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Dietary Diversity and Pattern Estimation in Ethiopia

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## List of Tables

1	Elements of Dietary Diversity Indicators . . . . .	3
2	Food groups and weight of HDDS . . . . .	6
3	Food groups and weight of FCS . . . . .	7
4	Elements of Dietary Diversity Indicators . . . . .	18
5	Consumption condition of target group . . . . .	21

## List of Figures

1	Household sample distribution . . . . .	4
2	WCSS for 12 food groups and 11 food groups . . . . .	8
3	Data structure of four indicators . . . . .	9
4	Food Richness map . . . . .	9
5	HDDS map . . . . .	10
6	FCS score map . . . . .	11
7	Entropy index map . . . . .	11
8	PCA plots on first two components (12 food groups on the left, 11 food groups on the right) . . . . .	13
9	Cluster center plots, 12 groups on the left, 11 groups on the right . . . . .	14
10	Occurrence rate of 12 food group clustering . . . . .	15
11	Occurrence rate of 11 food group clustering . . . . .	16
12	Variable importance plot . . . . .	17
13	Partial dependence plots . . . . .	19
14	Occurrence rate of target group . . . . .	20

# Contents

<b>List of Tables</b>	<b>II</b>
<b>List of Figures</b>	<b>II</b>
<b>1 Introduction</b>	<b>1</b>
<b>2 Background</b>	<b>2</b>
2.1 Dietary Diversity Indicators . . . . .	2
2.2 Ethiopia Diet Condition . . . . .	3
<b>3 Data and method</b>	<b>4</b>
3.1 Data . . . . .	4
3.2 Variables . . . . .	4
3.3 Method . . . . .	5
3.3.1 Indicators of the Dietary Diversity . . . . .	5
3.3.2 Food pattern analysis . . . . .	7
3.3.3 Locate the Target group . . . . .	8
<b>4 Result</b>	<b>8</b>
4.1 Richness and Diversity patterns . . . . .	8
4.2 Clustering of different dietary patterns . . . . .	12
4.3 Classification base on the locational conditions . . . . .	14
<b>5 Discussion and conclusion</b>	<b>17</b>
<b>Reference</b>	<b>22</b>
<b>A Unit conversion list</b>	<b>24</b>
<b>B Distribution map of food groups and important food items</b>	<b>25</b>

**Abstract:** This project develops methods to provide high spatial resolution baseline data on dietary diversity in Ethiopia. Such data can be used for the design and evaluation of food security programs and interventions but is generally not available. Data from the 2013 Living Standards Measurement Study (LSMS) were used to calculate the dietary diversity score of each household sample. Spatial prediction models of dietary diversity were fitted using the location of the households and spatial co-variates. The algorithm used was Random Forest. Predictions had cross-validation accuracy rates of  $> 75\%$ . K-means clustering was used to assign the households to different groups according to their consumption quantities of each food groups. One cluster with both the lowest total food consumption and the most moderate non-staple food consumption become the target group. Finally, Random Forest model that has a cross-validation accuracy rate of  $75\%$  was used to locate the spatial distribution of target group membership.

## 1 Introduction

There are many projects to improve the nutrition of people in developing countries. However, data on the populations nutrition status is generally not available at the subnational level. Valid and timely nutrition assessment is the foundation on which effective interventions and programs can be built to improve the food and nutrition situation of people. The best way of evaluation is to get the individual quantitative dietary intake surveys; however, sometimes these kind surveys are expensive and difficult to implement, so a substantial dietary diversity tool has been validated as a simple proxy of intake[11]. Dietary Diversity important because it has been confirmed by many studies that have a positive association with child growth, household per capita income and energy availability[18]. In this project, the dietary diversity indicator is the first tool used to analyze the food security condition in Ethiopia.

Ethiopia is the 11th poorest country in the world by income per person, and home to Sub-Saharan Africa's second largest population of about 92 million people, the vast majority of which are rural dwellers[7]. It is facing severe food security problems like underweight and stunting[12]. So in the last 20 years, it launched many nutrient programs. In the process of the developmental program, it is essential to do the targeting as accurate as possible, because poor targeting will 'leak' into market, harm the social justice as well as market efficiency[20]. Three primary targeting methods utilized in nutrition improvement programs in Ethiopia are administrative targeting, self-targeting, and community-based targeting [6]. For different programs with various scale and objectives, these three methods should serve cooperatively in separate steps.

According to Broussard (2012), adult nutrition in Ethiopia depends on the intrahousehold allocation of food consumption and energy expenditure that is determined by village prices, nonlabor income, and individual health endowments[4]. A model like this with a lot of personal information can deepen the understanding of the cause and effects of nutrition problem; however, it is not very easy to use it in targeting for the difficulty in the collection of the information. With data from LSMS, our project will try to use a more intuitive method to visualize the data and to estimate the spatial distribution of those households with the lowest food consumption. Ethiopia is one of the few countries globally and in Africa with representative data at both national and administrative region level for individual-level dietary intake data[1]. This project uses household-level data to analyze the geographical pattern to get a general understanding of the food intake distribution. One possible limitation of the method

is that LSMS collect data at the “household” level, but usually, we are interested in what individuals in the household consumed. Food is not always distributed equally within the household, but that assumption must be made in the analysis of LSMS data. It is true that the analysis generated by individual-level data can provide a more clear view of the nutrition condition for different groups of people, but the household-based study still has its unsubstituted impact on some food aid interventions which are not yet able to influence the allocation situation within the household. Furthermore, the adult equivalence scales also takes children and women into consideration. The result of our project will be more emphasis on economic accessibility to food and shows more value on the targeting of the food insecurity household, rather than the nutritional conditions. Food insecurity is not only a significant cause of the malnutrition but also can reflect the allocation of food resource. [21] We use cluster method on the quantitative food intake per person per day as the judgment criteria of the target group. So it can make sure the result be a better fit under Ethiopia context. The clustering decision referred to a coordinate of the total household consumption samples, and it produces results of not only the lowest consumption group but also the different diet patterns. Though compared to the nutrition recommendation value, this method may have a lower efficiency of improving a specific nutrient element intake; it can enhance the fairness of the resource allocation by considering the synthetic message.

## 2 Background

Living Standards Measurement Study (LSMS) which holds by the World Bank has a focus on the measurement of poverty and food insecurity and provides a large scale household data to solve this problem. Every household is coded with a unique ID and the geolocations formed in latitude and longitude are also collected by the survey. The section of Social-economic survey collects the detailed food consumption (“apparent consumption”) data for households in 7 days, which can be measured in grams and also be converted into dietary diversity indicators. These indicators are claimed as proxies for actual caloric intake and diet quality. Base on the quantity and diversity scores, we can to visualize and illustrate the quantitative distribution. We can also find if there is a geographical pattern of the Ethiopia dietary diversity and food consumption to understand the result.

### 2.1 Dietary Diversity Indicators

There are many Dietary Diversity Indicators for the measurement of the diet quality in developing countries. Among different kind of dietary diversity indicators, Household Dietary Diversity Score (HDDS), the Infant and Young Child Minimum Dietary Diversity(IYCF MDD), Women’s Dietary Diversity Score(WDDS) and the Food Consumption Score are utilized at large population level. Because these indicators are designed to meet different purposes, they may have a different number of food groups and thresholds. HDDS covers 12 food groups, and it lay special emphasis on economic access to food[25]. WDDS only included nine food groups to illustrate the micronutrient adequacy of the diet[10]. IYCF MDD has seven food groups to reflect the dietary quality of 6-23 month children[16].

To do the evaluate, many studies use the number of food groups the household or individual consumed as a threshold between good and bad standards[9][25]. For example, MDD-W use

5 or more of the 10 food groups as its threshold : the percentage  $X$  of women who got under 5 scores can be interpreted as “ $(100 - X)\%$  of women achieved minimum dietary diversity, and they are more likely to have higher (more adequate) micronutrient intakes than the  $X\%$  of women who did not” [9];. Contrast with the dichotomous evaluation method, FCS gives different weights to 9 food groups base on the “nutrient density” and use scores to do the assessment[24]. In this research, we use both HDDS and the Food Consumption Score (FCS) as the proxy of the dietary diversity indicator. There is subjectivity inherent in the weight design; nevertheless, it can still depict more dimensions of the dietary quality information than other indicators.

## 2.2 Ethiopia Diet Condition

Ethiopia Launched two 5-year-plans to accelerate and sustain the development to end poverty from 2005[8]. Till 2015, the hunger index of Ethiopia dropped from 48.5 to 33.9 and decreased by 30% [22]. However, there are still nutrient problems need to be solved. The previous surveys and studies specified the nutrition problems of Anemia[3], Vitamin A in Ethiopia.

Because the economy of Ethiopia is based on small landholder agriculture and more than 85% of the population of 63 million living in rural areas under very poor conditions[12], the decisive background of understanding Ethiopia diet condition is its complex geography and agroclimatic zones. It determined a large part of the local market development and food production. Temperature and rainfall are the most important climatic factors for agricultural production in Ethiopia. Altitude is a factor that determines the distribution of climatic factors and land suitability[15]. Ethiopia has eleven traditional ecological zones, and the standard of divisions are mainly annual rainfall and meters above sea level. In the different ecological zone, the crops are also different from each other. The “Dry weyna dega”, “Dry kolla”, and “Bereha” have less than 900mm annual rainfall. It located mainly in Afar, Somali, and east of Oromyia, and they also got a relatively lower altitude. The four moist zones, “Moist wurch”, “Moist dega”, “Moist weyna dega” and “Moist kolla” got annual rainfall between 900mm and 1400mm,. “High wurch” and other three wet zones(“Wet wurch”, “Wet dega”, “Wet weyna dega”) have more than 1400mm annual rainfall and located in the central area like Amhara and western Oromya. But because of the high altitude, they do not have a higher agricultural production compared with other zones in Ethiopia. Distance from the market and population centers also determines its accessibility to adequate food. These factors not only have high correlations with the household consumption condition but also easy to obtain which will improve the feasibility of targeting. Teff, wheat, sorghum, and barley are the five wide cultivated cereals in Ethiopia, and they all enclosed in the survey.

Table 1: *Elements of Dietary Diversity Indicators*

	HDDS	IYCF MDD	WDDS	FCS
Year	2011	2007	2011	2008
Organization	FAO	WHO	FAO	WFP
Number of food group	12	7	9	9
Sampled/unit of analysis	Household	Infants and young children aged 6-23m	Women aged 15-49 years	Household



Figure 1: *Household sample distribution*

[23]

### 3 Data and method

#### 3.1 Data

This project use data from Living Standards Measurement Study in Ethiopia in 2013[25]. The sample size is 5262 household, and its distribution is weighted by Ethiopia population density. We can have a look at the distribution of all the households on the map in figure 1. ESS 2013-14 Household Questionnaire, Section 5A ,Food Last 7 Day ( “sect5a\_hh\_w2”, “sect5b\_hh\_w2” [19] ) provides the weekly household food consumption data. The description of household consumption question is like this: “Over the past one week(7 days), did you or others in your household consume any[ITEM]? Include food both eaten communally in the household and that eaten separately by individual household members” [2] In “sect5a\_hh\_w2”, the consumption information was recorded by the quantity of each kind of food item; while “sect5b\_hh\_w2” collects for each 16 food groups the number of times, a household consumed it in 7 days. Both of the frequency and amount data contribute to the generating of dietary diversity indicators. According to the different score method, Richness, HDDS, and Entropy index use the amount data, while FCS uses the frequency data. The General Household SurveyPanel 2 (cons\_agg\_w2) is used to capture the necessary household information of the households like the household size and adult equivalence scales . Location information and position factors like distance to road or population centers are from Living Standards Measurement Study-Integrated Surveys on Agriculture ( Pub\_ETH\_HouseholdGeovars\_Y2). We get Ethiopia map information from GADM database.

#### 3.2 Variables

The prime key and unique ID for each sample household in LSMS survey is “household\_id2”, which is used to identify different cases. Except for ID variables, all the other variables are used to predict the consumption condition per day per person. The consumption information

of 26 food items was collected in the survey, and they are reflect in variables of “hh\_s5aq02.a”, “hh\_s5aq02.b”, “hh\_s5aq02.b.other” and “adulreq” is the adult equivalence scales. By combining variables of quantity and unit, we created “GramsCapita”. This variable indicates “How much in an average day did an adult in your HH consumed in grams in the past week?” It can make the comparison result of entropy and dietary pattern clustering method more precisely than those of frequency data.

In Africa, non-standard units (NSUs) are used quite regularly for the most important items in market and households[17]. Because 13% of the consumption data was recorded with NSUs, so the first job is converting all the unit into grams. For example, one liter of milk equals to 1030 grams of milk, and one banana was assumed to weigh 200 grams. There are 109 common and 200 uncommon units for 26 kinds of food. Every conversion factors are estimated base on secondary data and comparison with the average value. Appendice A display the sheet of conversion factors for “hh\_s5aq02.b”, “hh\_s5aq02.b.other”. Finally, we get the consumption per adult per day for each household by dividing the “adult equivalence scales” and seven days. The “adulreq” can offset the unbalance food consumption result from different age and gender of each family members, it will make the comparison between families more reasonable. For this reason, we use “adulreq” rather than “hh\_size” to get the individual data. There are many kinds of scalers and “OECD scale” is inherent in the LSMS data and accepted by this project. A disadvantage of this scaler is that “OECD scale” was first created to capture differences in need by age, and economies of scale in consumption and might not be very satisfactory. While it still provides a very similar result with the detailed measures of welfare include Calorie consumption per adult per day [5]. The scaler is calculated with the numbers of adults and children in a household by the function below:  $AE = 1 + 0.7(N_{adults} - 1) + 0.5N_{children}$  [14].

### 3.3 Method

#### 3.3.1 Indicators of the Dietary Diversity

To show the dietary richness, we firstly do a simple visualization of the household food consumption by the number of food items each household eat in 7 days. And then we use dietary diversity indicators to illustrate Ethiopia nutrient situation. In LSMS, there are questions asked the household whether they eat each of the 26 kinds of food listed in the survey. If the answer is “yes”, then we add 1 kind of food to the value of the food number they have eaten in 7 days. In this way, get the number of food items each household consumes in one week. Finally, combine the value with geolocation by household ID and Ethiopia map and finish visualization.

Richness score can be high when a household consumes a lot of kind of grains but not any other kind of nutrition. To understand more nutrient condition in Ethiopia, we have to sort the 26 kinds of food items into food groups. We use two dietary diversity indicators to score these 5262 families. The first one is HDDS. All the food items are sorted into 12 kinds of groups, and by adding the number of food groups a household consumed in last week, we can give the HDDS score. If a household got a HDDS score is larger than 7, the dietary quality are deemed as good. So base on the threshold of 7, we can do the comparison and find out the area that needs to get improvement in the diet. Table 3 is the classification of the 26 food groups.

FCS is the second dietary diversity tool we use. Rather than give the same score to each food group, FCS score lays more attention to the nutrient density and gives various

Table 2: *Food groups and weight of HDDS*

Food groups	Code	Items
Cereals	A	Barley, Bula, Kocho, Maize, Millet, Sorghum, Teff, Wheat
White tubers and roots	B	Potato
Vegetables	C	Onion
Fruit	D	Banana
Meat	E	Meat
Egg	F	Egg
Fish and other sea food	G	NA
Legumes, nuts and seeds	H	Haricot beans, Horsebeans, Chick pea, Field pea, Lentils
Milk and milk product	I	Milk, Cheese
Sugar	J	Sugar
Oils and Fats	K	Linseed, Niger seed
Condiments	L	Coffee, Salt, Chat/Kat

weight number to different food groups. We convert the existing food group information into FCS food group and calculate the FCS score following the method provided by the World Food Program(WFP). The first step of calculating the FCS score is to sum the consumption frequency of the same food group and the value above seven as 7. And then sum up the weighted food frequency of each group. The FCS can be explained as “Poor”, “Borderline”, and “Acceptable”, and the thresholds are 21.5 and 35. The food items and weight factors are as below.

However, if a household only takes a tiny amount of some food groups but a considerable amount of another kind of food in a single food group, it will be score the same as a family with a more balanced diet. To take the quantity and nutrient density into consideration, we create an innovational diversity index base on the FCS and entropy algorithm. For this indicator, we use FCS method to define the food group. But instead of count the frequency, we add up all grams of every food item by their weight. After removing all the outliers caused by missing data, we calculate the value  $p$ , which is the proportion of each food group in the total consumption for each household. Base on the proportion of each food group, the diversity index of each household is calculated. This index can reflect the quality and diversity of each family.

$$index = - \sum_{i=1}^{n=9} p_i * \ln(p_i)$$

We get richness, HDDS score, FCS score and the Entropy index of each household by those four methods introduced above. Then on the map, all the points are colored into blues and red, which symbolize the different numbers of food items they consumed. Some point of locations may represent more than one family, so the value of these points takes the average values of local households. The point distribution may not illustrate the pattern very obviously, so we do Thin plate splines (TPS) interpolation for each indicator. The reason for use TPS rather than other interpolation method is that the TPS can get a very smooth result and can show the pater more obviously.

Table 3: *Food groups and weight of FCS*

Food groups	Weight (w)	Code	Items
Main staples	2	A	Barley, Bula, Kocho, Maize, Millet, Sorghum, Teff, Wheat, Potato
Pulses	3	B	Haricot beans, Horsebeans, Chick pea, Field pea, Lentils
Vegetables	1	C	Onion
Fruit	1	D	Banana
Meat and fish	4	E	Meat, Egg
Milk	4	F	Milk, Cheese
Sugar	0.5	G	Sugar
Oil	0.5	H	Linseed, Niger seed
Condiments	0	I	Coffee, Salt, Chat/Kat

### 3.3.2 Food pattern analysis

The four indicators show very different distributions which means a high probability that there are different diet structures among the households in Ethiopia. In order to describe the different structures, we use K-means clustering methods to do unsupervised learning. Clustering is a data-driven method which can reflect the relationships between different lifestyle behaviors[13]. By using this method, we can uncover the homogenous groups of people based on the actual structure of the data. K-means can be described as below:

1. Randomly choose k cluster centroid.
2. repeat the process until convergence:  
for each sample  $i$ , calculate which cluster it belongs to

$$c^{(i)} := \arg \min_j ||x^{(i)} - \mu||^2$$

for every cluster  $j$ , recalculate its cluster centroids

$$\mu_j := \frac{\sum_{i=1}^m 1\{c^{(i)} = j\}x^{(i)}}{\sum_{i=1}^m 1\{c^{(i)} = j\}}$$

We use the sum amount of grams apparently consumed per adult male equivalent per day of each food groups to do the clustering. For the equivalent value of each household, there is 12 quantity for each food group, and this data frame reveals different consumption habits of each family. Here use the “within-cluster sums of squares(wcss)” test to choose the best number of clusters  $k$ , and the test result shows four is the best number for 12 food groups and six is the best number for the food groups without “Grains”. The K-means cluster method and can explain 75.4% and 64% variance of the total variation.

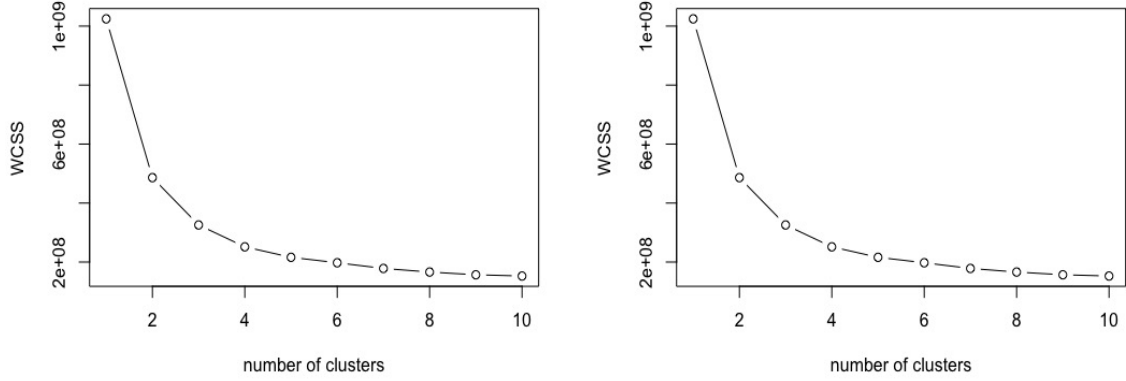


Figure 2: *WCSS for 12 food groups and 11 food groups*

### 3.3.3 Locate the Target group

There are 1105 households have both the lowest total food apparent consumption and the most moderate non-staple food consumption. We define this group as “Target group” because they have the highest risk of food insecurity problem and they are also got an obviously different diet compared with other groups. Targeting with simple information can help reduce the cost of the baseline survey and also improve the efficiency of projects. Random forest method was used to estimate whether a household belongs to the target group according to the location and natural resource information.

## 4 Result

### 4.1 Richness and Diversity patterns

Here we display the point distribution map and TPS interpolation map of the four dietary diversity indicators in figure four to seven. The four group of maps show the dietary diversity distributions vividly in different colors. The different distribution of the four maps also contains important information of the diet feature in different regions.

**Food Richness:** We add up the number of food species a household ate in one week and find out that most of them ate 710 kinds of food in one week. From TPS interpolation map, a pattern shows that people in mid of Ethiopia consume more kinds of food than people live near the border; however, households on the northern and western border also have high food consumption richness. The minimum richness happens along southern and eastern border and the middle of Amhara region.

**HDDS score:** Most of the families get a score between 4-6 and 71% household get a score less than 7. Southern Nations, Nationalities, and People’s Region (SNNPR) got the lowest score. In the Richness map, the south border of Oromiya Region got a score under average, but in the HDDS map, this area performance better than the average. This distinction indicates

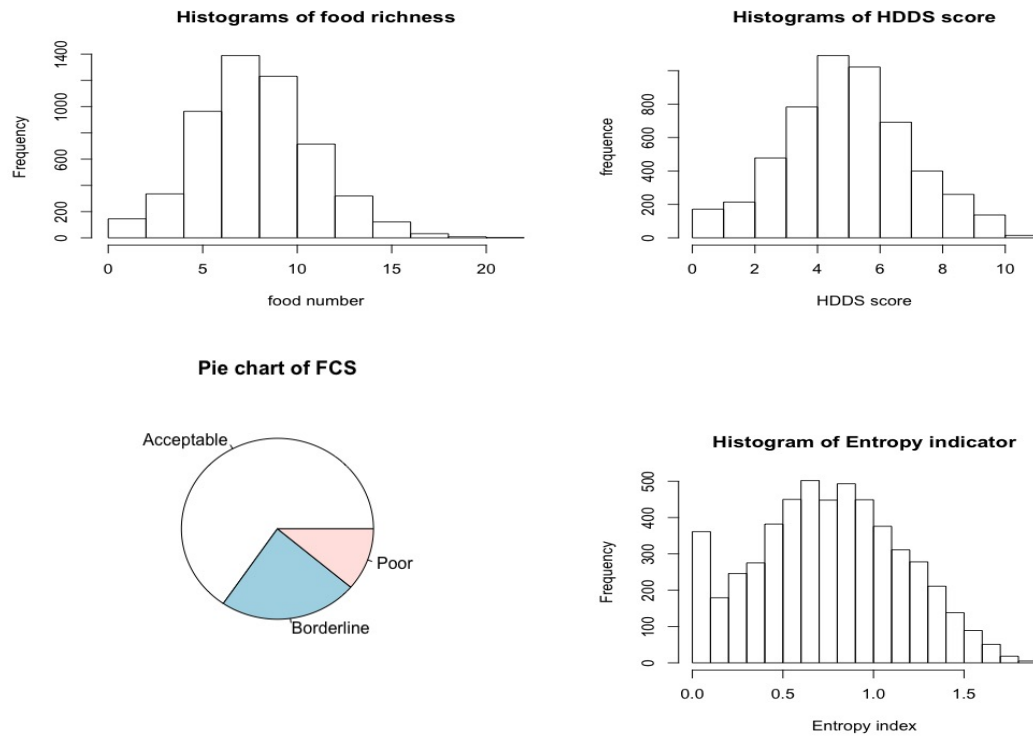


Figure 3: *Data structure of four indicators*

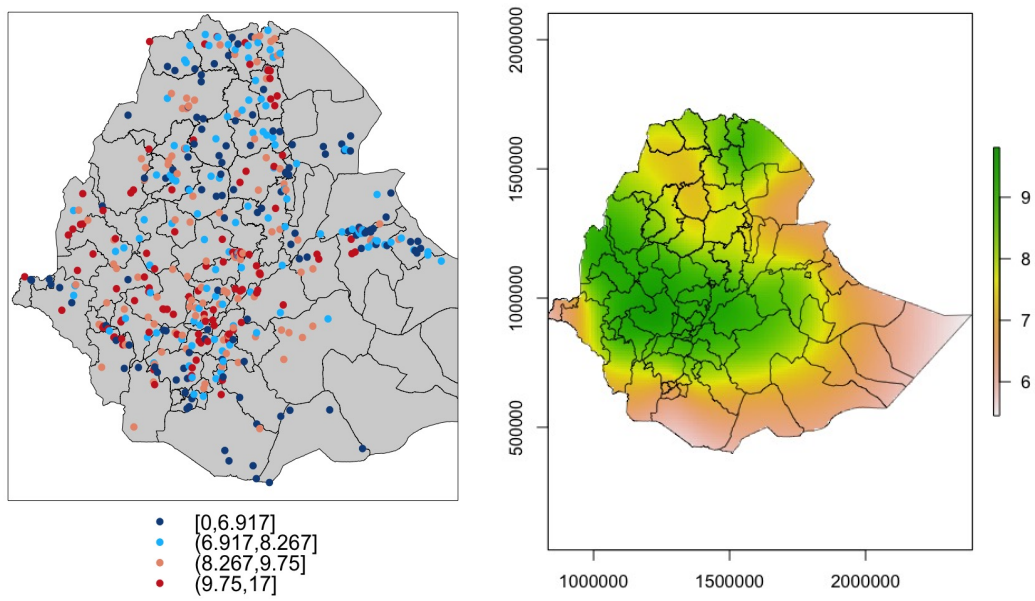


Figure 4: *Food Richness map*

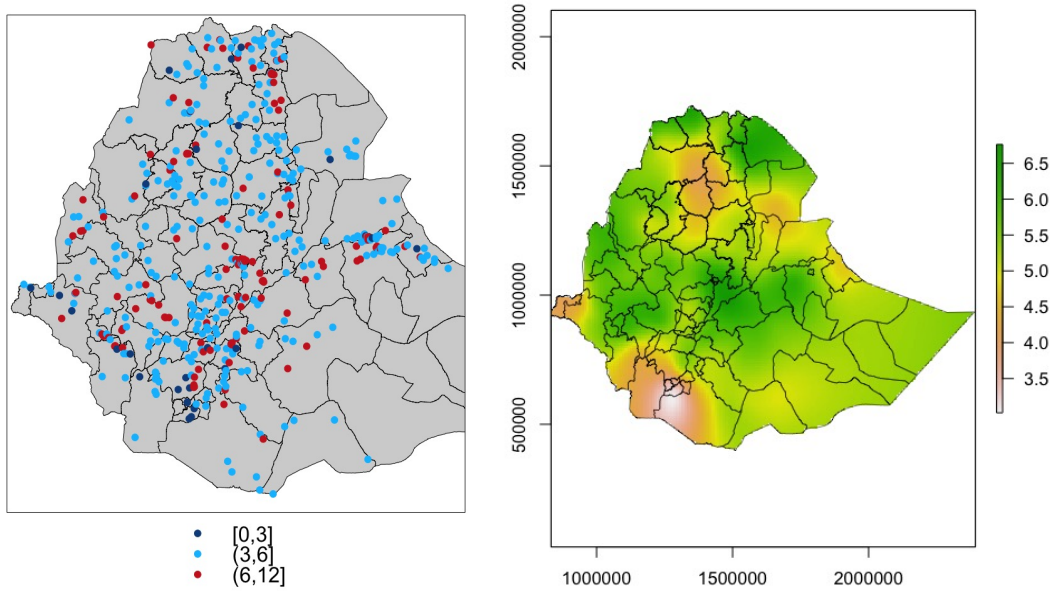


Figure 5: *HDDS map*

that people in the northeast may have a monotonous diet, but they intake balanced nutrient from different food groups. But households in the middle of the Amhara Region still got a relatively low score less than 4.

**FCS score:** In sample of 5262 households, 65% get an “Acceptable” FCS score, 23% are at “Borderline”, and 11% are classed as “Poor” dietary diversity. In FCS interpolation map, we can see an almost inverted pattern from that in the richness and HDDS map. The east area scores higher than the west, and all the “Borderline” and “Poor” diet household concentrate in the middle area. There seems a very sharp threshold between Oromiya Region and SNNPR, which is also the location of the Great Rift Valley. On the east side, households there got very high scores around 60, but on the west side, the lowest score appears. The difference between HDDS and FCS indicates that though the western households consume more food groups than the eastern families, they may have insufficient access to some foods with high nutrient density.

**Entropy index:** Foundation on the FCS food tags, we calculate the total grams of each group and use the entropy diversity index to take both quantity and the number of groups into consideration. The pattern of this index is more similar with that of FCS score; however, the threshold of entropy index move toward the east. This pattern is almost a completed inversion of the richness map. The central area around Addis Ababa is like an island with a high entropy score, but other places around this area such as Amhara Region and Oromiya Region scores lower than northeastern bordering area. The variation between Entropy and FCS implies that the households on border area may have more complicated calorie sources than those central area residents.

Incorporating the above patterns, the northern border and the western border got a better result in all the four tests, which means this two area not only consume more food items

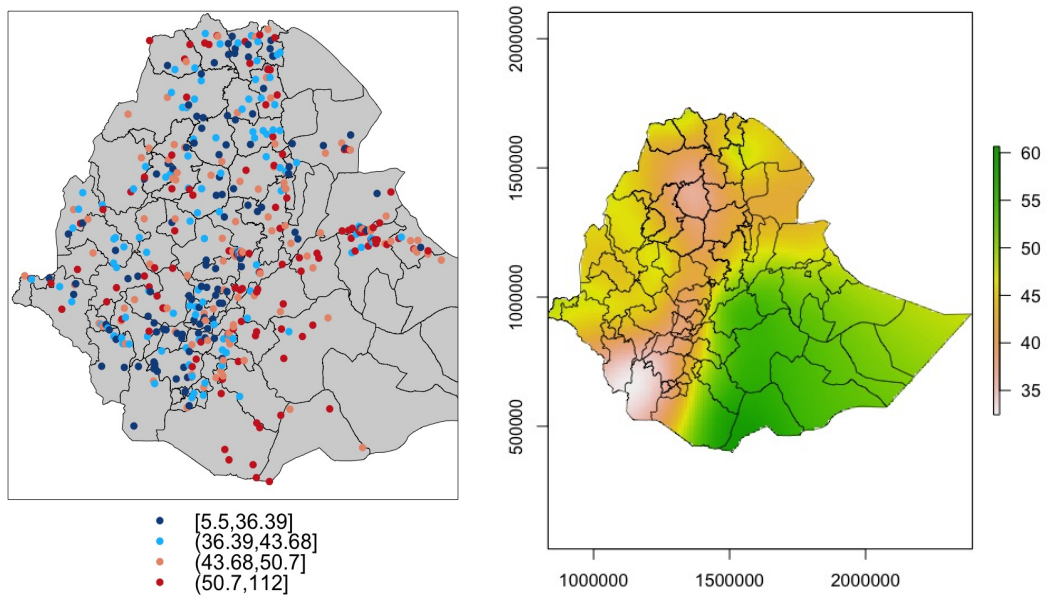


Figure 6: *FCS score map*

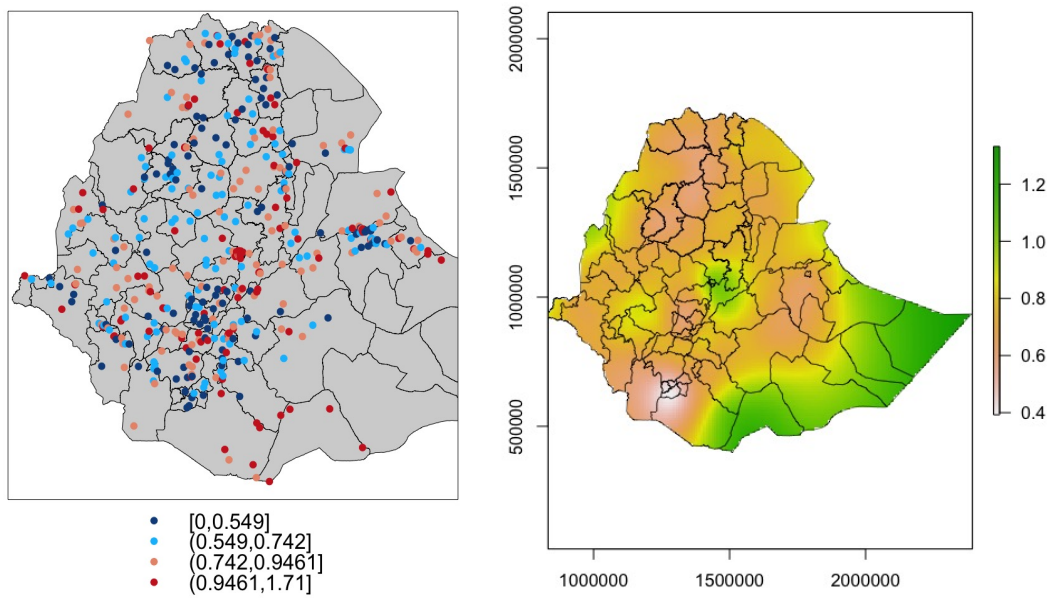


Figure 7: *Entropy index map*

than other places, they also consume more amount of food with high nutrient density. There is also a type of area got the lowest scores in all the four tests. This situation happens in the adjacent area of Afar Region and Somali Region, the central of Amhara Region and the north of SNNPR. Central and the northeastern area shows apparent contrasts in all four tests. Within this domain, the western households consume more food items while the eastern households consume more high nutrient foods. The variations result from different methods in the same area indicate that different indicators can only measure one aspect of the diet characters, and we should summarize the data in detail to get more information.

We can conclude that the area got a higher score in all the four indicators have a better dietary diversity situation and vice versa. However, these indicators cannot answer the question about “consumption quantity”, and this leads to a problem of the incomplete reveal of the nutrition condition. A household that was suffering from nutritional deficiency may get the same HDDS or FCS score as a family with a very healthy diet or even overnutrition diet. One should also be aware when interpolating the dietary diversity result, a higher score of these indicators does not guarantee a better nutrition condition, and it can only imply a smaller risk of having a nutrition deficiency.

## 4.2 Clustering of different dietary patterns

To overcome the flaws of the diversity indicators and detailed extract information from the consumption quantity data, we conduct the clustering measurement to investigate the diet patterns. Because the amount data of food group “grains” has a relatively large scale, to have a further understand on nonstaple food consumption; we make another clustering without the food group “Grain”. Standardize the group quantity data can also solve the problem brings by the considerable variation of grains; however, this method will dismiss a lot of meaningful information of the food structure. To maintain the diet structure, we didn’t choose the standardized method. In the end, two clustering we mentioned was conducted to split the households samples into different dietary patterns. After every household gets their group number of diet pattern, we can just put them on the map and find out their geographical distribution pattern.

**Principal Component Analysis (PCA):** Principal Components Analysis(PCA) is generally a dimensional reduction method and will help us capture the trend of the multidimensional data. Among 12 food groups, PCA analysis indicating that the first three Principal components can explain 42.74% of the total variations and to explain over 80 percent it needs eight components. On the first components, group “C”(Vegetable), “F”(Egg), “B”(Potato) have apparent impacts. Food group “A”(Grain) and “L”(condiments) and “H”(Pulses) has the largest loadings on the second impact. “I”(Milk) and “K”(Sugar) is the principal effector on the third component. It is also clear that group “A”(Grains) got the largest loading in all components. The staple food group was removed and the analysis run again on 11 food groups to make the difference of other food groups clear. And the result is, first three components explain 44.76% of the total sample variance and there need 7 PC to explain over 80%. Same with the result of 12 groups, “C”(Vegetable), “F”(Egg), “B”(Patoto) have the largest loads on the PC1; “I”(Milk), “K”(Sugar), “L”(condiments) contribute the most on the PC2, and “J”(Sugar), “L”,(comdiments) “H” (Pulses)got the biggest factor score in the PC3. Thought the analysis of PCA may not yield a very clear cut results, it gives us some trend that there are

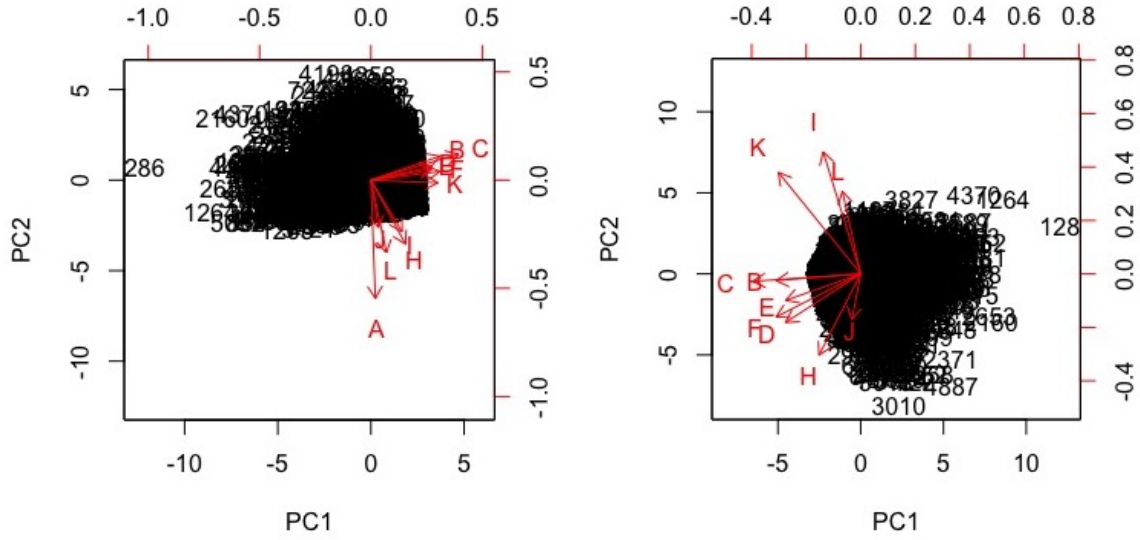


Figure 8: *PCA plots on first two components (12 food groups on the left, 11 food groups on the right)*

some internal relationships among food groups lies in different diet patterns. “C”(vegetable), “F”(eggs), “B”(potatoes); “I”(milk), “K”(sugar), and “L”(condiments) are some correlated food groups.

**K-means clustering:** We use K-means clustering method to find the suitable pattern type for the households. For the 12 food groups, we get a recommendation of 4 clusters, and for 11 food groups, 6 clusters can be a good choice. The number of 4 and 6 clusters can explain 75.4% and 54% of the total variations respectively. The cluster center plots below display the composition of each food patters.

1. for 12 food groups, the consumption quantity of food group “A”(Grain) cause most of the differences among the 4 clusters, other groups with an obvious variation are “I”(Milk) and “H”(Pulses). In 4776 household samples, there are separate 824, 1905, 1834 and 214 households categorized into 1 to 4 types of dietary pattern separately. Pattern type 3 consume the least quantity of food, so this group of households has the highest risk of nutrient deficiency. 38.4% of households are sorted into this type.
2. for the 11 food groups, 6 clusters got sizes of 2500, 104, 879, 151, 626, and 547 separately. This is not an even distribution, and more than half of the households belong to type 1 which only consume about 180 grams of non-staple food per adult equivalence per day. Low consumption quantity makes type 1 becomes the worst nutrient group among the six categories. Other five types have their own characters. Type 2 consume the largest amount of “I”(Milk) and “J”(Oil). It is very similar to type 6, which also consumes most of “I”(Milk) group as its non-staple food, but the quantity is only 29.9% of that in type 1. Because the “I”(Milk) groups contain a lot of water in it, it should not be regarded as a high nutrient group as type 2. In type 3 and type 4, “H”(Pulses) is the major part

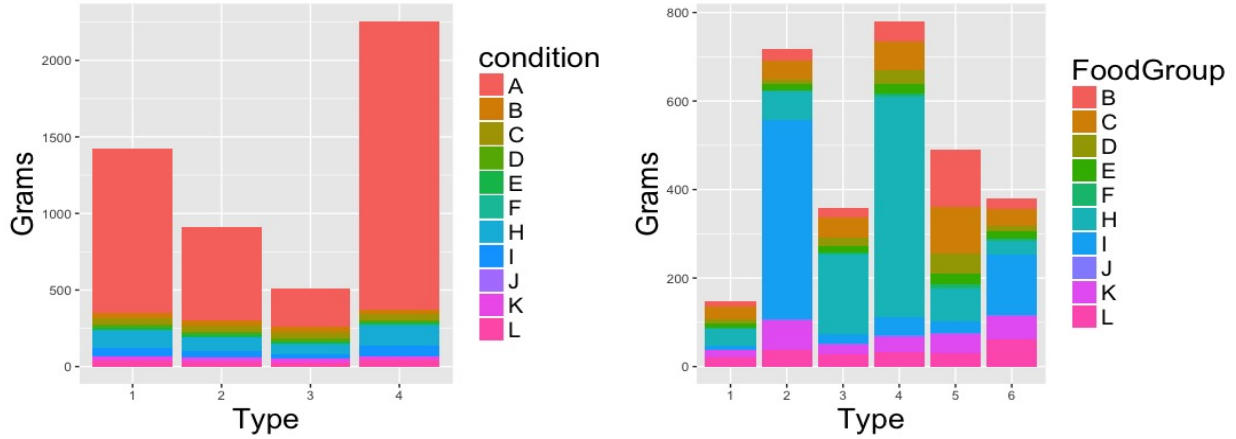


Figure 9: Cluster center plots, 12 groups on the left, 11 groups on the right

of their diet, and in type 4 they consume 498.9 grams per person per day. Type 4 also consume the second largest amount of “C” (Vegetable). Type 5 has the consume more “B”(Potato), “C”(Vegetable), and “D”(Fruit) than other types.

**Point pattern analysis:** It is difficult to find a pattern with the plot map because the households within the same food type can locate everywhere. And there are also a lot of family in the same type located in the same location. So we try to find out the distribution of each types using point pattern analysis. We use the “owin” class of each dietary type dividing the whole sample point distribution patterns to display the occurrence rate of the certain type of dietary pattern.

1. four types for 12 groups: Type 4, the largest consumption of food group “A”(Grains), happens in the north-central area and the highest occurrence rate of this type is about 7%. The second large consumption is type 1, and it gathers in two location. One is the northeast-central, and the other is the north border, the largest occurrence rate of this type is over 20%. Households located in northwestern border has an over 50% of chance to have a type 2 diet pattern. Approximately 70% of household lives on north border consume the least amount of food.
2. types for 11 groups: The occurrence rate of the most endangers type 1 decrease gradually from the northern and western border toward the east area. And it can be as high as 65% to lower than 20%. Type 2 and type 6 all occur more in the east, but the difference is, type 6 happens four times more than 2. Other three types all happens more in the central area. The highest occurrence rate of type 3 and type 5 is around 20%, and type 4 at most has about 5% happen rate in the southwest.

### 4.3 Classification base on the locational conditions

We run random forest model with 12 locational condition variables These variables are more easy to collect compared to the diet consumption data. According to the Variable Importance order in figure 12, we choose the variable sets with the lowest OOB(out-of-bag) errors (25.4%)

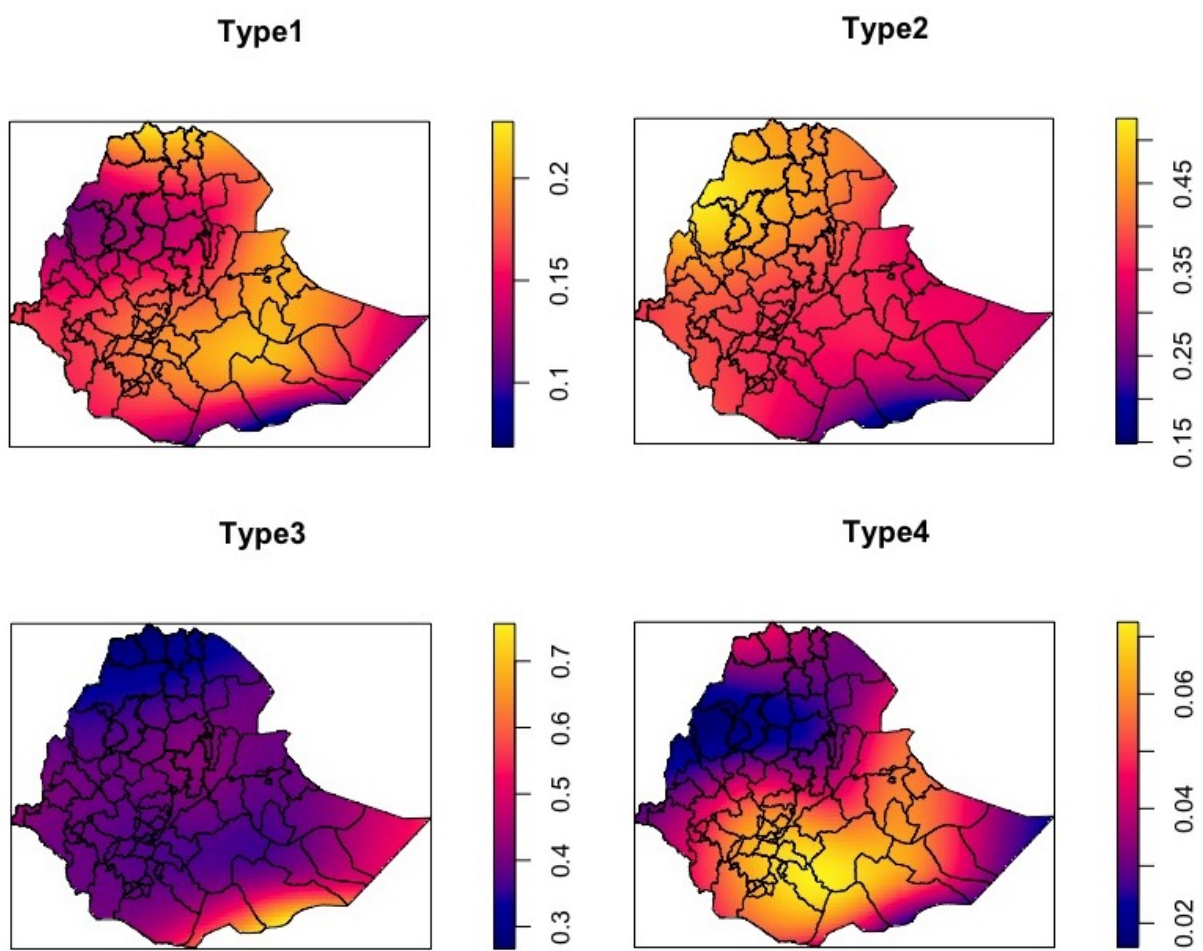


Figure 10: *Occurrence rate of 12 food group clustering*

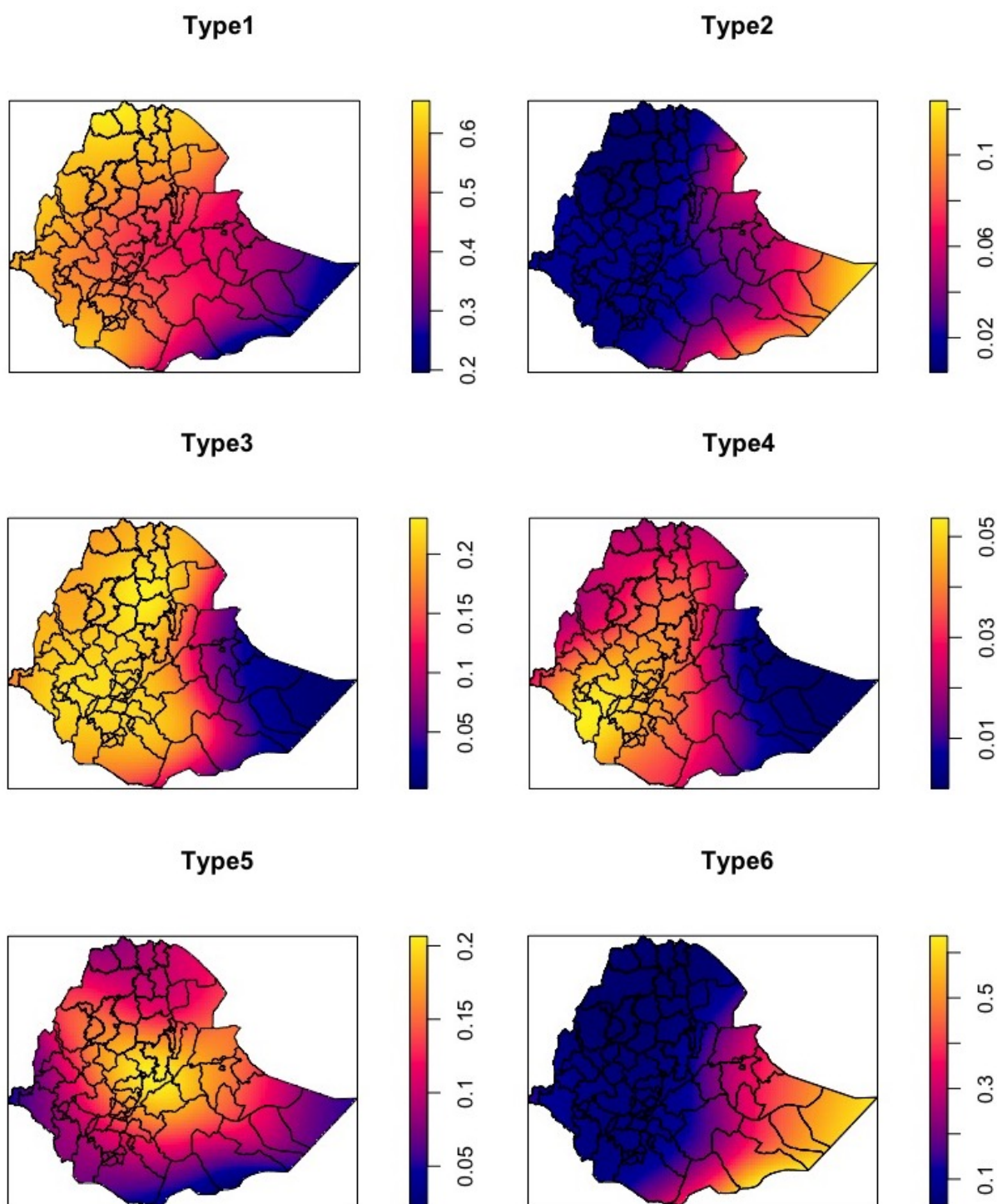


Figure 11: *Occurrence rate of 11 food group clustering*

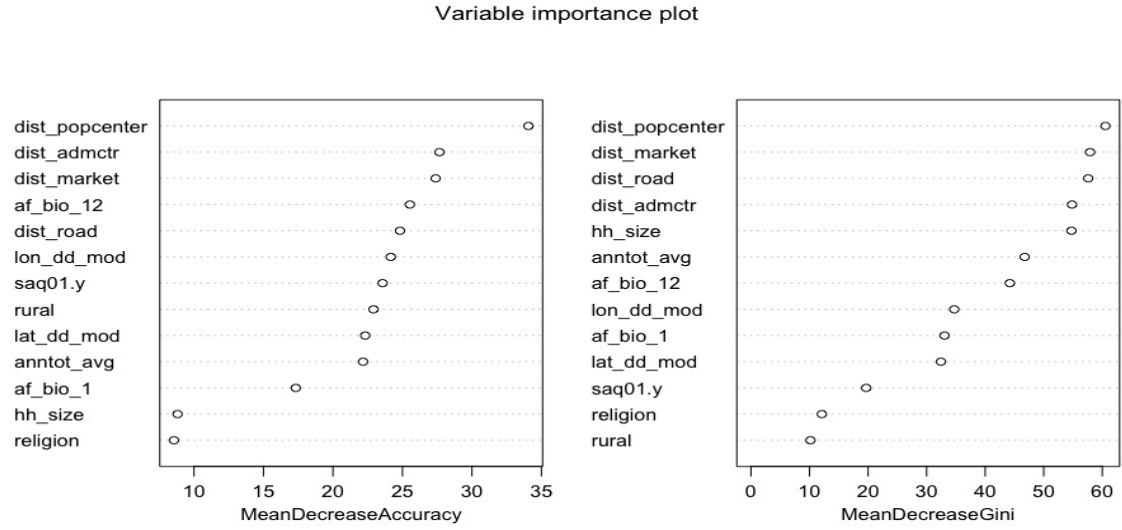


Figure 12: *Variable importance plot*

to be the characteristic variable. The “Mean Decrease Accuracy” on the left tests how worse the model performs without each variable, and the “Mean Decrease Gini” means how pure the nodes are at the end of the tree without each variable. Using selected variables, we finally generate a model with 75.5% cross-validation accuracy on the test data. The result shows that among the locational conditions, “household distance to nearest population center”, “distance to the capital of zone of residence,” “household distance to nearest major road ”and “rainfalls” have the most significant impact on the distinguish of the low nutrient intake target group. The partial dependence plot in figure 13 is a visualization of the marginal effects of given variables on the judgment of target group. The partial dependence plot of “dist\_popcent” indicates that if a household located within 10km of the population center, it will have a higher chance to be classified into the “target” group. As for the “distroad”, from 5km, the further the distance to nearest major road, the higher chance it belongs to the target group. There are two zones of the annual precipitation have higher marginal effects to the decision of target group, and they are the lower than 500mm zone and the higher than 1400mm zone. The average 12-month total rainfall between 500mm and 600mm have a lower chance falling into the target group.

## 5 Discussion and conclusion

The group of household with the lowest food consumption and non-staple food consumption are those households which belong to both the Type 3 of the classification of total food groups consumption and the type 1 of the non-staple food groups consumption classification. And here call it “Target group” for convenience. The population of this group of households is 1105, and about 23% of all the survey samples. In the targe households, the average consumption quantities of each food groups listed in the table below. The average intake of each kind of food groups in the target group is about 0.5 times as much as other households. A map of target type occurrence rate was drawn based on the location data to analyze the distribution of the target group. On the map of figure 14, it shows that occurrence rate can reach as high

Table 4: *Elements of Dietary Diversity Indicators*

Variables	Lables	Mean decrease in accuracy	Mean decrease in Gini	Selection result
dist_road	HH Distance in (KMs) to Nearest Major Road	24.154168	57.35291	choose
rural	Rural or Urban: rural /small town/large town	20.035398	10.40337	remove
dist_market	HH Distance in (KMs) to Nearest Market	24.802063	56.33477	choose
religion	The religion	10.517957	11.88231	remove
saq01.y	Region code	21.395527	19.61638	remove
lat_dd_mod	Latitude	21.651499	33.38026	remove
lon_dd_mod	Longitude	21.908636	33.38742	remove
af_bio_1	Annual Mean Temperature (C * 10)	15.161894	33.47984	remove
hh_size	Household size	8.379599	54.61543	remove
dist_popcenter	HH Distance in (KMs) to Nearest Population Center with +20,000	35.603092	60.97629	choose
dist_admctr	HH Distance in (KMs) to Capital of Zone of Residence	25.316933	54.75197	choose
af_bio_12	Annual Precipitation (mm)	24.891417	43.76922	remove
anntot_avg	Avg 12-month total rainfall(mm) for Jan-Dec	24.600500	47.79533	choose

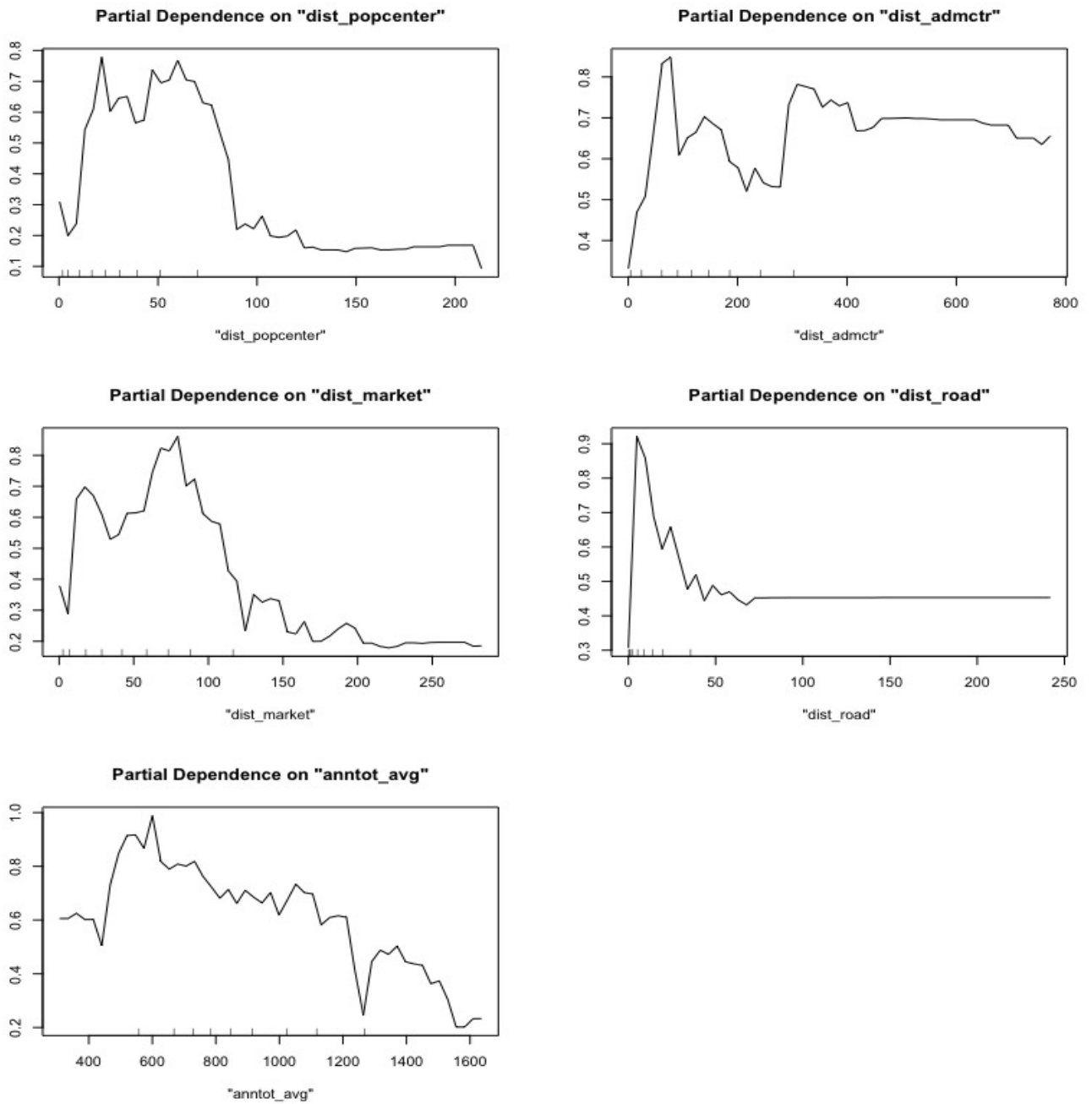


Figure 13: *Partial dependence plots*

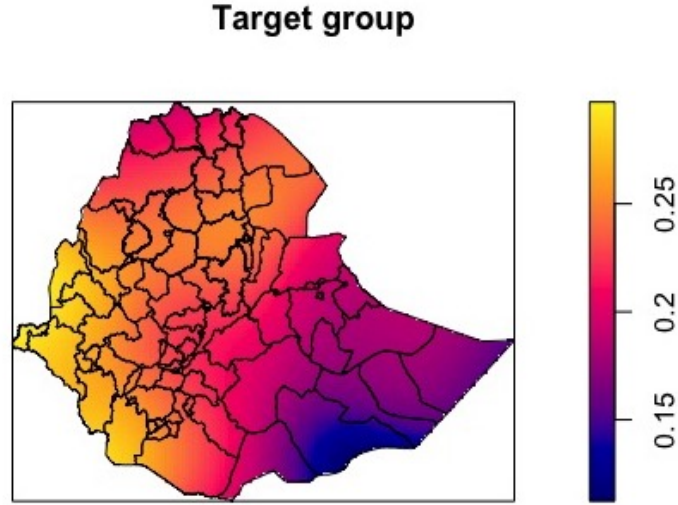


Figure 14: *Occurrence rate of target group*

as 30% in some area on the western and southwestern border. The northern border with a higher FCS score has the lowest occurrence rate.

The prevalence methods of measuring the dietary quality are to use the critical values as the cut point and those whose intakes less than the recommended amounts are treated as the objective groups. Our target group selection process consider the diet data structure over the Ethiopia, so the recommendation with this foundation will embody social justice consideration.

The distribution maps display the dietary diversity estimations in an intuitive way, so they are very easy for readers to understand and compare. As outcomes of this project, the raster map can also be used as secondary data in other studies to explore the relationships between dietary diversity and other social factors. The Results generated by the four dietary diversity indicators are different from each other in a reasonable way. The variance between them identifies that the single usage of one dietary diversity score cannot reflect the different indigenous dietary patterns. Dietary diversity indicators have the advantage of being simpler to use in survey field conditions. But the inverse pattern of HDDS with FCS demonstrate the importance of using more measurement to evaluate the food security condition. Base on the different diet pattern, different nutrient density weights can be created to calculate a local FCS. Also, the location distributions of dietary indicators and dietary patterns give evidence that there is strong nutrient heterogeneity within the administrative region. Classification result of Random forest also proved that the accessibility fo public service and the ability of self-sufficient play crucial roles of the food security.

In the end, some problems and weakness of this project should be clarified and explained. The most important thing is that this is a study based on the data of only one year, so those most vulnerable people who have the highest exposure to the climate change and agricultural disasters like drought are neglected. Apparently, they should be firstly targeted by every rescue intervention. As for this project, all the results and conclusions based on the LSMS, so the flaws of the data may cause some gross error of the estimation. For example, the food consumption survey only asks about 26 food items; however, a lot of important staple food

and vegetables like cassava and tomato are not included in the survey, and it determines that the project cannot reflect the full view of Ethiopia household diet. This problem was solved in 2015 to 2016 round survey for the number of food items the survey collected increased to 56. Other issues may reduce the accuracy of the estimation is the step of unit conversion. Not only the misunderstanding of the non-standard unit may cause problems but also the careless of the enumerators or coders can make some error. Another overlooked fact of this data is the fortification food. Ethiopia endorsed its first National Nutrition Strategy (NNS) in February 2008, and the fortification has influenced at least 10 to 50 percent women, children on Vitamin A, Iron and Zinc intakes. So the missing of this information makes the estimation result cannot reflect the micronutrient intakes comprehensively. For the LSMS, collect more food items, use more standard units and collect the information of fortified food are three directions of improvement.

Table 5: *Consumption condition of target group*

Group kind	unit	A	B	C	D	E	F	H	I	J	K	L
Non-target hh	(g)	712.90	37.28	48.28	19.47	14.66	5.32	96.20	47.28	2.05	29.64	32.29
Target hh	(g)	242.09	13.95	28.77	11.44	8.20	2.84	37.07	8.22	0.85	16.82	16.97
percentage	%	33.96	37.42	59.59	58.73	55.90	53.47	38.53	17.38	41.68	56.77	52.56

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# A Unit conversion list

**Table 1. Unit conversion**

hh_s5a q02_b	hh_s5aq0a	value	hh_s5 aq02_ b	hh_s5aq0a	value	hh_s5 aq02_ b	hh_s5aq0a	value	hh_s5 aq02_ b	hh_s5aq0a	value
3	Onion	1	6	Eggs	240	20	Cheese	1000	31	Eggs	200
3	Milk	1.03	6	Maize	140	20	Chick pea	1000	31	cheese	220
3	Bula	1	7	Banana	200	20	Coffee	1000	31	Milk	200
3	Chat/Kat	1	7	Cheese	600	20	Eggs	1000	31	Barley	800
3	Coffee	1	7	Eggs	300	20	Field pea	1000	31	Chat/Kat	150
3	Kocho	1	7	Chat/Kat	700	20	Haricot beans	1000	31	Chick pea	200
3	Salt	2.16	11	Meat	420	20	Horsebeans	1000	31	Coffee	200
4	Banana	120	11	Cheese	100	20	Kocho	1000	31	Field pea	200
4	Cheese	100	11	Eggs	100	20	Lentils	1000	31	Haricot beans	200
4	Eggs	70	11	Bula	230	20	Linseed	1000	31	Horsebeans	200
4	Maize	2	11	Chat/Kat	450	20	Maize	1000	31	Kocho	200
4	Meat	200	11	Chick pea	100	20	Meat	1000	31	Lentils	200
4	Milk	20000	11	Coffee	200	20	Milk	1000	31	Linseed	200
4	Onion	1047	11	Kocho	2000	20	Millet	1000	31	Niger seed	200
4	Sorghum	100	11	Niger seed	400	20	Niger seed	1000	31	Potato	200
4	Sugar	250	12	Milk	70	20	Onion	1000	31	Salt	400
4	Teff	5	12	Potato	6180	20	Potato	1000	31	Salt	400
4	Wheat	100	12	Bula	95	20	Salt	1000	32	Sugar	257.5
4	Barley	475	12	Chat/Kat	1000	20	Sorghum	1000	32	Cheese	950
4	Chat/Kat	400	12	Coffee	200	20	Sugar	1000	32	Eggs	800
4	Chick pea	400	12	Kocho	2000	20	Teff	1000	32	Meat	1080
4	Field pea	59	14	Onion	10000	20	Wheat	1000	32	Milk	600
4	Horsebeans	435	14	Eggs	100	31	Sugar	100	32	Potato	1030
4	Kocho	1400	14	Chat/Kat	100	31	Horsebeans	200	32	Chat/Kat	200
4	Linseed	2	16	Chat/Kat	300	31	Barley	160	32	Linseed	900
4	Potato	200	20	Banana	1000	31	Cheese	200			
4	Salt	500	20	Barley	1000	31	Eggs	200			
6	Banana	100	20	Bula	1000	31	cheese	220			

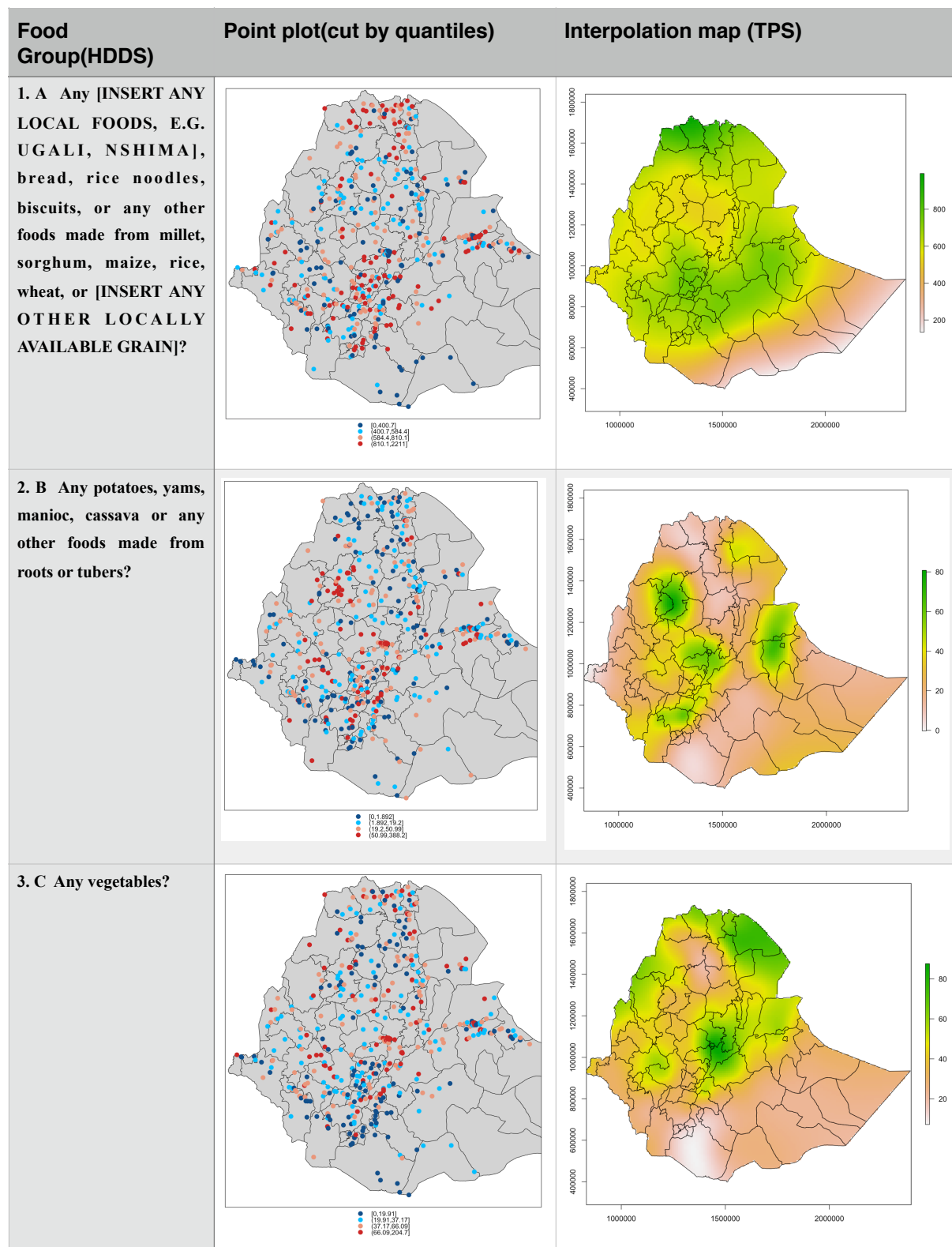
**Table 2. Other Unit Conversion**

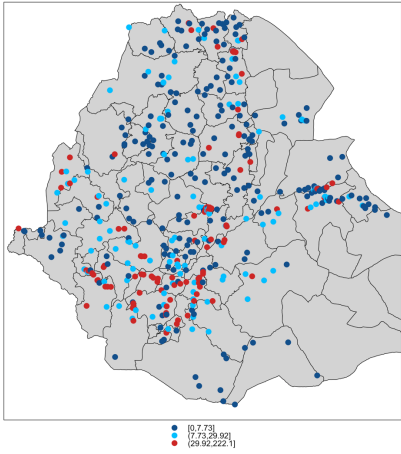
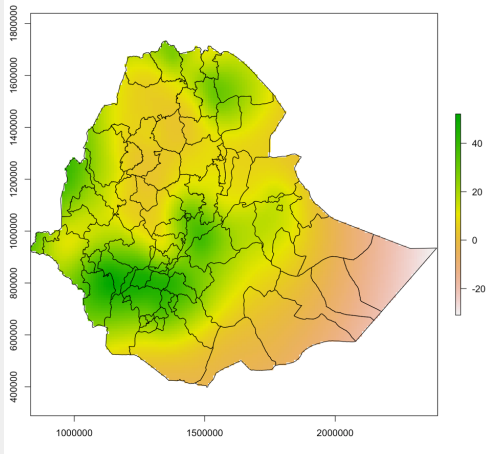
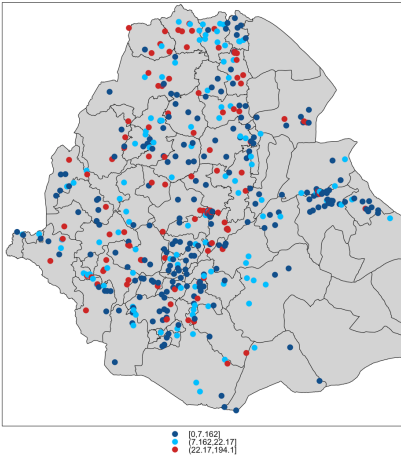
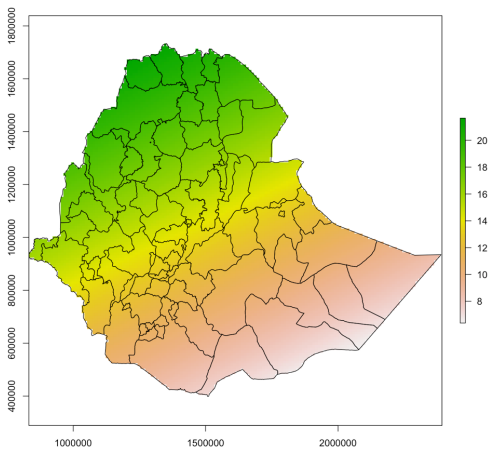
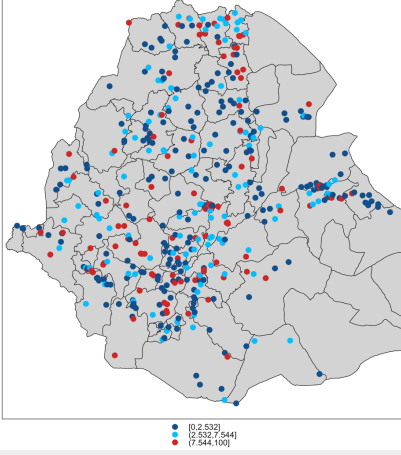
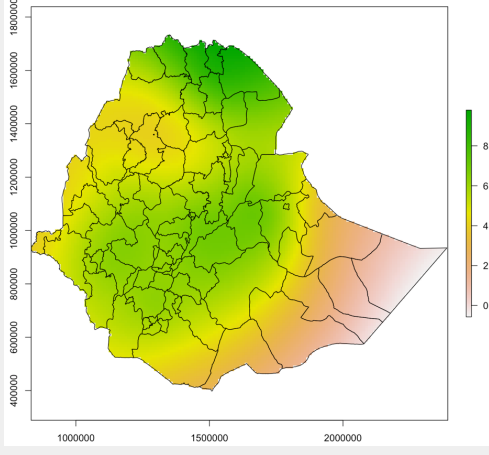
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ZURBA	Kocho	1000	SAHIN/ SAHANE	Maize	500	KUBAYA	Haricot beans	100
ZURBA	Chat/Kat	280	SAHIN/ SAHANE	Potato	300	KUBAYA	Quote	70
YEBET EMEBET	Coffee	100	SAHIN/ SAHANE	Wheat	500	KUBAYA	Lentils	70
TONO	Coffee	200	SAHIN/ SAHANE	Chick pea	500	KUBAYA	Linseed	70
TONO	Salt	300	SAHIN/ SAHANE	Coffee	300	KUBAYA	Salt	200
TASSA (TONO/TINISH TASA)	Teff	1000	SAHIN/ SAHANE	Field pea	500	KOCHO	Kocho	1000
TASSA (MERTI TASA)	Sorghum	1000	SAHIN/ SAHANE	Salt	600	KOBA	Chat/Kat	100
TASSA (MERTI TASA)	Teff	1000	NUMBER/KUTR	Eggs	70	KILLO GRAM	Cheese	1000
TASSA (MERTI TASA)	Wheat	1000	NUMBER/KUTR (ENJERA)	Maize	200	KILLO GRAM	Field pea	1000
TASSA (MERTI TASA)	Lentils	1000	MULU BEG (WHOLE SHEEP)	Meat	25000	KILLO GRAM	Haricot beans	1000
TASSA (MERTI TASA)	Coffee	1000	MULU (WHOLE)	Meat	25000	KILLO GRAM	Horsebeans	1000
TASSA (MERTI TASA)	Chick pea	1000	MILI LITER	Milk	1.03	KILLO GRAM	Kocho	1000
TASSA (MERTI TASA)	Coffee	1000	MILILIK	Sorghum	300	KILLO GRAM	Maize	1000
TASSA (MERTI TASA)	Field pea	1000	MILILIK	Horsebeans	200	KILLO GRAM	Milk	1000
TASSA (MERTI TASA)	Lentils	1000	MILILIK	Barley	300	KILLO GRAM	Onion	1000
TASSA (BALE GRAM )	Teff	1000	MILILIK	Millet	300	KILLO GRAM	Sorghum	1000
TASSA (BALE GRAM )	Maize	800	MILILIK	Teff	300	KERCHAT	Potato	1000
TASSA (TANIKA)	Teff	1000	MILILIK	Wheat	300	KERCHA	Meat	1000
TASSA (TANIKA)	Maize	800	MILILIK	Chick pea	300	KELKILO	Coffee	1000
TASSA (TANIKA)	Lentils	1000	MILILIK	Field pea	300	KELE	Milk	1030
TASSA (TANIKA)	Millet	1000	MILILIK	Linseed	240	HEKETAR	Kocho	10000
TASSA (TANIKA)	Salt	2000	MEREDO	Coffee	1000	HALF GOAT (GIMASH FIYEL)	Meat	8
TASSA	Sorghum	1000	MELEKIYA	Sugar	300	GNAGNA	Meat	100
TASSA	Horsebeans	800	MELEKIYA	Coffee	120	GNAGNA	Onion	100
TASSA	Sugar	2000	MELEKIYA	Salt	300	GNAGNA	Potato	100
TASSA	Sorghum	1000	MELEBO	Meat	1000	GNAGNA	Coffee	100
TASSA	Horsebeans	800	MEDEB	Onion	400	GNAGNA	Sugar	100
TASSA	Sugar	2000	MEDEB	Cheese	400	GIMASH ZURBA	Chat/Kat	2000
TASSA	Maize	800	MEDEB	Meat	400	GIMASH MERGHA	Chat/Kat	1000
TASSA	Millet	1000	MEDEB	Potato	400	GENFER	Chat/Kat	500
TASSA	Wheat	100	MEDEB	Bula	400	GEBETE	Kocho	1000
TASSA	Barley	1000	MEDEB	Chat/Kat	400	GEASH CHAT	Chat/Kat	1000
TASSA	Potato	600	MEDEB	Coffee	400	ESIR	Onion	400
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TASSA	Barley	1000	MEDEB	Salt	400	ESIR	Bula	400

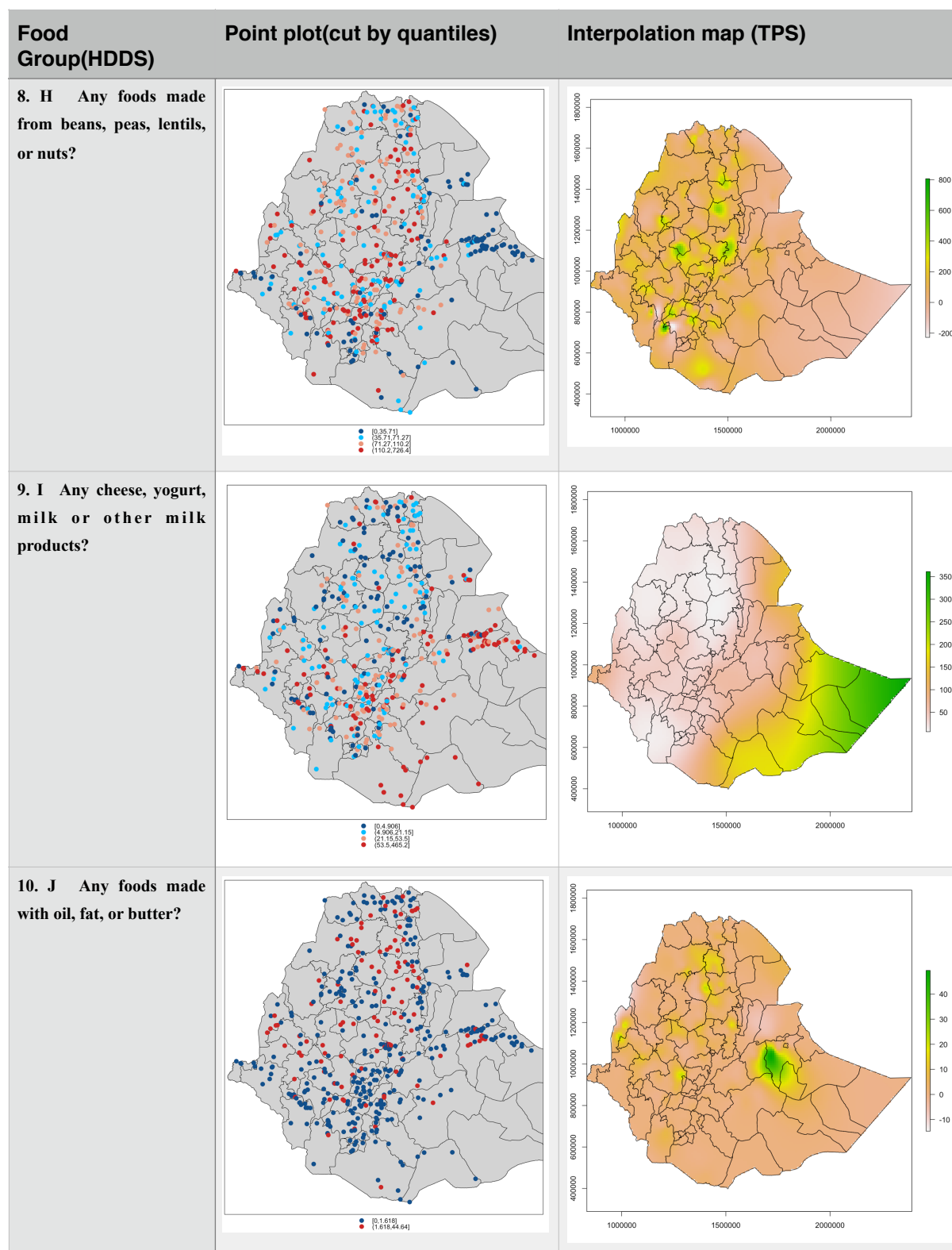
## B Distribution map of food groups and important food items

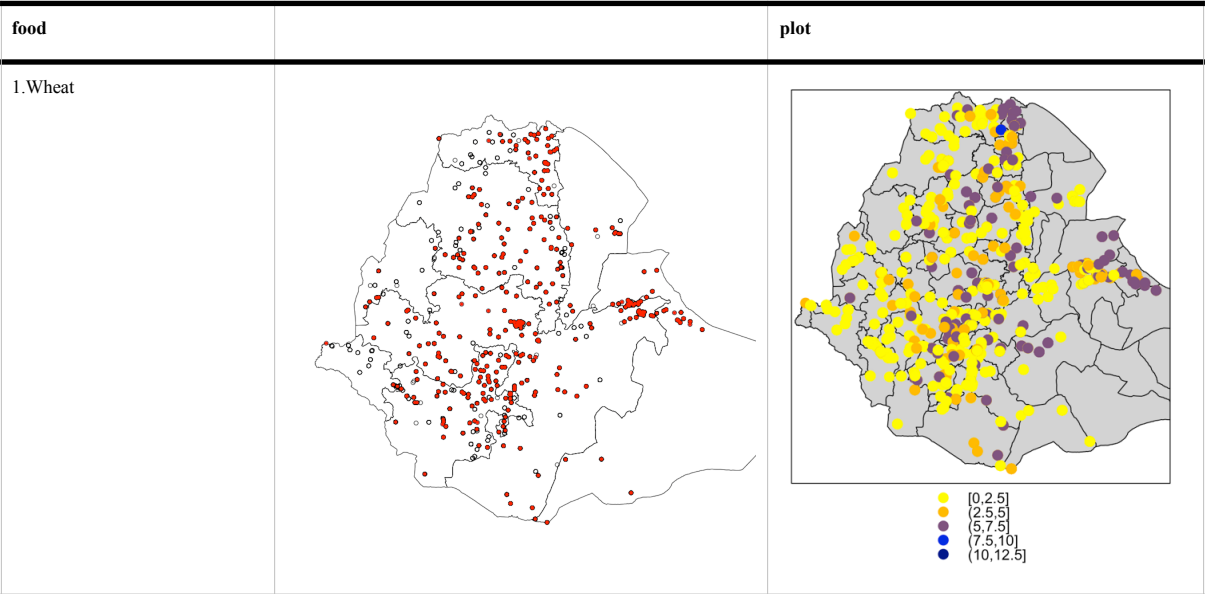
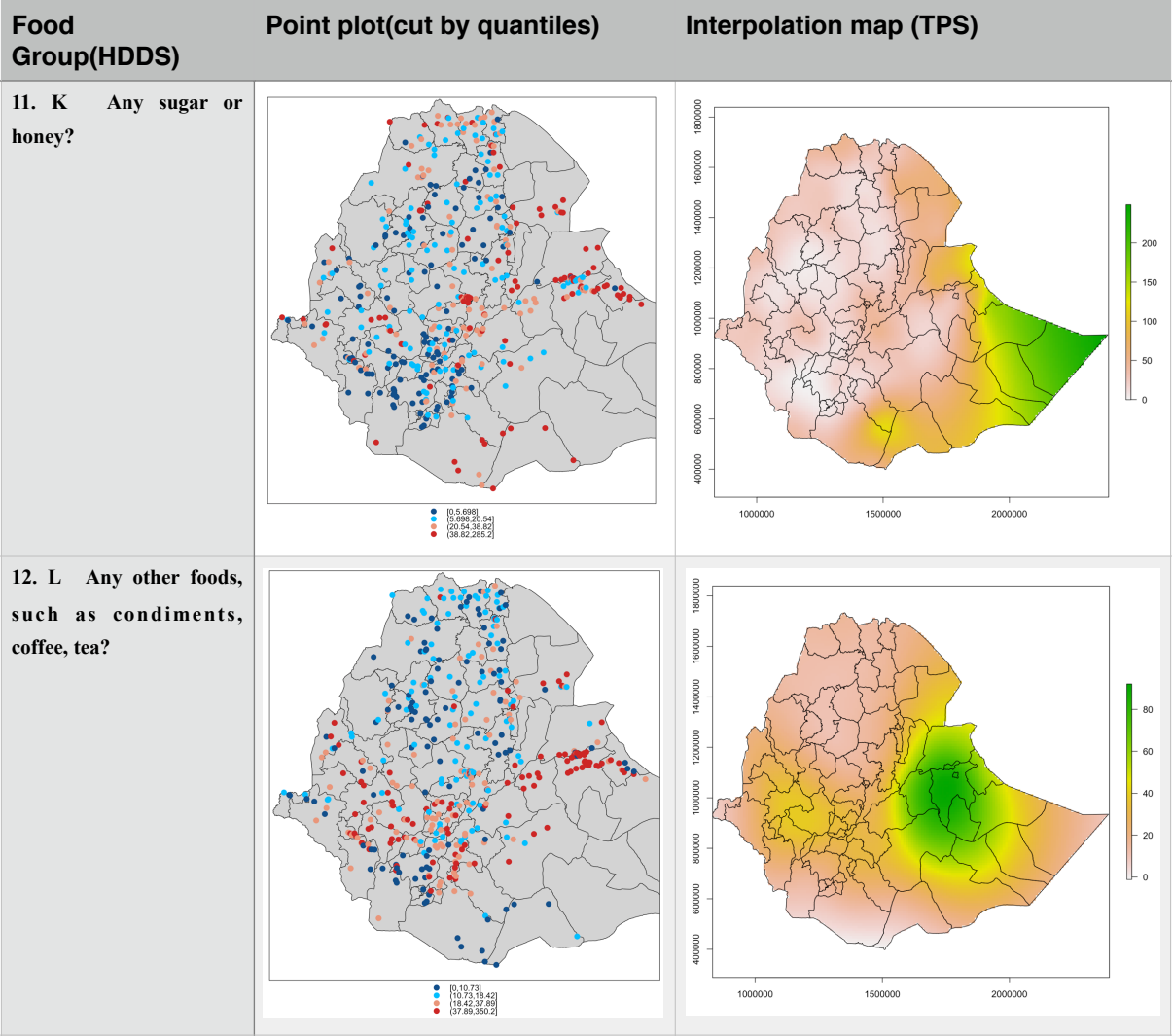
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TASSA	Chat/Kat	1000	MANKIYA TILUKU	Field pea	200	ESIR	Chat/Kat	400
TASSA	Chick pea	1000	MANKIYA TILUKU	Salt	400	ESIR	Cheese	800
TASSA	Coffee	800	MADABERIYA	Potato	1000	ESIR	Kocho	400
TASSA	Field pea	1000	MAMA MILK	Milk	1030	ESIR	Potato	800
TASSA	Haricot beans	800	LEYU GURAGE	Chat/Kat	1000	ESIR	Salt	1500
TASSA	Lentils	800	LAMBA	Coffee	1000	CHATE	Chat/Kat	1000
TASSA	Linseed	800	LAMBA	Linseed	1000	BIRR	Coffee	1000
TASSA	Salt	2000	KUNA	Sorghum	500	BIRCHIKO (YEWUHA)	Horsebeans	80
TASSA	Chick pea	1000	KUNA	Horsebeans	350	BIRCHIKO (YEWUHA)	Sorghum	100
SISI (RUB LITER/ QUARTER LITER)	Milk	257.5	KUNA	Barley	500	BIRCHIKO (YEWUHA)	Sugar	200
SIRA	Salt	1000	KUNA	Potato	350	BIRCHIKO (YEWUHA)	Barley	100
SINI	Sugar	200	KUNA	Teff	500	BIRCHIKO (YEWUHA)	Wheat	100
SINI	Onion	100	KUNA	Wheat	500	BIRCHIKO (YEWUHA)	Lentils	100
SINI	Cheese	100	KUNA,	Chick pea	500	BIRCHIKO (YEWUHA)	Chick pea	100
SINI	Coffee	80	KUNA	Salt	800	BIRCHIKO (YEWUHA)	Field pea	100
SINI	Kocho	80	KUBAYA	Sorghum	100	BIRCHIKO (YEWUHA)	Salt	200
SINI	Salt	200	KUBAYA	Horsebeans	80	BIRCHIKO	Horsebeans	80
SHEMBER	Onion	1000	KUBAYA	Barley	100	BIRCHIKO	Sorghum	100
SHEMBER	Teff	1000	KUBAYA	Cheese	80	BIRCHIKO	Sugar	200
SHEMBER	Barley	1000	KUBAYA	Lentils	100	BIRCHIKO	Wheat	100
SHEMBER	Wheat	1000	KUBAYA	Maize	100	BIRCHIKO	Milk	123.6
SHEMBER	Lentils	1000	KUBAYA	Milk	123.6	BIRCHIKO	Chick pea	100
SHEMBER	Maize	1000	KUBAYA	Millet	100	BIRCHIKO	Coffee	200
SHEMBER	Potato	1000	KUBAYA	Potato	60	BIRCHIKO	Salt	200
SHEMBER	Field pea	1000	KUBAYA	Sugar	200	BEWANE YETEGEZA	Potato	1000
SHEKIM	Milk	1030	KUBAYA	Teff	100	AREKI MELEKIYA	Coffee	1000
SEFER	Coffee	1000	KUBAYA	Wheat	100	AMOLE	Salt	200
SANTIM	Salt	100	KUBAYA	Bula	100	AMBAZA	Banana	1000
SAHIN/ SAHANE	Sorghum	500	KUBAYA	Chat/Kat	80	AKARA	Chat/Kat	1000
SAHIN/ SAHANE	Horsebeans	350	KUBAYA	Chick pea	100	50 BIRR	Chat/Kat	500
SAHIN/ SAHANE	Teff	500	KUBAYA	Coffee	80	.	Meat	1000
SAHIN/ SAHANE	Barley	500	KUBAYA	Field pea	100			

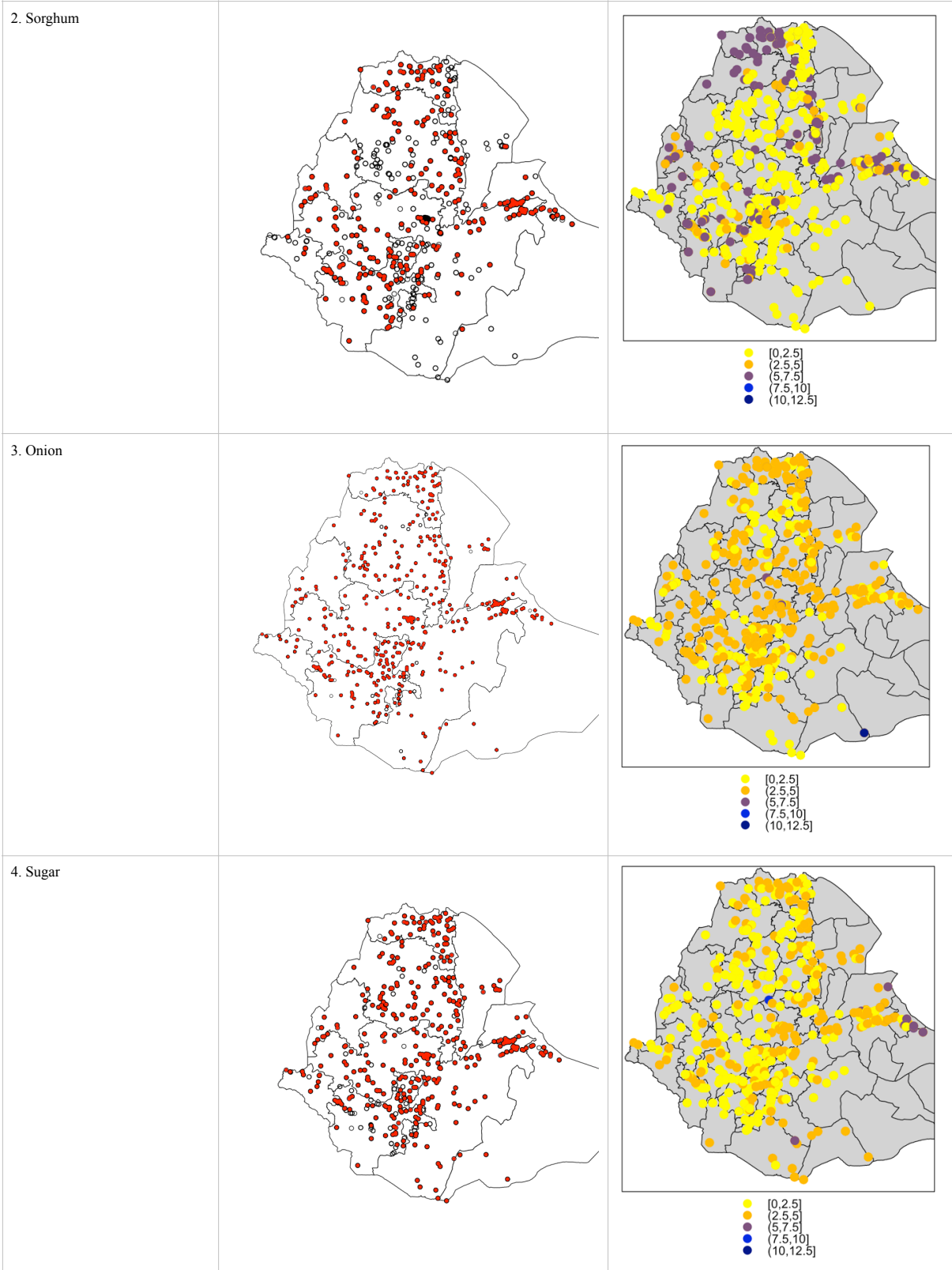
## B Distribution map of food groups and important food items



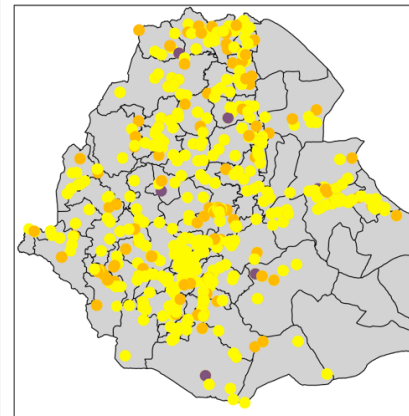
Food Group(HDDS)	Point plot(cut by quantiles)	Interpolation map (TPS)
4. D Any fruits?		
5. E Any beef, pork, lamb, goat, rabbit wild game, chicken, duck, or other birds, liver, kidney, heart, or other organ meats?		
6. F Any eggs?		
7. G Any fresh or dried fish or shellfish?	NA	NA



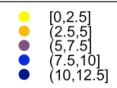
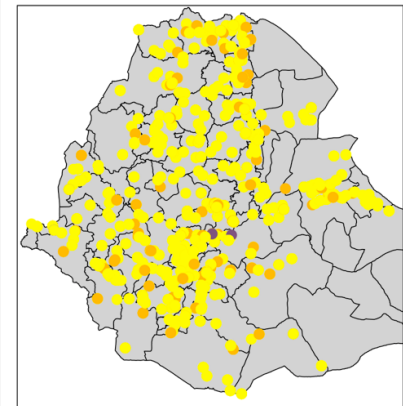
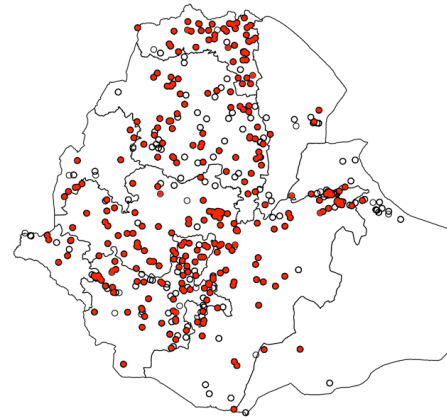




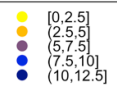
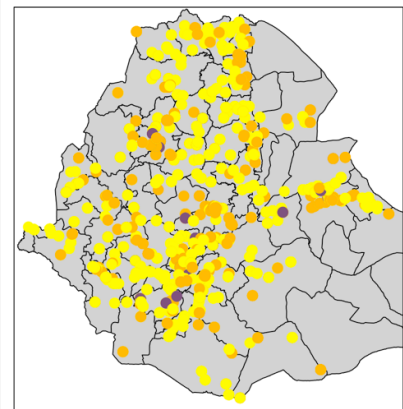
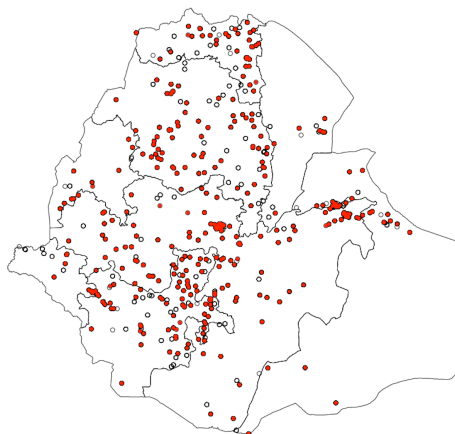
5. Meat



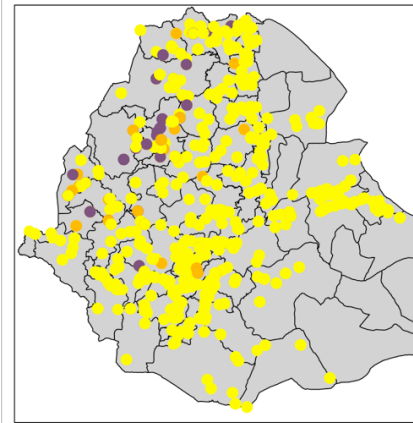
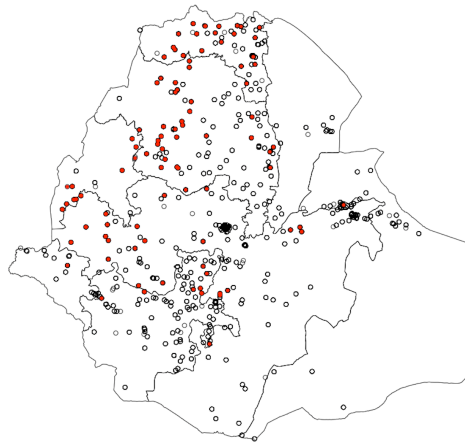
6. Eggs



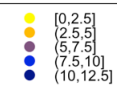
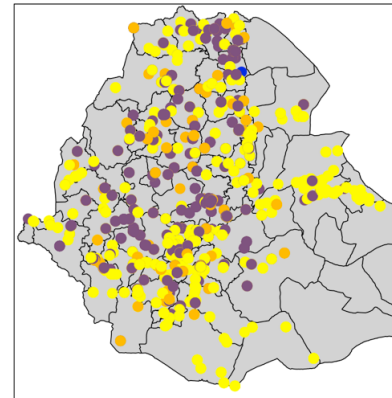
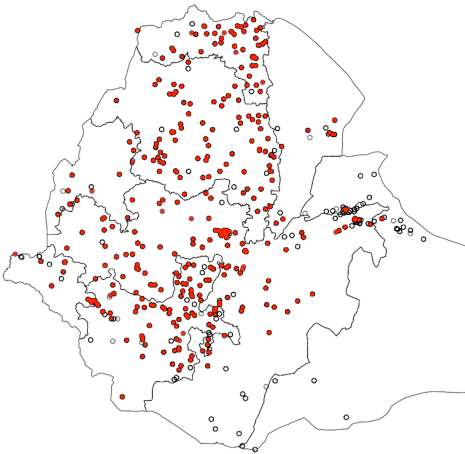
7. Potato



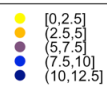
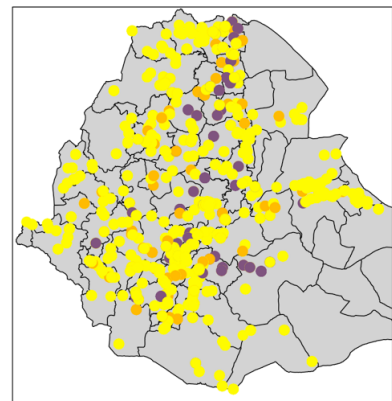
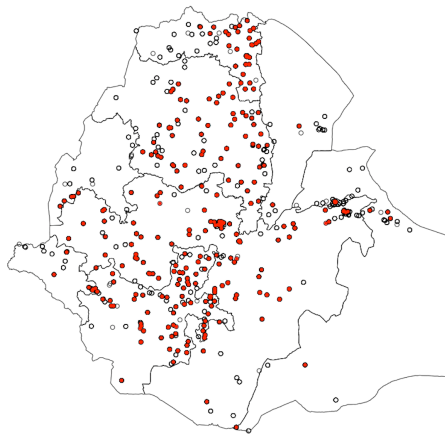
8. Millet



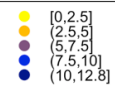
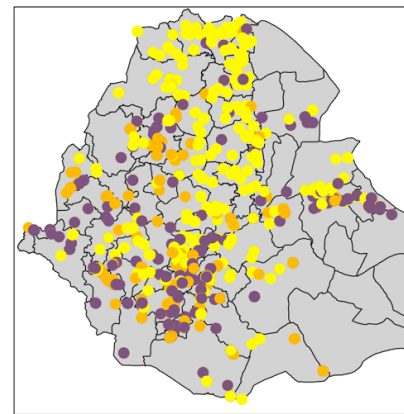
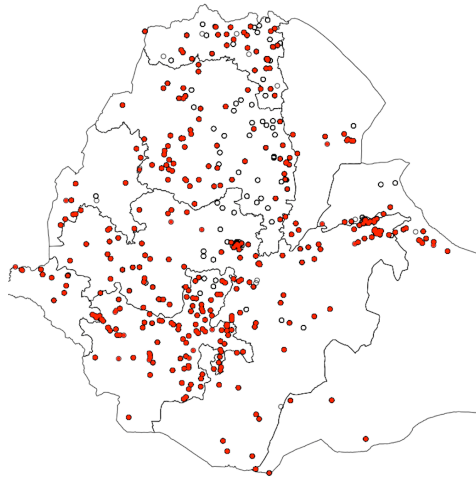
9. Teff



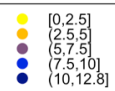
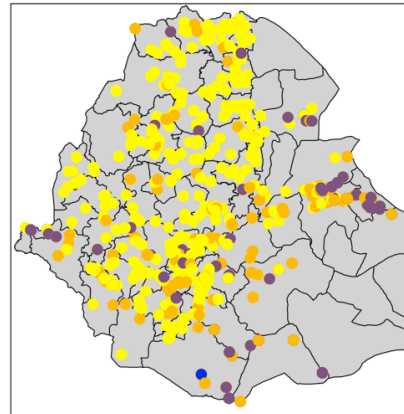
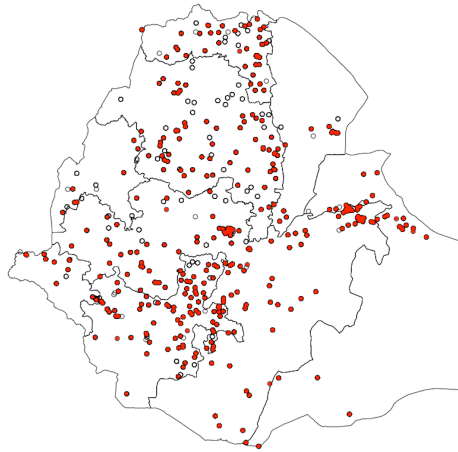
10. Barley



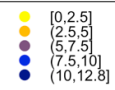
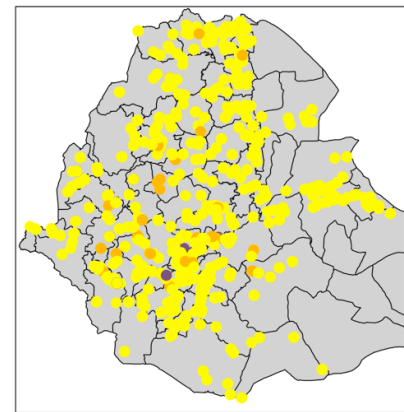
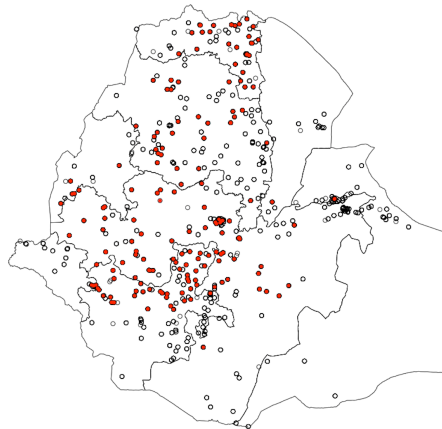
11. Maize



12. Milk



13. Cheese



14. Banana

