fully adopted the coffee-based system and known all the technical know-how

Table 4. Farm production and dietary diversity by the agroforestry type.

Agroforestry types	Production diversity score			Dietary diversity score		
	Mean	t-tests	p-value	Mean	t-tests	p-value
Traditional	13.05	-1.723	0.089	5.46	-1.155	0.252
Coffee based	13.50			5.79		

in the field.

Alongside our argument, previous studies have also reported greater potential of agroforestry in improving the food security, climate change adaptation, provision of additional harvests for sale or home consumption, and conserving and strengthening the environmental resource base of rural agricultural landscapes (Mbow *et al.*, 2014; Thangata and Hildebrand, 2012). Other studies in Nepal have shown a highly significant change in food sufficiency of the households adopting agroforestry (Pandit *et al.*, 2019). Slightly higher farm production diversity in the coffee-based agroforestry system in this research shows the improved food access of the households for enhanced diet diversity and nutrition after the full adoption and functioning of the system.

Whereas, the food group wise comparison shows a significant association between coffee-based agroforestry and consumption of dark green leafy vegetables (Chi square- 5.385; df=1; $p<0.05$) among rest of the food groups. Meanwhile, global studies have shown that low intake of vegetable alone is attributed for 1.5 million deaths and 34 million Disability-Adjusted Life Years particularly in low and middle income countries (Afshin *et al.*, 2019). This result indicates improved nutrition security among the coffee-based agroforestry farmers while minimum level of fruit and vegetable consumption are the issues in nutrition security. As per the focus group discussion findings, farms under coffee-based agroforestry system have better access to other services provided by DAFRC and associated organizations, such as vegetable seeds and fruit saplings distribution, trainings and workshops on farm diversification, bio-intensive farming methods, disease and pest control, importance of kitchen gardening and healthy diet. We expect greater access of the coffee-based farmers in DAFRC services as of their frequent visit to DAFRC for collecting coffee saplings, selling coffee parchments and related involvements. The promotion of farm diversification and nutrition education both increases the possibility of higher dietary diversity among those adopting coffee based agroforestry system (Boedecker *et al.*, 2019).

In the study area, the forthcoming transition from traditional agroforestry to coffee-based agroforestry could demand growing more tree crops, cash income, and perhaps market-oriented food economy. This is because, while comparing between the two groups, coffee-based farmers already had significantly higher tree plantation in their farms as compared to the traditional farmers. Negligible numbers of households included coffee in the diet, and they mainly grew it with an intent to sell the coffee parchment to DAFRC. The income generated from coffee sale was used to supplement own harvest with market purchase of food. As shown by the results, the changes are slightly visible now, even after less than a decade of the introduced agroforestry intervention. In this sense, the findings get along with the prior studies that report the growing evidence that agroforestry can be one viable solution to solve the issues of both food and nutrition security together with enhanced income and sustainable farms (Atreya *et al.*, 2021; Carson, 1992; Neupane *et al.*, 2002).

Finally, we would like to put study limitations. Because of COVID-19 lockdown in Nepal, this study could not incorporate diet data of different seasons, and was conducted in January right after the rice harvest season in the area, which is generally thought to be as food sufficient time of the year. The study was focused more on the constituents of own farms and 24h diets and excluded consumption of processed foods. However, the study provides household level evidences to support promoting coffee-based agroforestry system from the nutrition security perspective.

Conclusion

This study observed a significant positive association between the farm production diversity and household dietary diversity in Nepal's hill farming. The farm production diversity and household dietary diversity was enhanced in the coffee-based systems. Coffee based agroforestry system had relatively higher consumption shares of different food groups while consumption of dark green leafy vegetables was significantly higher as compared to traditional system. Agroforestry interventions are therefore likely to be beneficial in enhancing farm production diversity and hence dietary diversity of smallholders. Consequently, agroforestry adoption is not only beneficial in enhancing biodiversity and improving farm income but also in improving food and nutrition security. However, future studies should account for the influence of other demographic, socioeconomic and market linkages in dietary diversity. More context based, long-term studies on large sample sizes considering the before and after scenarios of agroforestry intervention regarding the environmental implications and food security are vital. This is important because conservation of the great diversity in agricultural land is only possible if the smallholders in the hills see it resourceful in meeting their food and livelihood needs.

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