Is Nutritional Functional Diversity In The Rural Food And Nutrition System Associated With Food Security And Nutrient Adequacy? A Case Study of Rural Areas of Zahedan City, Iran

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Is Nutritional Functional Diversity in the Rural Food and Nutrition System Associated with Food Security and Nutrient Adequacy? A Case Study of Rural Areas of Zahedan City, Iran

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Abstract

Background: An often overlooked problem in food and nutrition systems analysis is assuring adequate diversity of nutrients for healthy diet**.** Ntritional functional diversity (NFD) is a metric that describes diversity in providing nutrients from farm fields to markets and all the way to the consumption level. The objective of this study was to determine the NFD score at different stages of rural food system, from Household's agricultural and home production, processing, to purchased food and diet, and to explore the association between NFD and nutrient adequacy, food security and anthropometric indicators.

Methods: A cross sectional study was conducted on 321 household's in 6 villages of Zahedan district**.** The NFD score was measured at three subsystems (production, processing and consumption) of food and nutrition system. To assess the association between NFD and food and nutrition indicators, such variables as household's food security, mean adequacy ratio (MAR), and anthropometric indicators of household's head were also measured. Different bivariate and multivariate statistical techniques were applied to study the association between variables.

Results: In rural food and nutrition system, the foods purchased from the city play the main roles in the household's NFD score. Their role in NFD was twice that of the foods purchased

from village. As well, NFD score of homestead production and household's processing were found to be five times less than those of foods purchased from cities. The food insecure household's had significantly lower NFD scores of food purchased from the city as well as higher NFD score for purchased foods from the rural market and native plants consumption. Additionally, a strong and positive relationship was observed between NFD of household's diet with that of household's MAR. Of note, no significant association was found between NFD score of homestead production and processing and food insecurity, MAR, and household head anthropometric.

Conclusion: NFD score can serve as a good indicator in assessing the food system, which can also be used by policy makers to identify gaps in the local food and nutrition system, and plan appropriate interventions for improving diversity and addressing food insecurity.

Keywords: Nutritional functional diversity, food system, food security, Nutrient adequacy, rural, Iran

Background

The trend of hunger, after decades of steady decline, has been slowly on the rise worldwide since 2014 [1]. More than 690 million people in all over the world are still hungry and 2 billion people have no regular access to safe, sufficient, and nutritious food, so they are suffering from moderate to severe level of food insecurity [2]. Given these conditions, the goal of achieving the zero hunger by 2030 seems unrealistic [2, 3]. COVID-19 pandemic, disproportionate slowdowns or downturn economy, climate variability, and conflict are currently exacerbating these trends [2, 4].

While receiving sufficient calories is still considerd as a major challenge, an often overlooked problem in food and nutrition systems is having an access to adequate diversity of nutrients for providing healthy diet and life [5]. It is well recognized that hidden hunger and

malnutrition have several roots in dysfunctional food and nutrition systems that is accompanied with nutrient inadequacy of diet, especially in poor communities [6-9].

Diversity through a food and nutrition systems' approach could be considered as a driver for causing a change by improving direct interactions between food producers and consumers, and by increasing the quality of diet, and fighting against the triple burden of malnutrition (undernourishment, micronutrient deficiencies, and overweight and obesity). Such approach can also be associated with lower rates of food insecurity and mortality [10-17].

One of the main gaps in food diversity research is that most of them have deal with food diversity in one or two subsystems and a holistic perspective which encompass food diversity in all subsystems of food and nutrition system is missing [18, 19]. Various indicators have been used to assess food diversity in these studies. Therefore, the focus has been mainly on the consumption rather than food provision, and little is known about how diversity is transmitted to dietary diversity at the household level [20]. For this purpose, proper metrics are required to assess the ongoing food policy at both national and regional levels of food and nutrition system, in order to modify or design appropriate interventions for its improvemet. nutritional functional diversity (NFD) is a metric firstly introduced by Remans et al. [21], used to describe diversity in available nutrients from farms to markets and all the ways directed to the consumption level. NFD shows nutritional differences and variations in all groups of foods and food items that are not captured by a food variety score and/or by a diet diversity score [22]. Notably, NFD score can be used at any level (from farm to diet), because it is based on the nutritional composition of foods for 17 nutrients that paly key roles in human beings' health status [21]. Therefore, NFD score can reflect the potential of a food system in meeting the nutritional requirements of a population as well as the link among subsystem diversity, food security, and health. This issue has not been well-addressed in the studies conducted on the food and nutrition systems in Iran.

This study aimed to determine the NFD score at different subsystems of rural food and nutrition system from household's agricultural and homestead production and processing, to purchasing food and its diet. Moreover, this research aimed to explore the association of NFD score of rural food and nutrition system with nutrient adequacy, food security, and anthropometric indicators in rural communities of Zahedan city, in the Southeast of Iran.

Conceptual framework

NFD indicator is a new concept in food and nutrition research and data on its linkages with food and nutrition security and the related dimensions are still scarce [20, 21]. NFD indicator can be applied to describe the diversity of food at different stages of the food and nutrition system. Up to now, little is known about food diversity at different stages of rural food and nutrition systems and the way of its transmission to dietary diversity at the household level [20, 23]. Remans et al. in their research proposed potential determinants of NFD, including agro-ecological, socio-economic, and socio-cultural factors at both farm and village in different seasons as well as the possible effect of NFD score on food and nutrition indicators, including food insecurity, diet diversity, anthropometry, and nutrient deficiencies [21]. Based on another study by Bellon *et al*., there is a triangular connection among three facets of diversity on farm, market and diet [24]. Moreover, endogenous connections exist between on-farm diversity and dietary diversity through self-consumption, between on-farm diversity and market diversity through sale, and between dietary diversity and marked diversity through purchase. Besides, these are all affected by some confounding factors such as land quality and tenure, climatic variability, different types of markets, and ethnicity [24].

Our conceptual framework was based on a combination of the two above-mentioned concepts (Figure 1). We measured NFD score in the food and nutrition system of rural households. Correspondingly, food and nutrition system of rural households is a local food system that

gathers all the elements and activities related to the production, processing, distribution, preparation, and consumption of food, as well as the outputs of these activities, including food security, socio-economic, and environmental outcomes [25]. This study paid a specific attention to NFD score in rural food and nutrition system and its association with nutrition and health outcomes of food systems. We hypothesized that in rural food and nutrition system, NFD on farm, homestead production, and household's processing are linked through the following two routes: on market through sale and on dietary diversity through self-consumption. Agro-ecology (including climatic, soil types and conditions, water quality, greenhouse gas emissions, native species diversity, and distribution of species), socio economic condition (including having access to diversity of seeds, access to fertilizers, access to knowledge, and access to markets), and socio cultural factors (including cultural preferences for species and subspecies, and multiple purposes and advantages of crops) can affect NFD on-farm and home products. Homestead production of diverse foods can play important roles in providing enhanced food supply and increased dietary diversity. Various studies have previously shown that combining home garden and poultry production system could improve food insecurity, malnutrition, and anemia among children and women [26-28]. Market NFD was indicated to be linked with dietary NFD through purchase (from city, village or as a gift or other places), which is influenced by a set of factors, e.g. market access and place, links to different types of markets, availability of infrastructure, food price, household's income, ethnicity, and knowledge. In this regard, market linkages would enable households to consume diverse diets through both the demand via enhancing households' ability to sell part of their produce and supplying a side via making more diverse and nutritious foods available to households, especially in the lean season [23, 29] . In rural areas of the developing countries worldwide, markets often have poor functions. Rural markets are highly variable in what they provide and having any access to urban markets is difficult for

low-income households due to the lack of road infrastructure and transportation roads [30-32].

Therefore, NFD score in rural food and nutrition system affects food and nutrition indicators, including food and nutrition security, dietary quality, anthropometry, and nutrient deficiencies, which are themselves affected by some factors such as family size, age, sex, and educational level of household's head, household's income and welfare, and distance from market. The relationship between NFD scores at different subsystems of rural food and nutrition system with each other and with food and nutrition indicators, does not seem to be a simple linear relationship. Accordingly, this can be complex, depending on different regions and various factors.

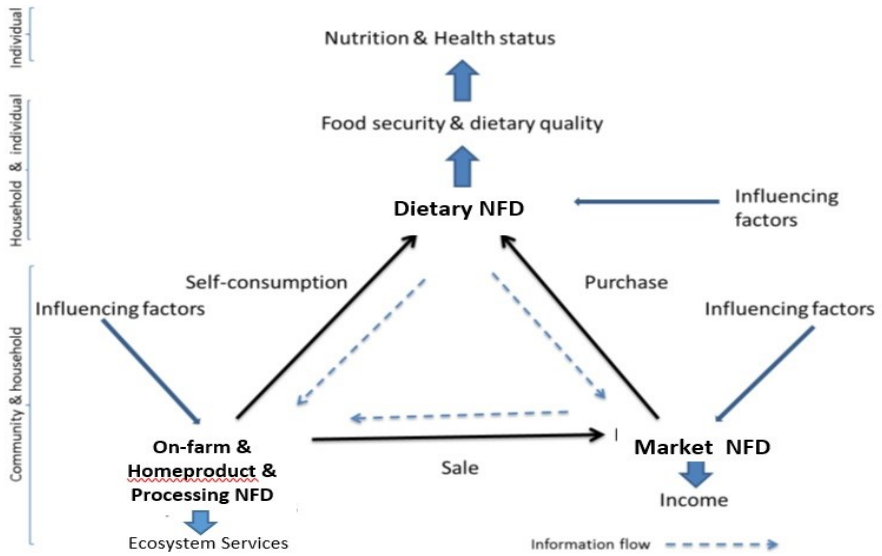

Figure 1. Conceptual framework on the linkage among the farm, homestead production and household's processing NFD, as well as the purchased food and dietary NFD in rural food and nutriton system [24]

Methods

Setting and study design

This population-based cross sectional study was conducted in Zahedan rural communities from April to July 2019. Zahedan is one of the main counties of Sistan & Baluchistan Province, located in the Southeast of Iran, with long, sweltering, arid, and clear summers and cold, dry, and mostly clear winters; with a little amount of rain throughout the year [33]. Based on the "food security information and mapping system in Iran" survey [34] , this province has the highest food insecurity rate in the country (58.8 percent) [35], where 12.8% and 20.7% of children aged under five years old are suffering from underweight and stunting, respectively [34]. Zahedan county is subdivided into the following three administrative districts: Central, Kurin, and Nosratabad. Two villages from each district were randomly selected. According to the Cochran's formula and based on the rural household's population, sample size of this study was determined as 320 household's.

Data collection

Before starting the fieldwork, 12 interviewers who were fluent in local language of that region, i.e. Baluchi, were recruited from community health staff members. Thereafter, they were trained in a two-day workshop in order to be coordinated and to reduce interpersonal variation in data collection process. The required data were collected through face-to-face interviews with mothers (assisted by their husbands).

Measurements

Household's demographics: Demographic information and socioeconomic variables, including age, gender, educational level, and employment of all household's members, household size, household's subsidy supports, and household's facilities were collected using the validated questionnaire of Statistical Center of Iran [36] . To calculate household's welfare index, the household's facilities and equipment were recorded and then weighed between 0-10 by the research team, based on price, necessity, and importance and total score for household's were finally computed.

Household's agricultural and homestead production, and processing: Household's were asked to report details of their household's agricultural and home production and processing during the last 12 months using a questionnaire consisted of the following 3 sections: 1) existence of home-garden/ household's processing in the house as well as the type and amount of produced/processed product(s), 2) the presence of livestock/poultry in the household's, and its type and quantity, and 3) ownership of agricultural land and type of any crop(s) cultivated.

Household's dietary intakes and food sources: Household's dietary intakes and having access to different types of markets were recorded by the trained community health workers by completing 24-hour diet recalls for two non-consecutive days in one week. All foods and dishes and their ingredients consumed by the household's were recorded according to the main meals and snacks and also according to the source of each food (purchased from any place, own production, and/or gift). Any foods consumed by the household's were weighed using a calibrated digital scale with a precision of ±1 gram. (Kitchen Scale EK8450, Camry Electronic Ltd, Guangdong, China).

Nutritional values of the items of the consumed food were calculated using the Iranian food composition table [37] and the USDA Food Data Central [38]. Considering the dietary reference intake (DRI) for energy, protein and limiting micronutrient in the region, including vitamin A, calcium, iron, and zinc [39, 40] , adequacy of household's dietary intake was estimated by calculating household's adult male equivalent units (AMEs) using the method introduced in a study by Weisell *et al.* [41]. AMEs were computed according to the energy requirement of an adult male aged between 18 and 30 years old with moderate level of physical activity [42, 43]. Number of the present household's members and guest(s) per each meal based on their age and sex was taken into account, and AME for each meal was then calculated separately. Daily meals, including breakfast, lunch, dinner, and snack(s) were

calculated with relative weights of 0.16, 0.43, 0.30, and 0.11, for each meal, respectively. This weighting value was then applied to each meal representing the energy contribution of that meal to the daily energy intake, which is an important factor to be considered when the food consumed through the day is measured and one that is often neglected [41]. Finally, the adequacy of household's dietary intakes was assessed by dividing household's dietary intakes for energy and micronutrient to household's AME. As well, nutrient adequacy ratio (NAR) was calculated for each nutrient as the percent of the nutrient meeting, the DRI for energy, protein, and 10 micronutrients, named as iron; zinc; calcium; vitamins A, C, B1, B2, B3, and B12; and folate. The mean adequacy ratio (MAR) of the diet was calculated by the addition of the 12 NARs and then divided by the number of nutrients [44].

Nutritional Functional Diversity (NFD) score: NFD is based on the functional differences of available foods in a food and nutrition system, in a way that higher scores indicate a more diverse diet. The NFD score of food and nutrition system is usually measured at three levels as follows: 1) in production subsystem via a researcher- made questionnaire by measuring various annual household's agricultural and home products, 2) during processing subsystem using a questionnaire by measuring various annual household's processing levels, and 3) in consumption subsystem by obtaining household 24-hour diet recalls for two non-consecutive days, which also included some questions on place of purchasing/obtaining the food items and their prices.

In this study, NFD score was calculated according to the four main steps described in a study by Luckett *et al.* [20]: firstly, a food–nutrient matrix was created. In this matrix, each row contained one of the food items in rural food system, and each one of these columns contained a nutrient, so each cell of the matrix gave the nutrient content of each one of the food items. In all levels of rural food and nutrition system, after excluding foods with negligible nutritional value (e.g. salt and spices), 133 food items were selected to be included

in the final analysis. In this regard, the food–nutrient matrix was composed of energy and the following sixteen nutrients: protein, fat, carbohydrate, fiber, vitamin A, vitamin D, vitamin C, thiamin, riboflavin, niacin, folate, vitamins B12, Ca, K, Fe, and Zn. Nutritional values were calculated per 100 g of the foods obtained from the Iranian food composition table [37] and the USDA Food Data Central [38] . Thereafter, the nutrient values in the food matrix were standardized in the following two ways: 1) they were divided by the recommended dietary allowances (RDA) for adult male subjects aged between 18 and 30 years old , and 2) these were then standardized to have mean=0 and SD=1. Secondly, the food–nutrient matrix was converted into a food–food distance matrix. Finally, the distance matrix was used to produce a cluster diagram, called a dendrogram, which was then used to calculate the NFD score.

household food security: Household's food security status was assessed by the household food insecurity access scale (HFIAS), which was validated for Iranian population [45]. This questionnaire is consisted of nine Likert-type questions on a four-week recall period. The respondent was firstly asked an occurrence question, as whether the condition in the question happened in the past four weeks (yes or no). In this regard, if the respondent answered "yes" to this occurrence question, frequency-of-occurrence was then asked to determine whether the condition happened rarely (once or twice), sometimes (three to ten times) or often (more than ten times) for him/her in the past four weeks. Of note, the HFIAS categorized households into the following four levels of food insecurity: food secure, mild, moderate or severe food insecure [46].

Anthropometric indicators: At this stage, body weight and height of household's head and his spouse were measured using a digital scale (Seca, Germany) and body mass index (BMI) was then calculated as weight (kg)/height (m^2). Weight status of those aged between 19 and 60 years old was classified into one of the following classes: underweight (BMI<18.49), normal weight (18.5 – 24.9), overweight (25–29.9), and Obese (>30 Kg/m^2) [47, 48]. In older

individuals (≥60 years old), BMI cut offs were defined as: ≤20.9 (wasting), 21 – 26.9 (normal), 27–29.9 (overweight), and ≥30 (obese).

Waist circumference was also measured with a precision of 1 mm in young and middle-aged groups with a non-elastic tape at mid-way between the lowest rib and the iliac crest. As well, abdominal obesity was defined as waist circumference more than 80 cm in women and 94 cm in men [49].

Statistical analysis

The obtained data were expressed as mean ± standard error (SE) or percentages. The Kolmogorov–Smirnov test and histograms were used to test the normality of the interval/ratio level variables. After confirming the non-normal distribution of the quantitative variables, nonparametric Mann–Whitney and Chi square tests were both performed to compare the outcomes between food secure and insecure household's.

Afterward, NFD scores were calculated using the R software. The association among NFD scores at different levels of food and nutrition system with household's food security and waist circumference of household's head were also analyzed by binary logistic regression. Additionally, those of BMI of household's heads were analyzed by multinomial logistic regressions. Moreover, the association between NFD score of food system with micronutrient adequacy was analyzed by linear regression. Thereafter, Odds ratios (OR) and regression coefficients with 95% confidence intervals (CI) were calculated for different regressions. Notably, both unadjusted and adjusted models were used in these analyses.

In the adjusted model for food security, family size, household's income, household's under additional subsidy plan (Except for national subsidy), distance from city, sex, educational level and employment of household's head, and household's welfare index were considered as the control variables. The control variables for the mean adequacy ratio model included the similar variables to the food security model, but instead of sex, the variable of household's

head's age was used. In the adjusted model for BMI of household's head, the control variables of the mean adequacy ratio model and residence status were included as the control variables. For waist circumference of household's head, the control variables were as follows: family size, age, sex, and marriage status of household's head; household's income, household's under additional subsidy plan (Except for national subsidy); and household's welfare index. All the unadjusted models were run with no control variables.

Data analysis was performed using Statistical Package for the Social Sciences (SPSS) version 16.0 (SPSS Inc., Chicago, IL, USA) software. A p value of 0.05 or less was considered as the statistical significant level.

Results

Household's demographic characteristics: Data were obtained from 324 household's selected from 6 villages (average 54 household's per each village). The average family size was 4.6 and 30% of the households had more than six members. About 70% of the household's heads were middle-age, 82% were men, more than 60% of them were illiterate or with primary educational level, and 40% of them were unemployed/housewife (table 1). In Iran, all household's at seven low income groups [50] are under the cover of the national unconditional cash transfer (UCT) program . This program covered 98.8% of the households studied and 23.5% received an additional help through Imam Khomeini Relief Committee.

Based on body mass index, about 52% of the household's heads had a normal weight, 16% were underweight, and 31% of them were overweight and obese. Of note, abdominal obesity was observed in 22% of the household's heads.

Household's food security status: The prevalence rate of mild and moderate/severe household food insecurity was 12.7 and 53.3%, respectively. Since mild food insecure household's constituted a small proportion of the sample and their socio-economic

characteristics, i.e. household income and household's head's employment status were similar to those of the food secure household's, the two groups' participants were pooled in a single group. The proportion of household food insecurity was found to be significantly higher in those with greater household size, lower income, welfare index, and MAR, as well as households whose heads were unemployed and had far distance from urban areas. No significant difference was observed in anthropometric indices based on the household food security status.

NFD score of rural food and nutrition system: Table 1 presents the results of the NFD scores in different levels of rural food and nutrition systems from household's agriculture to home production to purchasing food and diet. The NFD score for each household's at different levels was calculated as percentage of the total NFD score in each village's food and nutrition system. It was indicated that only 5.2% of the household's (n=17) had agricultural products with the mean NFD score of 1.4. As well, the purchased foods more contributed to household's nutritional diversity than home produced foods. The amount of food purchased from city was twice the NFD score of foods purchased from village. About 50.9 % of the household's received foods as a gift; however, this had a low contribution to NFD score. Overall, lower NFD score at all levels consequently led to low levels of NFD score of the household's diet. Moreover, the household's with moderate and severe levels of food insecurity had significantly lower NFD scores of food purchased from the city as well as higher NFD score for purchased foods from the rural market and native plants consumption.

NFD and relationship with food security: No significant association was found among NFD scores of home food production and household's processing and household food insecurity before and after adjusting the covariates, including family size, household's income, household's under additional subsidy plan (Except for the national subsidy) , distance from

city, sex, education level and employment of household's head, and household's welfare index (table 2).

NFD score of purchased foods from city was 8.4% lower in food insecure household's which after adjusting covariates, reduced to a 7.2% decline. NFD score of food purchased from village had a 4.5% increase in food insecure household's and after controlling the covariates, this effect became even stronger (5.1%). Notably, with one a unit increase in NFD score of native plants, the odds of being food insecure increased by 31.1%; however, this relationship was not significant in the adjusted model (table2).

NFD and relationship with mean adequacy ratio: There was an inverse association among NFD scores of home production and household's food processing and household MAR, although it was not significant. An inverse and strong association was also found between NFD score of food purchased from city with household MAR, even after adjusting covariates. Additionally, a strong and positive relationship was observed between NFD of household's diet (90.4% and 71.4% in the unadjusted and adjusted models, respectively) and household's MAR (table3).

NFD and relationship with anthropometric indicators: There was an inverse association among NFD score of home production and household's food processing and BMI and waist circumference of household's head; however, this relationship was not significant (Tables 4-5). A significant association was also found between the NFD score of food purchased from city and abdominal obesity of household's head, in a way that the odds of being in abdominally obese category increases by 5.8% with one unit increase in NFD; however, this effect faded out after adjusting covariates. Notably, no significant association was found between NFD score of rural food and nutrition system and BMI of household's head.

Table1. Characteristics of household's included in the study, Zahedan rural areas

Variables		household's food security status			
		Total household (n=321)	FS[1] 150 (46.7%)	FI[2] 171 (53.3%)	
		Mean (SE)	Mean (SE)	Mean (SE)	p-value[†]
Family size (persons)		4.64 (0.11)	4.28 (0.15)	4.98 (0.16)	0.004
Age of household's head (years)		43.57 (0.82)	43.72 (1.39)	43.45 (0.95)	0.235
Household's income (rial[3])		10309304.6 (573032.7)	13361259.0 (994321.5)	7644593.8 (565466.2)	<0.001
Household's income without cost of subsidy (rial[3])		7783696.4 (564935.8)	10957500.0 (982080.1)	5008812.5 (540812.1)	<0.001
Village distance from city (Km)		68.90 (1.27)	64.76 (1.65)	72.77 (1.88)	0.006
MAR[4]		67.43 (0.75)	69.50 (1.11)	65.74 (1.01)	0.009
NFD[5] household's agriculture, (n=17 household's) (5.2%)		1.4 (0.5)	-	-	-
NFD of homestead production,(n= 145 household's) (44.8%)		3.72 (0.20)	3.5 (0.34)	3.83 (0.26)	0.415
NFD of household's food processing, (n=141 household's) (43.5%)		3.69 (0.25)	3.57 (0.36)	3.77 (0.35)	0.966
NFD of Consumption	Food purchased from city, (n=311 household's) (96%)	15.92 (0.34)	17.58 (0.47)	14.53 (0.48)	<0.001
	Food purchased from village, (n=277 household's) (85.5)	6.93 (0.37)	6.05 (0.53)	7.72 (0.51)	0.021
	Received gift, (n=159 household's) (50.9%)	3.24 (0.32)	2.65 (0.41)	3.62 (0.48)	0.374
	Native plants, (n=208 household's) (64.2%)	1.23 (0.08)	0.98 (0.12)	1.40 (0.12)	0.029
	Household's dietary, (n=321 Household's) (100%)	16.28 (0.19)	16.62 (0.31)	16.00 (0.25)	0.280
		n (%)	n (%)	n (%)	p-

					value††
Household's Welfare index	Low	106 (32.7)	42 (40)	63 (60)	0.002
	Medium	107 (32.7)	41 (39)	64 (61)	
	High	111 (34.3)	66 (60)	44 (40)	
Residence status	Ownership	249 (77.7)	117 (47)	132 (53)	0.775
	Rent/other	71 (22.3)	32 (45.1)	39 (54.9)	
Household's under additional subsidy plan (excluding the national subsidy)	Yes	79 (23.5)	32 (42.7)	43 (57.3)	0.421
	No	248 (76.5)	118 (48)	128 (52)	
Household's head characteristics					
Gender	Male	266 (82.1)	128 (48.5)	136 (51.5)	0.175
	Female	58 (17.9)	22 (38.6)	35 (61.4)	
Education level	Illiterate and primary	215 (67)	94 (43.7)	121 (56.3)	0.124
	High school and higher education	106 (33)	56 (52.8)	50 (47.2)	
Employment	Employed	188 (58.9)	104 (55)	85 (45)	0.001
	Unemployed/ housewife	132 (41.1)	46 (35.4)	84 (64.6)	
Married status	Married	258 (80.2)	123 (47.7)	135 (52.3)	0.492
	Other (Single / Divorced / Widowed)	63 (19.8)	27 (42.9)	36 (57.1)	
Weight status (based on BMI[6])	Normal	162 (52.6)	78 (48.8)	82 (51.2)	0.096
	Wasted	50 (16.2)	18 (33.3)	36 (66.7)	
	Overweight/ obese	96 (31.2)	46 (50.5)	45 (49.5)	
Waist circumference	Normal	236 (77.1)	107 (45.7)	127 (54.3)	0.759
	Abdominal obesity	70 (22.9)	33 (47.8)	36 (52.2)	

[1] Food Secure, [2]Food Insecure, [3]Rial is the currency of Iran, [4]Mean Adequacy Ratio, [5]Nutritional Functional Diversity, [6]Body Mass Index.† Using Mann–Whitney U test, ††Using Chi-squared test.

٣٤٣ Table2. Association between NFD score of rural food and nutrition system with household's

٣٤٤ food security, Zahedan, Iran

Predictors		Household's food security status			
		Unadjusted		Adjusted†	
		FS[1]	FI[1]	FS	FI
		OR (CI95%)		OR (CI95%)	
NFD of homestead production		Reference	1.047 (0.918-1.193)	Reference	1.123 (0.930-1.355)
NFD of household's food processing		-	1.023 (0.916-1.143)	-	1.047 (0.899-1.219)
NFD of Consumption	Food purchased from city	-	0.916 (0.880-0.955)***	-	0.928 (0.881-0.978)**
	Food purchased from village	-	1.045 (1.005-1.088)*	-	1.051 (1.000-1.104)*
	gift	-	1.061 (0.979-1.150)	-	1.057 (0.961-1.164)
	Native plants	-	1.311 (1.036-1.659)*	-	1.195 (0.890-1.604)
	Household's diet	-	0.952 (0.894-1.013)	-	0.969 (0.895-1.048)

[1]Food Insecurity, *p<0.05, **p<0.01, ***p<0.001

†Adjusted for family size, income, household's under additional subsidy plan (Except for national subsidy), distance from city, sex and education of household's head, household's welfare index, employment of household's head

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٣٤٦ Table 3. Association between NFD score of rural food and nutrition system with household's

٣٤٧ Mean Adequacy Ratio, Zahedan, Iran

Predictors		Household's MAR	
		Unadjusted MAR[1] B (CI95%)	Adjusted† MAR B (CI95%)
NFD of homestead production		-0.035 (-1.065-694)	0.412 (-0.450-1.275)
NFD of household's food processing		0.121 (-0.194-1.219)	0.419 (-0.297-1.134)
NFD of Consumption	Food purchased from city	0.233 (0.273-0.756)***	0.353 (0.108-0.599)**
	Food purchased from village	0.032 (-0.192-0.332)	-0.017 (-0.266-0.232)
	Received gift	0.146 (-0.036-1.007)	0.458 (-0.059-0.976).
	Native plants	0.127 (-0.100-2.733)	0.876 (-0.504-2.256)
	household's dietary	1.904 (1.539-2.270)***	1.714 (1.328-2.100)***

[1]Mean Adequacy Ratio, *p<0.05, **p<0.01, ***p<0.001

†Adjusted for family size, age of household's head, household's income, household's under additional subsidy plan (Except for national subsidy), education of household's head, household's welfare index, employment of household's head

٣٤٨ Table4. Association between NFD score of rural food and nutrition system with BMI of

٣٤٩ household's head

Predictors	BMI[1] of household's head					
	Unadjusted			Adjusted†		
	Normal	Wasting	Overweight/obesity	Normal	Wasting	Overweight/obesity

			OR (CI95%)	OR (CI95%)		OR (CI95%)	OR (CI95%)
NFD of homestead production		Reference	0.955 (0.788-1.158)	1.035 (0.883-1.213)	Reference	0.947 (0.739-1.212)	0.977 (0.803-1.189)
NFD of household's food processing		-	0.900 (0.764-1.061)	0.941 (0.823-1.074)	-	0.874 (0.722-1.059)	0.966 (0.818-1.140)
NFD of Consumption	Food purchased from city	-	0.959 (0.912-1.009)	1.054 (1.007-1.103)	-	0.961 (0.902-1.023)	1.033 (0.983-1.085)
	Food purchased from village	-	0.990 (0.939-1.044)	0.978 (0.934-1.023)	-	1.023 (0.961-1.090)	0.981 (0.934-1.031)
	gift	-	1.025 (0.926-1.134)	1.034 (0.945-1.130)	-	1.005 (0.894 - 1.130)	1.047 (0.943-1.162)
	Native plants	-	0.854 (0.611-1.195)	1.016 (0.801-1.289)	-	0.949 (0.646-1.396)	0.966 (0.737-1.267)
	Household's diet	-	0.942 (0.860-1.033)	1.064 (0.991-1.142)	-	0.988 (0.892-1.116)	1.026 (0.946-1.113)

[1]Body Mass Index, *p<0.05, **p<0.01, ***p<0.001

†Adjusted for family size, age of household's head, household's income, household's under additional subsidy plan (Except for national subsidy),residence status, education of household's head, household's welfare index, employment of household's head

٣٥٠

٣٥١ Table 5. Association between NFD score of rural food and nutrition system with waist

٣٥٢ circumference of household's head

	Waist circumference of household's head	
Predictors	Unadjusted	Adjusted†

		Normal	Abdominal obesity	Normal	Abdominal obesity
			OR (CI95%)		OR (CI95%)
NFD of homestead production		Reference	0.988 (0.843-1.158)	Reference	0.914 (0.751-1.112)
NFD of household's food processing		-	0.987 (0.863-1.129)	-	0.973 (0.828-1.144)
NFD of Consumption	Food purchased from city	-	1.058 (1.010-1.108)*	-	1.032 (0.979-1.088)
	Food purchased from village	-	0.975 (0.928-1.024)	-	0.974 (0.924-1.027)
	Gift	-	1.032 (0.945-1.126)	-	1.041 (0.934-1.161)
	Native plants	-	1.089 (0.850-1.394)	-	0.987 (0.749-1.300)
	Household's diet	-	1.041 (0.968-1.119)	-	0.982 (0.897-1.075)

*p<0.05, **p<0.01, ***p<0.001

†Adjusted for family size, age and sex of household's head, household's income, household's under additional subsidy plan (Except for national subsidy), household's welfare index, married status of household's head

Discussion

The results of the present study show that in rural food and nutrition system, the food purchased from city play the main role in the household's NFD score. In other words, it was shown that rural households highly rely on Zahedan city for household's dietary diversity. Additionally, NFD score of food purchased from the city was lower in food insecure household's whose distance was farther from the city compared to food secure households. Similar findings from a study performed in rural areas of Malawi showed that purchased foods more contribute to household nutritional diversity than home produced foods and household's living farther from roads and population centers had lower overall diversity [20]. It was reported that smallholder farming household's of Malawi, often purchased more than half of the foods consumed from the market [19].

٣٦٤ Data on NFD score and the relationship between farm production diversity and diet diversity are
٣٦٥ scarce [21, 22, 51, 52]. As well, no data are available on NFD on the continuum of a food system
٣٦٦ or the association among the NFD score at different food sub-systems and nutrient adequacy and
٣٦٧ household food security. Moreover, results of a meta-analysis showed that the effects of
٣٦٨ production diversity on dietary diversity and nutrition in smallholder farm households are
٣٦٩ positive, but small [53]. This finding may be due to the role of markets in achieving diverse diets
٣٧٠ [20, 54]. In our study, very few households were the owners of agricultural land and NFD score
٣٧١ of crop production was very small. In contrast, more than 40% of the households had homestead
٣٧٢ production and processing; however, NFD score were low and no association was found between
٣٧٣ NFD score of home production/ processing and the nutritional outcomes, i.e. household food
٣٧٤ security status, MAR, and anthropometric indicators. Remans *et al*. in their study did not observe
٣٧٥ a significant association among NFD of edible crops, household dietary diversity score, and
٣٧٦ household food security in rural areas of Africa [21].
٣٧٧ We found no study examining the relationship of NFD score of household's food purchases and
٣٧٨ diet with food insecurity and adequacy of micronutrients. Food insecure households had lower
٣٧٩ NFD score of foods purchased from city than the NFD score for those foods purchased from the
٣٨٠ village and native plants consumption compared to food secure households. As well, the NFD
٣٨١ score of diet was low and a positive association was found between NFD score of household's
٣٨٢ diet and their MAR. It seems, that the socio-economic factors, such as illiteracy and
٣٨٣ unemployment of household's head, low level of household's welfare index, household size, and
٣٨٤ village's distance from city have impacts on low NFD score, nutrient inadequacy, and food
٣٨٥ insecurity. Luckett et al. in their research found that some factors such as each additional person

in a household, lack of a primary-school education, and household's heads older than 50 years old increase the likelihood of household's falling into the lowest quintile of total NFD [20].

One of our intentions in assessing NFD score in rural food and nutrition system was identifying the relative role(s) of homestead production, processing, markets, and diet in nutritional diversity as well as investigating its effect on household nutrient adequacy and food security. Since NFD scores of homestead production and processing in food secure and insecure household's were found to be similar, the women empowerment program [54-56] can be considered as an effective approach on both increasing diversity in household's and reducing food insecurity. As well, the development of local food markets with more affordable prices can increase household access to diverse foods [18, 24]. Finally, although the NFD score of native plants was low, it was indicated that they can play an important role in household diet in certain seasons, especially in food insecure households.

Strengths and limitations

One of the strengths of this study was that the food and nutrition system was seen at different stages, while most studies performed in this field have only seen the relationship between production diversities or diet diversity with nutritional consequences separately [22, 53]. Furthermore, examining the relationship between NFD score and various nutritional outcomes, i.e. food security status, adequacy of micronutrients, and anthropometric indicators was another important point of the current study, while previous studies have often examined one or two nutritional outcomes.

However, the results of the present study should be interpreted with some cautions, and its limitations also need to be considered. It should be noted that we were not able to assess some

factors affecting the NFD score of home products, including soil and water quality, garden size, and environmental factors. Half of the surveyed villages had no access to piped water and their sources of agricultural water were saline water wells. Therefore, improving water access for subsistence farms seems to be a more promising development strategy.

The NFD of purchased foods was calculated from the data by two non-consecutive 24h dietary recalls, which did not include any seasonal difference. Analyzing the NFD in household's diets and food sources in different seasons would require data collection at different seasons.

Conclusion

A holistic perspective to food security which encompasses food diversity in all aspects of food and nutrition system is missing in Iran. NFD is a metric describing diversity in providing nutrients from farm to markets and all the ways directed to the consumption level. This study showed the foods purchased from the city play the main roles in rural household's NFD score. NFD score of homestead production and household's processing were found to be five times less than those of foods purchased from cities. An inverse and strong association was found between NFD scores of foods purchased from city and MAR.

More studies are required to clarify whether NFD score can better reflect diversity compared to other indicators of diversity. Besides, the cut-off points for NFD to rate diversity adequacy should be defined. Additionally, further studies are needed to gain a better understanding on the issue that what types of markets and market transformations have what kinds of nutritional outcomes in the rural area of developing countries. Overall, the NFD score seems to have a potential to be used as a policy tool, because it can help policy makers to identify gaps in the

local food and nutrition system and then to plan appropriate interventions, especially in low-income communities.

Abbreviations

NFD: Nutritional Functional Diversity; MAR: Mean Adequacy Ratio; DRI: Dietary Reference Intake; AMEs: Adult Male Equivalent units; NAR: Nutrient Adequacy Ratio; HFIAS: Household Food Insecurity Access Scale; BMI: Body Mass Index; SE: Standard Error; OR: Odds Ratios; CI: Confidence Intervals; SPSS: Statistical Package for the Social Sciences; UCT: Unconditional Cash Transfer; FS: Food secure; FI: Food Insecure.

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Authors' contributions

MS, HEZ and NO designed the study, performed the study and analyses, and wrote the main paper. SMT helped analyses and interpret the data. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the authors on reasonable request.

Declarations

Ethics approval and consent to participate

The study was approved by the ethics committee of National Nutrition and Food Technology Research Institute, Shahid Beheshti University of Medical Sciences, Tehran, Iran (ID: "IR.SBMU.NNFTRI.1398.032"). The required data were collected through face-to-face interviews with mothers (assisted by their husbands), after signing an informed consent form. All protocols were carried out in accordance with relevant guidelines and regulations.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

References

1. McGuire S. WHO, World Food Programme, and International Fund for Agricultural Development. 2012. The State of Food Insecurity in the World 2012. Economic growth is necessary but not sufficient to accelerate reduction of hunger and malnutrition. Rome, FAO. Advances in Nutrition: An International Review Journal. 2013;4(1):126-7. https://doi.org/10.3945/an.112.003343
2. WHO. The state of food security and nutrition in the world 2019: Safeguarding against economic slowdowns and downturns: Food & Agriculture Org.; 2019.
3. Griggs D, Stafford-Smith M, Gaffney O, Rockström J, Öhman MC, Shyamsundar P, et al. Policy: Sustainable development goals for people and planet. Nature. 2013;495(7441):305.
4. WHO. The state of food security and nutrition in the world 2018: building climate resilience for food security and nutrition: Food & Agriculture Org.; 2018.
5. Graham RD, Welch RM, Saunders DA, Ortiz-Monasterio I, Bouis HE, Bonierbale M, et al. Nutritious subsistence food systems. Advances in agronomy. 2007;92:1-74. https://doi.org/10.1016/S0065-2113(04)92001-9
6. Mergenthaler M, Weinberger K, Qaim M. The food system transformation in developing countries: A disaggregate demand analysis for fruits and vegetables in Vietnam. Food Policy. 2009;34(5):426-36. https://doi.org/10.1016/j.foodpol.2009.03.009
7. Kennedy GL, Pedro MR, Seghieri C, Nantel G, Brouwer I. Dietary diversity score is a useful indicator of micronutrient intake in non-breast-feeding Filipino children. The Journal of nutrition. 2007;137(2):472-7. https://doi.org/10.1093/jn/137.2.472
8. Graham RD. Micronutrient deficiencies in crops and their global significance. Micronutrient deficiencies in global crop production: Springer; 2008. p. 41-61. https://doi.org/10.1007/978-1-4020-6860-7_2
9. Pollan M. Farmer in chief. New York Times Magazine. 2008;12.

10. Arimond M, Ruel MT. Dietary diversity is associated with child nutritional status: evidence from 11 demographic and health surveys. The Journal of nutrition. 2004;134(10):2579-85. https://doi.org/10.1093/jn/134.10.2579

11. Moursi MM, Arimond M, Dewey KG, Treche S, Ruel MT, Delpeuch F. Dietary diversity is a good predictor of the micronutrient density of the diet of 6-to 23-month-old children in Madagascar. The Journal of Nutrition. 2008;138(12):2448-53. https://doi.org/10.3945/jn.108.093971

12. Warren E, Hawkesworth S, Knai C. Investigating the association between urban agriculture and food security, dietary diversity, and nutritional status: A systematic literature review. Food Policy. 2015;53:54-66. https://doi.org/10.1016/j.foodpol.2015.03.004

13. Kant AK, Schatzkin A, Harris TB, Ziegler RG, Block G. Dietary diversity and subsequent mortality in the first national health and nutrition examination survey epidemiologic follow-up study. The American journal of clinical nutrition. 1993;57(3):434-40. https://doi.org/10.1093/ajcn/57.3.434

14. Lv Y, Kraus VB, Gao X, Yin Z, Zhou J, Mao C, et al. Higher dietary diversity scores and protein-rich food consumption were associated with lower risk of all-cause mortality in the oldest old. Clinical Nutrition. 2020;39(7):2246-54. https://doi.org/10.1016/j.clnu.2019.10.012

15. Gaitán-Cremaschi D, Klerkx L, Duncan J, Trienekens JH, Huenchuleo C, Dogliotti S, et al. Characterizing diversity of food systems in view of sustainability transitions. A review. Agronomy for sustainable development. 2019;39(1):1-22. https://doi.org/10.1007/s13593-018-0550-2

16. Pinstrup-Andersen P. Agricultural research and policy for better health and nutrition in developing countries: a food systems approach. Agricultural Economics. 2007;37:187-98. https://doi.org/10.1111/j.1574-0862.2007.00244.x

17. Ruel M. Animal source foods to improve micronutrient nutrition and human function in developing countries. Operationalizing Dietary Diversity: A Review of Measurement Issues and Research Priorities. Journal of Nutrition. 2003;133:3911S-26S.

18. Ambikapathi R, Gunaratna NS, Madzorera I, Passarelli S, Canavan CR, Noor RA, et al. Market food diversity mitigates the effect of environment on women's dietary diversity in the Agriculture to Nutrition (ATONU) study, Ethiopia. Public health nutrition. 2019;22(11):2110-9. doi:10.1017/S136898001900051X

19. Jones AD. On-farm crop species richness is associated with household diet diversity and quality in subsistence-and market-oriented farming households in Malawi. The Journal of nutrition. 2017;147(1):86-96. https://doi.org/10.3945/jn.116.235879

20. Luckett BG, DeClerck FA, Fanzo J, Mundorf AR, Rose D. Application of the nutrition functional diversity indicator to assess food system contributions to dietary diversity and sustainable diets of Malawian households. Public health nutrition. 2015;18(13):2479-87. doi:10.1017/S136898001500169X

21. Remans R, Flynn DF, DeClerck F, Diru W, Fanzo J, Gaynor K, et al. Assessing nutritional diversity of cropping systems in African villages. PloS one. 2011;6(6).

22. Le Garff M. Nutritional functional diversity in farmer households: case study from semi-arid Burkina Faso: Master of Organic Agriculture), Wageningen University & Research, Wageningen …; 2016.

23. Koppmair S, Kassie M, Qaim M. Farm production, market access and dietary diversity in Malawi. Public health nutrition. 2017;20(2):325-35. doi:10.1017/S1368980016002135

24. Bellon MR, Ntandou-Bouzitou GD, Caracciolo F. On-farm diversity and market participation are positively associated with dietary diversity of rural mothers in Southern Benin, West Africa. PloS one. 2016;11(9):e0162535.
25. NutritionHLPE. food systems: a report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security. Committee on World Food Security: Rome, Italy. 2017.
26. Alders R, Aongola A, Bagnol B, de Bruyn J, Darnton-Hill I, Jong J, et al., editors. Village chickens and their contributions to balanced diverse diets throughout the seasons. World Veterinary Poultry Association Congress Cape Town; 2015.
27. Osei A, Pandey P, Nielsen J, Pries A, Spiro D, Davis D, et al. Combining home garden, poultry, and nutrition education program targeted to families with young children improved anemia among children and anemia and underweight among nonpregnant women in Nepal. Food and Nutrition Bulletin. 2017;38(1):49-64. https://doi.org/10.1177/0379572116676427
28. Ferdous Z, Datta A, Anal AK, Anwar M, Khan AMR. Development of home garden model for year round production and consumption for improving resource-poor household food security in Bangladesh. NJAS-Wageningen Journal of Life Sciences. 2016;78:103-10. https://doi.org/10.1016/j.njas.2016.05.006
29. Babu SC, Dorosh PA. From famine to food security: Lessons for building resilient food systems. 2017.
30. Gupta S, Vemireddy V, Pingali PL. Nutritional outcomes of empowerment and market integration for women in rural India. Food security. 2019;11(6):1243-56. https://doi.org/10.1007/s12571-019-00978-z
31. Barrett CB. Smallholder market participation: Concepts and evidence from eastern and southern Africa. Food policy. 2008;33(4):299-317.
32. Chamberlin J, Jayne TS. Unpacking the meaning of 'market access': evidence from rural Kenya. World development. 2013;41:245-64. https://doi.org/10.1016/j.worlddev.2012.06.004
33. Ansari H, Shahbaz B, Izadi S, Zeinali M, Tabatabaee SM, Mahmoodi M, et al. Crimean-Congo hemorrhagic fever and its relationship with climate factors in southeast Iran: a 13-year experience. The Journal of Infection in Developing Countries. 2014;8(06):749-57. https://doi.org/10.3855/jidc.4020
34. Kolahdooz F, Najafi F, Sadeghi Ghotbabadi F. Report of a national survey: food security information and mapping system in Iran. Tehran: Ministry of health and medical education. 2012.
35. Mortazavi Z, Dorosty AR, Eshraghian MR, Ghaffari M, Ansari-Moghaddam A, Mohammadi M. Household food insecurity in Southeastern Iran: severity and related factors. International journal of food science ;2017.
36. https://www.amar.org.ir/Portals/0/info-unit/Files/94.pdf. Accessed 13 May 2021.
37. Kalantari N, Ghaffarpur M, et al. Appendixes of National Report of "The Comprehensive Study on Household Food Consumption Patterns and Nutritional Status of I.R.Iran, 2001-2003". Nutrition Research Group, National Nutrition and Food Technology Research Institute, Shaheed Beheshti University of Medical Sciences, Ministry of Health, Tehran, I.R. Iran, 2005, Pages 151-191.
38. https://fdc.nal.usda.gov. Accessed 10 May 2021.
39. Joint, FAO, World Health Organization. Protein and amino acid requirements in human nutrition: report of a joint FAO/WHO/UNU expert consultation: World Health Organization; 2007.
40. United Nations University, World Health Organization. Human Energy Requirements: Report of a Joint FAO/WHO/UNU Expert Consultation: Rome, 17-24 October 2001: Food & Agriculture Org.; 2004.

41. Weisell R, Dop MC. The adult male equivalent concept and its application to Household Consumption and Expenditures Surveys (HCES). Food and nutrition bulletin. 2012;33(3_suppl2):S157-S62. https://doi.org/10.1177/15648265120333S203

42. Bermudez OI, Lividini K, Smitz M-F, Fiedler JL. Estimating micronutrient intakes from Household Consumption and Expenditures Surveys (HCES): an example from Bangladesh. Food and nutrition bulletin. 2012;33(3_suppl2):S208-S13. https://doi.org/10.1177/15648265120333S209

43. Fiedler JL, Lividini K, Bermudez OI, Smitz M-F. Household Consumption and Expenditures Surveys (HCES): a primer for food and nutrition analysts in low-and middle-income countries. Food and nutrition bulletin. 2012;33(3_suppl2):S170-S84. https://doi.org/10.1177/15648265120333S205

44. M'Kaibi FK, Steyn NP, Ochola S, Du Plessis L. Effects of agricultural biodiversity and seasonal rain on dietary adequacy and household food security in rural areas of Kenya. BMC Public Health. 2015;15(1):422. https://doi.org/10.1186/s12889-015-1755-9

45. Mohammadi F, Omidvar N, Houshiar-Rad A, Khoshfetrat M-R, Abdollahi M, Mehrabi Y. Validity of an adapted Household Food Insecurity Access Scale in urban households in Iran. Public health nutrition. 2012;15(1):149-57. https://doi.org/10.1017/S1368980011001376

46. Coates J, Swindale A, Bilinsky P. Household Food Insecurity Access Scale (HFIAS) for measurement of food access: indicator guide: version 3. 2007.

47. Tjepkema M. Adult obesity. Health reports-statistics canada. 2006;17(3):9.

48. https://www.euro.who.int/en/health-topics/disease-prevention/nutrition/a-healthy-lifestyle. Accessed 14 May 2021..

49. Brown JE. Nutrition through the life cycle: Cengage learning; 2016.

50. Haqiqi I, Shahi Z, Ismaili M. Impact of Cutting Cash Subsidy Transfer to the Rich in a Nonlinear Programming Model for Economic Input-Output Analysis. Journal of Economic Research (Tahghighat-E-Eghtesadi). 2017;52(3):581-618. https://doi.org/10.22059/JTE.2017.63306

51. DeClerck FA, Fanzo J, Palm C, Remans R. Ecological approaches to human nutrition. Food and Nutrition Bulletin. 2011;32(1_suppl1):S41-S50. https://doi.org/10.1177/15648265110321S106

52. Wood S. Crop functional trait diversity and human nutrition in southeastern Senegal. J Appl Ecol (Forthcoming). 2017. https://doi.org/10.1111/1365-2664.13026

53. Sibhatu KT, Qaim M. Meta-analysis of the association between production diversity, diets, and nutrition in smallholder farm households. Food Policy. 2018;77:1-18. https://doi.org/10.1016/j.foodpol.2018.04.013

54. Voufo BT, Uchenna E, Atata SN. WOMEN EMPOWERMENT AND INTRA-HOUSEHOLD DIETARY DIVERSITY IN NIGERIA. Journal of Research in Gender Studies. 2017;7(2).

55. Murugani VG, Thamaga-Chitja JM. How does women's empowerment in agriculture affect household food security and dietary diversity? The case of rural irrigation schemes in Limpopo Province, South Africa. Agrekon. 2019;58(3):308-23. https://doi.org/10.1080/03031853.2019.1610976

56. Kassie M, Fisher M, Muricho G, Diiro G. Women's empowerment boosts the gains in dietary diversity from agricultural technology adoption in rural Kenya. Food Policy. 2020;95:101957. https://doi.org/10.1016/j.foodpol.2020.101957

Figures

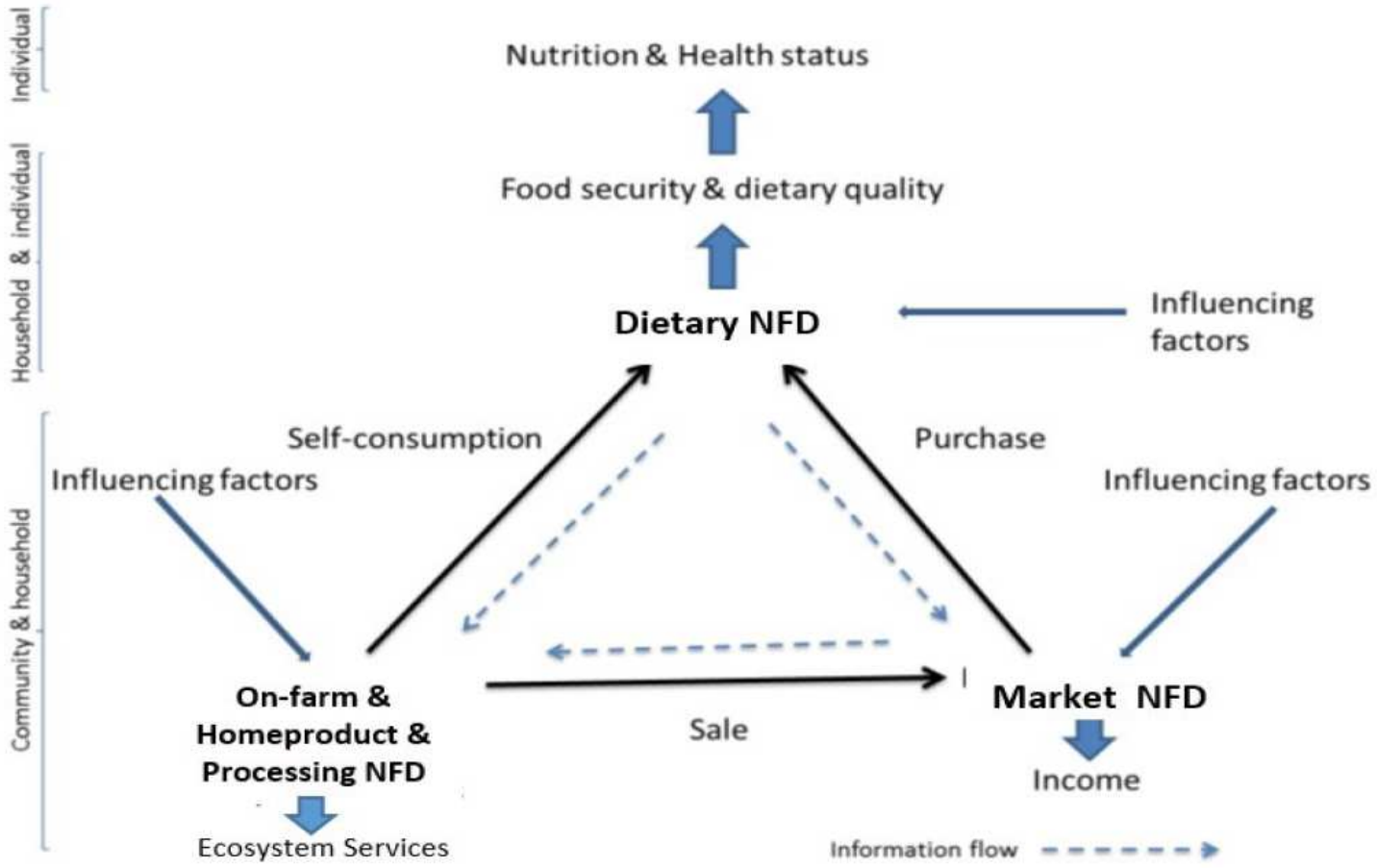

Figure 1

Conceptual framework on the linkage among the farm, homestead production and household's processing NFD, as well as the purchased food and dietary NFD in rural food and nutriton system [24]