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Nutritional functional diversity in farmer households: case study from semi-arid Burkina Faso

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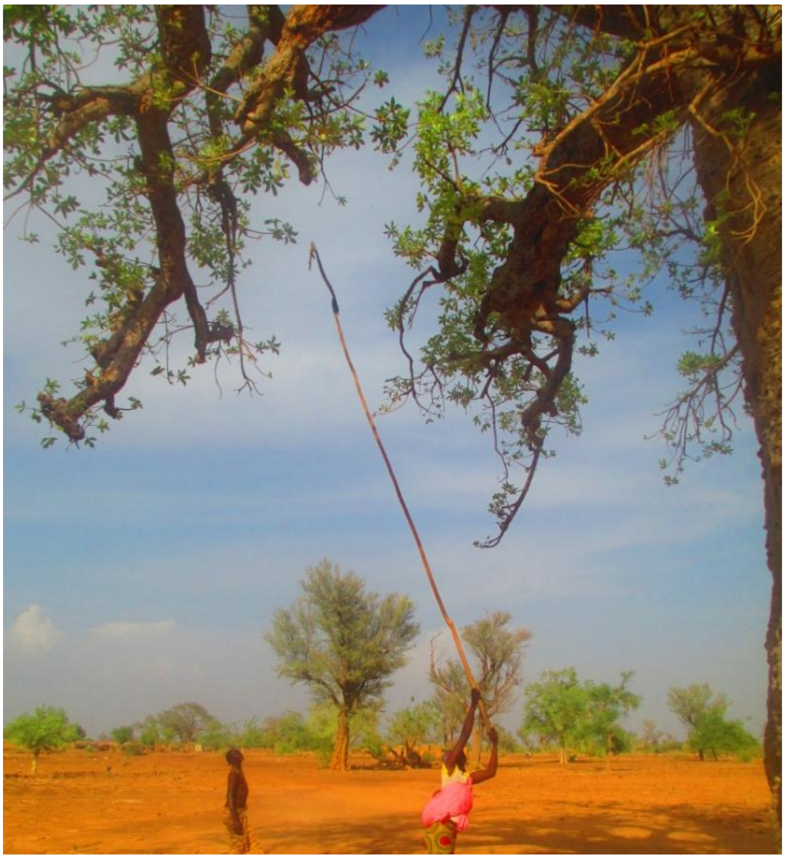

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Executive summary

Many agricultural systems rely on biodiversity to improve crop productivity, dietary diversity and food security. Nowadays food systems focus on a reduced number of cash crops, especially staple crops considered as calorie-dense but micronutrient-poor food. As a consequence, problems of micronutrient deficiencies occur, especially in developing countries where diets mainly rely on the local biodiversity. In Burkina Faso, agriculture is largely food self-sufficiency oriented but food production presents cycling periods of both abundance and shortage, within the same year. In 2012, 18% of households experienced moderate food insecurity in Burkina Faso, as their food consumption did not reach their human energy requirements. Assessing the diversity of household farm diet in periods of food shortage (FS) and abundance (FA) by using nutritional functional diversity (NFD) indicator could link the effect of biodiversity with human nutrition. The Food Security Ratio (FSR) and Food Self-Sufficiency Ratio (FSSR) are indicators of the energy-input adequacy of households.

A survey of food items consumed was conducted between June 2015 and May 2016 in Yilou among 12 households. Four of them also answered a second survey regarding the quantities of food consumed in periods of food shortage and abundance, and the FSR and FSSR were calculated as well. NFD was calculated for periods of FS and FA, and also regarding different sources of food (market (M), landscape (L), farm (F) and gift (G)). The food available was more nutrient-diverse during periods of FS. Food from the market contributed the most to the nutritional diversity, and the number of items purchased was positively correlated with the NFD of the households. This correlation might be explained by the highest number of food items purchased compared with other sources. Nevertheless, L products seemed more nutrient-dense but fewer in absolute numbers. L products had an interesting contribution in vitamin A intake (especially in FS period), but F products contributed the most for iron, vitamin A, zinc and energy intakes for the 4 households. However, regarding the FSR and FSSR, the energy requirements of these households were not reached in neither of the considered period (FA nor FS). To conclude, market products had the most important contribution to the NFD total, but products from the landscape are more nutrient-dense and have an interesting contribution for vitamin A intake, while farm products also contribute to energy, iron, zinc and vitamin A intake.

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Glossary

DRI – Daily requirement intake

F – Farm

FA – Food abundance

FS – Food shortage

FSR – Food Security Ratio (FSR)

FSSR – Food Self-Sufficiency Ratio

FVC – Food-value chains

G – Gift

L – Landscape

M – Market (M)

NFD – Nutritional functional diversity

NFD_F – Nutritional functional diversity from food produced on-farm

NFD_{FA} – Nutritional functional diversity in period of food abundance

NFD_{FS} – Nutritional functional diversity in period of food shortage

NFD_G – Nutritional functional diversity from food offered by someone as gift

NFDHH – Nutritional functional diversity of individual household NFD

NFDL – Nutritional functional diversity from food collected in the landscape

NFD_M – Nutritional functional diversity from food purchased on the market

NFD_{tot} – Nutritional functional diversity total

TFA – Total food availability

WASSA – Woody Amendments for Sudano-Sahelian Agriculture

WEP – Wild edible plants

1. Introduction

Biodiversity has been defined by the Convention on Biological Diversity, as '*the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems*' (Secretariat of the Convention on Biological Diversity, 2010). High biodiversity contributes to the supply of a range of ecosystem services, which provides the supply of goods: food, timber or medicinal plants (also known as 'provisioning services'). Biodiversity plays a role in carbon storage, rainfall control, cleaning air and water from pollutants, and serves as protection during disaster such as landslides (so-called 'regulating services') (Secretariat of the Convention on Biological Diversity, 2010). Moreover, biodiversity provides 'cultural services' as part of spiritual and religious values, where symbols are often represented by elements of the natural world. This simultaneously improves people's *ecoliteracy* as they better understand how nature sustains life. For instance aesthetic values are often use by ecological organizations to raise people's awareness regarding climate threats, among others. Finally, supporting services are necessary for the functioning of ecosystems, such as the formation of soils and the growth of plants (Romanelli, et al., 2014; Secretariat of the Convention on Biological Diversity, 2010; Sunderland, 2011; Thrupp, 2000). Many agricultural systems rely on these ecosystem services for biomass production, soil fertility, pollinator attraction, and pest and disease control (especially in large-scale monoculture) (Thrupp, 2000). Crop diversification has in many places proved to build more resilient system in the face of climate change, while at the same time improving crop productivity, dietary diversity and food security (Romanelli, et al., 2014).

Despite increases in agricultural production worldwide, a tremendous loss of biodiversity has been observed during the last century, mainly due to habitat change, overexploitation, pollution, invasive alien species and climate change. Humans have impacted natural habitats, mainly for land conversion in order to extract resources and expand cultivated areas, through deforestation and river degradation (Secretariat of the Convention on Biological Diversity, 2010). For instance about 6 400 animals and 3 100 plants were at-risk of extinction in 2014 and about three million hectares of forest are converted in agricultural lands each year to meet food needs and international demand for biofuels (Zorba, 2015).

This significant loss of biodiversity and ecological services has also led farmers to increase their input use, when they have access to it aiming for higher farm productivity. Biodiversity loss has in fact, decreased resilience and stability of ecosystems, increasing risks of food insecurity worldwide (Secretariat of the Convention on Biological Diversity, 2010; Sunderland, 2011; Thrupp, 2000). This has impacted human diets, as of the more than 7000 species of plants possibly consumed worldwide, only 150 are important from a commercial point of view, and 60% of the calories consumed derive mainly from three crops: rice, wheat and maize (Sunderland, 2011; Thrupp, 2000). Modern agriculture and food systems tend to simplify environment structure, to replace nature's biodiversity with a reduced number of cash crops (Allen, et al., 2014). Moreover, the majority of traditional 'ancient' varieties have a higher nutrient content than modern cultivated varieties. Nevertheless, they have been replaced by commercial crops as the latter present higher productivity characteristics, even if less nutritious (DeFries et al., 2015; Romanelli, et al., 2014; Thrupp, 2000).

‘New’ high-yielding varieties of staple crops have been introduced by policymakers between the 1960s and 1970s (Green Revolution) to provide sufficient intake of energy and to avoid food insecurity, with no regards to other nutrients. Malnutrition, however, is a broader issue. Its definition includes problems of ‘undernourishment’ (insufficient intake of energy and protein), and also problems of micronutrient deficiencies and overweight/obesity (DeFries et al., 2015; Gomez et al., 2013; Romanelli, et al., 2014; Sunderland, 2011; Vinceti et al., 2013). The latter is characterized by an excess of calorie intake, although obesity prevalence in 2008 in Africa was still low, it more than doubled in 28 years (Gomez et al., 2013). Micronutrient deficiency is another type of malnutrition also called ‘hidden hunger’, which can co-exist with the other two. Indeed staple crops are calorie-dense but micronutrient-poor food because they contain low amounts of limiting nutrients (short supply relative to other nutrients) per unit of energy. As a consequence, even if staple crops provide enough calories, lack of certain micronutrients can occur. Vitamin A, iron, and zinc deficiencies are some of the most prevalent in childhood from developing countries. This highlights the importance of a nutrient-dense diet during pregnancy, since vitamin A and zinc deficiencies were responsible for more than one-third of all under-5 child deaths in these countries (Bhutta & Salam, 2012). Consumption of micronutrient-dense foods, such as fruits, pulses, vegetables and animal sourced foods, offers a way to match nutrient adequacy, instead of only caloric adequacy (Gomez et al., 2013; Romanelli et al., 2014; Sunderland, 2011; Vinceti et al., 2013). Indeed, especially in developing countries, diets are mainly determined by local food availability, and rely on the environment biodiversity to match their nutrient adequacy. Many studies have shown that forest foods and wild edible plants (WEP) could supply significant amounts of accessible and affordable nutrient-dense food. Key nutrients often missing in the diet of populations living in developing countries can be provided by native trees and shrubs over one year as different species of trees have different harvesting times during the year and can contribute to closing the nutrient gap (Ebert, 2014). It also contributes to the caloric intake in period of food shortage, or provide an income by selling forest products in order to reach food security (Romanelli,et al., 2014; Toledo & Burlingame, 2006; Vinceti et al., 2013).

Nevertheless, spread of modernization and development technologies introduces a new range of refined and processed food. Many populations nowadays consider traditional food as *inferior* when comparing with this new imported products, and discontinued growing and consuming nutrient-dense products, such as pulses, legumes and/or high-protein traditional grains (Romanelli et al., 2014; Termote et al., 2012; Thrupp, 2000; Toledo & Burlingame, 2006; Vinceti et al., 2013). An additional threat is to lose traditional knowledge and cultural habits around local food resources, including WEP identification, management and preparation (Vinceti et al., 2013).

Food diversity is a relevant indicator for nutrient adequacy and health as micronutrient intake is positively correlated with food diversity (Allen, et al., 2014; Foote, et al., 2004). A way to assess the diversity of household farm diet is to use nutritional functional diversity (NFD) indicator. « Functional diversity » has been developed by ecologists to link the effect of biodiversity in natural and managed systems with human nutrition, by taking into account nutrients trait diversity in cropping systems (Luckett, et al., 2015). This score can be used at any scale (from farm to market) and can reflect large nutritional differences between species (Luckett et al., 2015). Its specific objectives are: to observe the nutritional diversity available in a system, to identify sources of food which are providing specifically nutrient-dense food, and to assess the resilience of provisioning nutrient-dense food system. Few studies already applied this metrics, and conclude that the NFD score is a relevant indicator to detect population at-risk of low nutritional diversity, and associations between NFD, food and nutrition indicators were significant at village level (Luckett et al., 2015; Remans et al., 2011). This novel metrics aim at addressing agricultural interventions towards better nutrient adequacy, and promote strategies to integrate agriculture, ecology and nutrition (Remans et al., 2011).

The comparison between energy requirements and intake is also used as indicator of food security and food self-sufficiency (Food and Agriculture Organization, 2015). Indeed, the FAO introduced the concept of **food security** as a state when '*all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life'*. This definition relies on four pillars: food availability, access, utilization and stability (Food and Agriculture Organization, 2006). However, it does not take into account the origin of the food. The concept of **food sovereignty** is defined as *'the right of peoples to healthy and culturally appropriate food produced through ecologically sound and sustainable methods, and their right to define their own food and agriculture systems*' (Jarosz, 2014). One dimension concerns the right to produce nutritious and culturally adapted food to reach food self-sufficiency. Food self-sufficiency is generally understood as '*the extent to which a country can satisfy its food needs from its own domestic production'*, which mainly concern the availability pillar of food security, with regard to the domestic capacity of sufficient food production (Food and Agriculture Organization, 2015). The Food Security Ratio (FSR) is calculated as the ratio between energy in consumed food during a predefined period and the total energy requirements of the sample (a person or group of people such as a household). Food Self-Sufficiency Ratio (FSSR) quantifies proportion of the energy in the food consumed that has been produced on-farm or collected in the landscape during the period (Rufino et al., 2013). Both indicators are holistic and focus on energy requirements of different household, without considering nutrient diversity.

Indeed guidelines for measuring household and individual dietary diversity assert that by assessing the diversity of the household diet during the period where food shortage prevails depicts the food security situation of the household. Moreover the period after harvest is when the food availability and diversity is maximal, and the food consumed by the household can have four main sources : the farm production, the landscape, gifts (currently offered by neighbors or family) or the market (Kennedy et al., 2010).

Burkina Faso is one country suffering from problems of cycling periods of food abundance and shortage (Programme Alimentaire Mondial, 2014). It is a continental country situated in West Africa isolated from the sea, and surrounded at the North and West by Mali, at the East by Niger and at the South by Benin, Togo, Ghana and Ivory Coast (see Annex I). Its population is young (59% under 20 years old) and grows very fast (5.5% growth per year) although the country is one of the ten least developed in the world, with 46.7 % of its population under the poverty threshold in 2009 (Programme Alimentaire Mondial, 2014). The economy of Burkina Faso highly depends on agriculture, and farmers represented 92% of the labor force in 2012 (Dao, et al., 2015; Korodjouma, n.d.).

Most of the agricultural systems are agro-pastoral, mainly extensive with low mechanization and external inputs. An average of 40% of farmers cultivated less than 3 ha in 2012/2013, with half of them which had fields of 1 – 2 ha (Programme Alimentaire Mondial, 2014). Agriculture is mainly food self-sufficiency oriented, with 90% of the arable area cultivated for native species such as sorghum

(*Sorghum bicolor*) and millet (*Pennisetum glaucum*), and also maize (*Zea mays*) introduced in Africa in 1500 (Amherst College, n.d.). In these agro-pastoral systems, livestock is mainly composed by cattle, sheep, goats, pigs and poultry, and its population increased tremendously the last decades (+4.5% per year between 1980 and 1990, and +2.4% per year between 1990 and 2000) (Food and Agriculture Organization, 2005; Vierich & Stoop, 1990).

The Sahel climate of Burkina Faso continuously challenges farmers, with in between 1991 and 2009 eleven major floods, three important droughts and a locust invasion (Programme Alimentaire Mondial, 2014). Food production is not stable, and the important pressure exerted on land and inadequate farming techniques (low fallow period, intensive woodcutting and bushfires), reinforce land degradation and poor soil fertility (Lahmar et al., 2012; Tittonell et al., 2012). In 2012, 18% of households experienced moderate food insecurity (food consumption below requirements) and 1% severe food insecurity. In addition, rates of chronic and acute malnutrition in the population are close to the critical threshold determined by the World Health Organization. In between the issues regarding climatic variations, the constraining environment and the lack of financial resources, farmers are ones of the most vulnerable part of the Burkina Faso's population (Programme Alimentaire Mondial, 2014).

As a consequence, assessing to which extent the food produced on-farm, gathered from the landscape, offered, or purchased on the market, contributes to the NFD of the household in abundant and lean periods of the year, would reflect nutrient availability in a specific environment. Information gathered through these methods may allow for better targeted food security interventions from local and international policymakers, especially those initiatives that seek sustainability of family livelihoods and enhanced ways of living with local resources. Contribution of landscape elements to family nutrition might reveal new insights on locally adapted forest management, reduction of deforestation, and woody resource increase operations.

2. Research scope

This research aims to assess the contribution of the food produced on-farm to the nutritional functional diversity (NFD) of the food available to the farm household, compared to the foodstuff collected from the landscape, offered as gift or purchased on the market, during periods of food shortage and of abundance over one year (June 2015 – May 2016). The different sub-objectives of this study in the village of Yilou are to:

1. Report total foodstuffs consumed per household and total foodstuffs accessible over a year (June 2015 – June 2016).
2. Quantify the potential NFD (total food accessible).
3. Assess differences in NFD between the period of food shortage and food abundance.
4. Assess differences in NFD between/from various village components/sources (farm, landscape, market or gift).
5. Identify correlations between household NFD and farm characteristics (species diversity on-farm, species diversity collected from landscape, family size, number of women per household, among others).
6. Quantify the food consumed during period of food shortage and food abundance, and assess contributions of each source to energy, iron, zinc and vitamin A intake of selected households.

From this, research questions asked would be:

- ***What products were available in the locality of Yilou (Burkina Faso) over one year between June 2015 and May 2016, and do they have different origins throughout the year?***
  Hypothesis 1: There are strong differences in food items available and their sources throughout the year.

- ***For periods of food shortage and abundance of year 2015/2016, are there significant differences of nutrient diversity consumption in Yilou?***
  Hypothesis 2: During the period of food abundance 2015/2016, the diversity of nutrients consumed is higher than in period of food shortage.

- ***For year 2015/2016, is one of the food sources (field, landscape, market or gift) contributing significantly more to the NFD in Yilou?***
  Hypothesis 3: Products from the farm are energy-dense but nutrient-poor crops, while products from the landscape are more nutrient-rich.

- ***What is the contribution of the landscape to nutrient availability in period of food shortage for the population of Yilou, during the year 2015?***
  Hypothesis 4: Products from the landscape can help to close the nutrient gap during a period of food shortage.

- ***Which farm and household characteristics are correlated with NFD of households in Yilou?***
  Hypothesis 5: The household size and the number of women cooking per persons fed can influence positively the household NFD.

3. Material and methods

3.1 Area of study

Our study was conducted in Yilou (Figure 1), a village situated in the Bam region at 75km North of Ouagadougou (13°01' N, 01°32' W). This village of the Sudano-Sahelian region has a unimodal rainfall pattern, with an average of 8 months of dry season and an annual rainfall of 600-800 mm (Diarisso et al., 2015). Annex II presents the rainfall pattern in Yilou between June 2015 and May 2016. The largest amount of rain per month (258 mm) was registered August 2015.

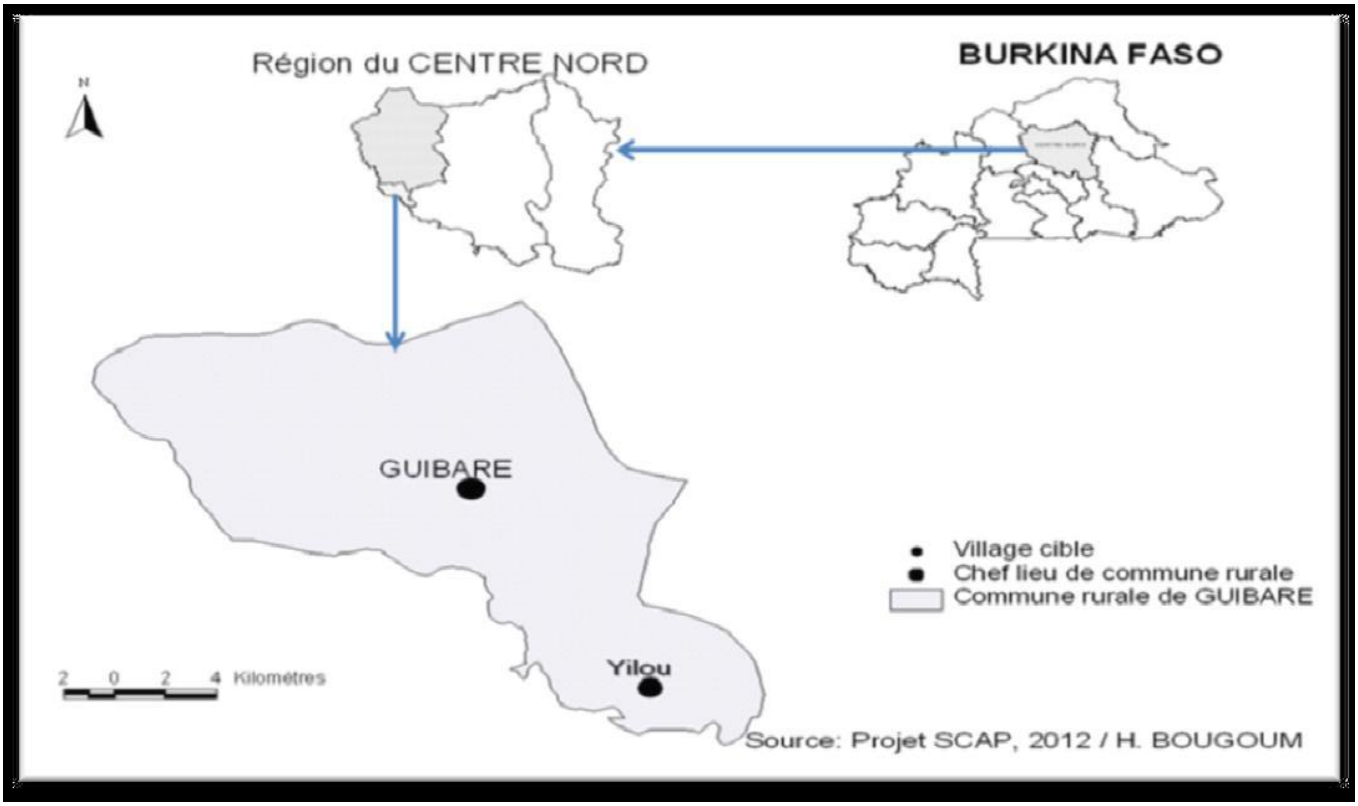

Figure 1: Map of the Centre Nord region and Yilou village (Source: Kouabenan, 2015)

In 2009 the census reported 23,454 people in Yilou, mainly composed by households (HH) of smallholder farmers (Kouabenan, 2015). Agriculture is rainfed and main crops are has sorghum, maize, rice and millet. External inputs use is limited but accessible on the market nonetheless (Diarisso et al., 2015; Félix, 2015; Kouabenan, 2015). The village is densely populated, and the pressure on natural resources is widely reflected by patches of unproductive areas. Associated with human activity, wind and water erosion, reduced soil water infiltration and storage capacity have led to severe soil degradation and has negatively affected farm productivity, agro-pastoral production and crop yields (Diarisso et al., 2015; Ouedraogo, 2014). Yilou has been a site for various research and development projects, which have documented experiments and social dynamics of the village. One of the projects is the Woody Amendments for Sudano-Sahelian Agriculture (WASSA) project, which aims to restore soil through the smart use of woody biomass. Another research project conducted in Yilou aimed to analyze food security, and it showed that the Bam region has a deficit in cereals which threatens food availability (Kouabenan, 2015). Indeed the Centre North region is one of the regions where families are the most likely to suffer from poverty, and has a high prevalence of food insecurity (26%) (Programme Alimentaire Mondial, 2014).

3.2 Selection of households

Sample selection was based on plot-level surveys carried out by Georges Félix in 2014. Farmers were asked to show the two most extreme fields of their farming system, i.e. the one where production was perceived “best” and the one where production was usually perceived as “worst”. This inquiry resulted in 76 plots observed. These plots were managed by 40 farming families surveyed in Yilou in 2014, 36 having shown two plots (i.e. best and worst) and 4 having shown only one plot (i.e. best). The list of interviewees was based on a short-list constructed by Marcel Ouédraogo (2013). Geographical location, rotations, perceived yields across years, soil types, and management operations were recorded during 2014. Woody biomass, including shrub and tree vegetation types, was assessed on 60 out of 76 plots in 2015, within the thesis project of Timothée Chérière. From the gathered data, perceived yields across years and labor input were plotted as a proxy to efficiency (Figure 2). Plots of farmers who only had shown one plot and extreme outliers in yields (i.e. 40 donkey carts of fresh sorghum per hectare) or labor input (i.e. 0 or 8000 man-days per year) were excluded from the dataset.

As a result, a sample of 12 HH heads have been selected by Georges Félix, with the aim to cover the variability of productivity or labor input of the HH (according to areas of the graph). From Figure 2, a range of farmers were chosen (blue squares and green symbols) by first looking at their labor input per plot, and after regarding the field productivity as perceived by the interviewee. Another characteristic taken into account was the status of the HH head, with 3 widow wives and 9 men as HH head.

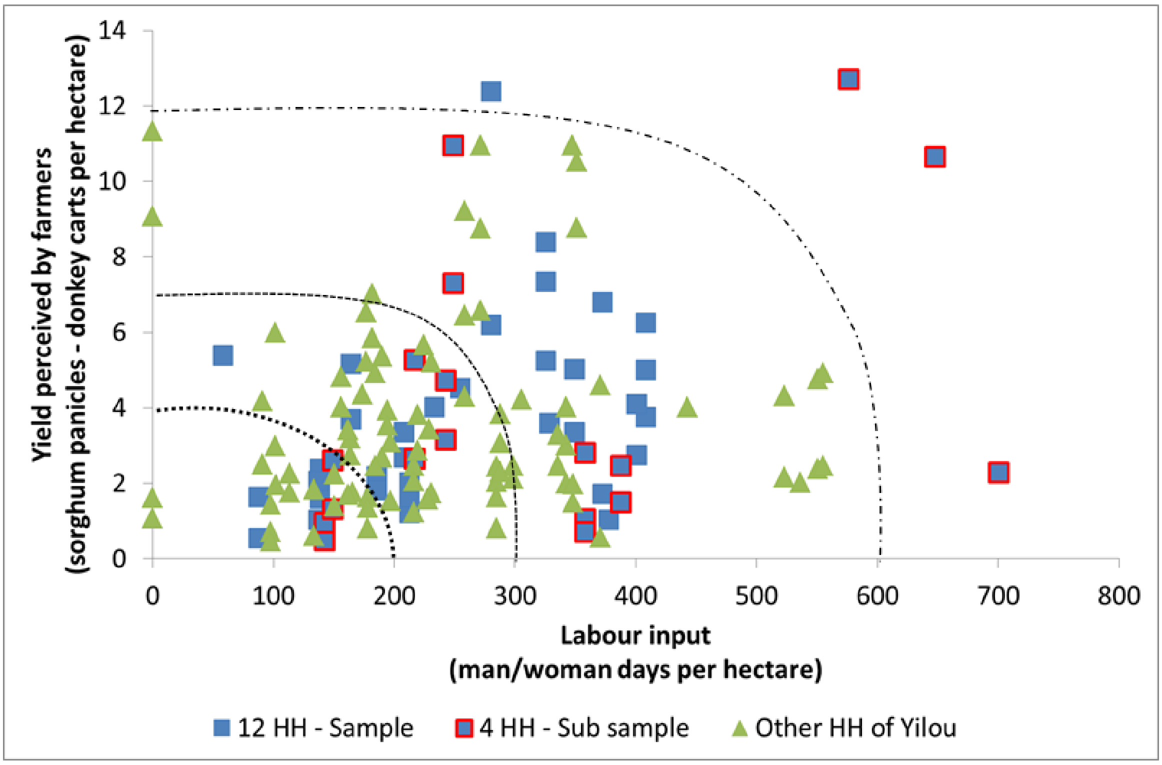

Figure 2: Scatter plot of perceived yield and labor input as proxy to efficiency (Source: Georges Félix).

The blue squares (with and without) red border are included in the 12 HH but these represent the HH where surveys were conducted with the persons in charge of the HH meals. These were principally wives of the HH head, wives of the brother of the HH head, daughters or wife of the son of the HH head. Surveys concerned the food used to prepare the meals that the farmer will consume and its origin. The HH has been considered as the persons and family who eat with the farmer on a regular basis.

The blue squares with red border represent four HH which also answered a second survey. From the first survey, a list of foodstuffs consumed in period of food shortage and abundance was compiled. During the second survey, this list was re-used to report frequencies of these foodstuffs consumption over the two periods (shortage and abundance), as well as the quantities of food they used to cook. The four HH have been chosen among the twelve, with the same criteria of variability regarding their field productivity and labor input.

3.3 Determination of food shortage and abundance

In Yilou food availability highly depends on the period of harvest, as HH rely all year long on their on-farm produced and landscape harvested supplies. As a result, it is expected that the period of food shortage (FS) and food abundance (FA) would be respectively before and after harvesting time for al the H.

Comparing both periods should be representative of food sources contribution to the sampled HH dietary diversity, and coping strategies during food shortages. Determination of periods for food shortage and abundance was investigated in existing literature but answers provided by interviewees were also taken into account. HH members were asked about which period is most difficult to feed their family regarding the availability of food and quantity, and when do they have no problems at all to prepare meals and have enough for everyone.

3.4 Methods

3.4.1 Food availability calendar and origins

Data was collected between mid-April 2015 and mid-May 2016. Three previous survey-tests have been conducted in Ouagadougou with women in charge of the meals as well as chef in restaurants in order to report a complete a list of food available. However, foodstuffs availability was different in urban and rural areas, as they have better access to foodstuffs imported from other countries (which means that the food available is also affordable), but smaller access to wild products. As a consequence three others survey-tests have conducted in Yilou to adjust the list of foodstuffs available as well as the methodology. Once the setup of the interview was systematic, we started gathering actual data on the field in Yilou with the 12 above mentioned households. Surveys were conducted basically with women, often with small children around. We started with greetings and presentation of ourselves. It was also a time where we could help them during their tasks, especially cooking and meal preparation, while discussing general issues to build some trust. After having spent enough time with the ladies of the house, we explained the purpose of the research and the surveys began with as first component questions regarding the HH structure (Annex III).

The second part of the survey list the products reported during previous survey-tests, with a calendar of availability for each product, between June 2015 (beginning of the rainy season) and May 2016 (actual period and end of the dry season) (Annex IV). The list of different products recorded from survey-tests and used during surveys, has been translated in French and Mooré (local language) (Annex V). The food item availability at the landscape level is represented by the sum of food items consumed by the 12 HH ('community'). It means that if at least 1 HH out of the 12, consumed one product during a month, it was considered as available and was reported in the list.

Unknown plants and fruits with name in Mooré were identified with the help of the forestry center of Ouagadougou and M. Prosper and M. Bouda, researchers of the IRD and CIRAD's center (products highlighted with ▢ in Annex V).

M. Saunier, M. Prosper and M. Bouda, also contributed to define the following sources of food items:

Farm products:

Food products raised or grown in the field of the farmer in order to feed the HH.

Landscape products:

Food products collected/hunted on areas where nobody spend time to look after except while harvesting. This includes plant products from bushes/trees or fish from rivers. If trees are present on-farm, as long as nobody is regularly looking after, the products belong to the 'landscape' category.

Market products:

Food products that have been purchased (with money) at the local market or from anyone.

Gifts:

Food products that have been offered by someone outside the HH, to a member of the HH.

3.4.2 RStudio and Species Dendrogram

Nutrient contents in terms of carbohydrates, protein, vitamin A, vitamin C, iron, zinc, and folate were collected from secondary sources, because these nutrients are the most at-risk to be deficient in the diet worldwide (Bhutta & Salam, 2012; Ramakrishnan, 2002). These data have mainly been found in the Food and Agriculture Organization food composition table (Stadlmayr et al., 2012), except for some wild edible plants from the landscape. In this case, literature has been researched to document the nutritional values needed, and the tree of decision to choose the data are represented in Annex VI.

From the final total list of food recorded the species dendrogram was constructed and NFD maximal (NFD_{tot}) was calculated by summing up the branch lengths of this tree-like structure diagram, using RStudio (Annex VII).

3.4.3 NFD calculation and comparisons

The NFD_{tot} of the sample was considered as 100% score. NFD from the market (for a specific period, see below) was calculated by summing up the branch lengths of the dendrogram regarding the overall purchased food available (from all HH summed up), and divided by the total branch lengths of the dendrogram, multiplied by 100. An example of NFD calculation by Luckett et al. (2015) is provided in Annex VIII.

Comparison:

The potential NFD_{tot} for all HH where the survey was conducted (n= 12) was calculated, by summing all the food items consumed over one year, as this represented the total food availability in this community.

This NFD_{tot} was calculated for two individual periods, according to interviews :

- When the HH is the most at-risk of food shortage (NFD_{FS}),
- When the food availability is the highest (NFD_{FA}).

Then, different NFD will be calculated regarding the source of the food consumed :

- The food produced on-farm (NFD_F)
- The food collected in the landscape (NFD_L)
- The food purchased on the market (NFD_M)
- The food offered by someone as gift (NFD_G)

Table 1 gives an overview of the comparisons which that were done, and their interest :

Table 1: NFD Comparisons

$NFD_{tot;FA}$ x $NFD_{tot;FS}$	Difference of the NFD between the period of FA and FS (overall sampled HH).
$NFD_{F;FA}$ x $NFD_{M;FA}$ x $NFD_{L;FA}$ x $NFD_{G;FA}$	Difference of the NFD origin in period of FA (sources, overall).
$NFD_{F;FS}$ x $NFD_{M;FS}$ x $NFD_{L;FS}$ x $NFD_{G;FS}$	Difference of the NFD origin in period of FS (sources, overall).
$NFD_{F;FA}$ x $NFD_{F;FS}$	Difference of the contribution of the food produced on-farm on the NFD in period of FA or FS (between periods, fields).
$NFD_{M;FA}$ x $NFD_{M;FS}$	Difference of the contribution of the food purchased on the market on the NFD in period of FA or FS (between periods, market).
$NFD_{L;FA}$ x $NFD_{L;FS}$	Difference of the contribution of the food collected from the landscape on the NFD in period of FA or FS (between periods, landscape).
$NFD_{G;FA}$ x $NFD_{G;FS}$	Difference of the contribution of the food offered from the landscape on the NFD in period of FA or FS (between periods, gifts).

The total food availability (TFA) was calculated by dividing the number of products available at and from a certain period and source by the total number of food products available in Yilou between June 2015 and May 2016. Dividing NFD by TFA represents the average nutritional diversity per products.

The contribution of each source of NFD and food availability per type will be assessed, at different levels of food availability (i.e. FS vs FA), and recommendations could be drawn for future nutritional improvements concerning the dietary diversity requirements.

3.4.4 Correlations between household NFD and diversity of products

Individual household NFD (NFD_{HH}) was calculated by summing food items consumed by each household over one year, and divided by NFD_{tot}, then multiplied by 100. Correlations between NFD_{HH} and socio-economic and biophysical variables added indications on factors influencing HH consumption. Scatter plot diagrams could represent the trends between NFD_{HH} (y-axis) and HH characteristics including the following:

- On-farm biodiversity (number of species grown);
- Environment biodiversity (number of species collected in the landscape);
- Diversity from the market;
- Total number of food items consumed;
- Number of persons living in the HH;
- Amount of time for cooking spent by women per person fed;
- Number of women in charge of the meals per person fed.

3.4.5 Food sources contribution for specific energy and nutrient intake

A second survey was conducted with a sub-sample of 4 HH selected out of the sample of 12 HH (red plots in Figure 2). From the previous survey, food items mentioned by the HH interviewees in period of FS and FA were used as starting point for the second survey. Their frequencies of consumption during both periods are reported in Annex IX.
In addition, regarding these food items, quantities consumed per HH were also estimated with interviewed women and weighted to depict HH food consumption for each period.

The amount of each foodstuff has been added up for the 4 selected sampled HH, in order to have the total amount of food consumed in each of the periods. Then a food composition table (Stadlmayr et al., 2012) was mobilized to identify the percentage of contribution of each foodstuff to the total intake of energy and of three nutrients: vitamin A, iron, and zinc, because their deficiencies are the most prevalent in childhood in developing countries worldwide (Bhutta & Salam, 2012).

3.4.6 Energy adequacy indicators

Food security ratio (FSR) takes into account the total energy provided by food from all sources, while dividing by the energy requirements of the HH (Equation 1). If FSR is higher than one, then HH members have access of a surplus of energy (Rufino et al., 2013).
Food self-sufficiency ratio (FSSR) uses the total energy provided only by food produced on-farm or collected in the landscape, while dividing by the energy requirements of the HH (Equation 2). If the FSSR is higher than one, the HH produce and collect enough food to generate a surplus of energy (Rufino et al., 2013).

$$FSR = \frac{\sum_{m=1}^{p}(QF_m + QG_m + QL_m + QM_m)\cdot E_m}{\sum_{j=1}^{n} ER_j} \quad (1)$$

$$FSSR = \frac{\sum_{m=1}^{p}(QF_m + QL_m)\cdot E_m}{\sum_{j=1}^{n} ER_j} \quad (2)$$

Where:
QF_m is the quantity of foodstuff *m* produced on-farm that has been consumed by the HH (kg/month).
QG_m is the quantity of foodstuff *m* offered as a gift to the HH (kg/month).
QL_m is the quantity of foodstuff *m* consumed by the HH, collected in the landscape (kg/month).
QM_m is the quantity of foodstuff *m* purchased and consumed by the HH (kg/month).
p is the number of foodstuffs.

E_m represents the energy content of the food item *m* (kcal/kg), which have been reported in a food table composition.
ER_j is the theoretical energy requirements of the HH (n=4) in kcal/month.
n is the number of HH surveyed (Rufino et al., 2013).

Energy requirements were calculated with the energy requirements indicated by the FAO (Food and Agriculture Organization, 2001).

Comparison between FSR_{FS}, FSR_{FA}, $FSSR_{FS}$ and $FSSR_{FA}$ were emphasized to depict energy adequacy situations for the sampled HH.

4. Results

4.1 Households characteristics

Among the 12 HH, average number of persons per HH was about 15. There was a mean of 2.3 women cooking per HH, which represents 0.2 women cooking/person fed, and women spent about 162.9 min/day for cooking and were living in the same courtyard. Most of the HH ate 3 meals per day except during the month of Tabaski or Ramadan (in 2015 = September) where 6 HH reduced to 2 meals, based on religious fasting rules within Islamic communities.

In Yilou, local market takes place every 3 days and small shops are open every day in the village. After the rainy season, the 12 HH decreased their frequency of market visits, due to the increase of field workload and the lack of income. They return to the market after the harvest as they have more free time and enough money.

4.2 Periods of food shortage and abundance: Interviewee perception

All HH answered that the period after harvest, corresponding to the month of November (2015), was the period the more secure in terms of abundance of food. Regarding the period of FS, answers varied in between the months of April (3 HH) until June (3 HH), July (2 HH) and August (4 HH) as some HH had their cereal attics empty earlier than others, so they perceived FS earlier. August has been chosen as month of food shortage, because the highest number of households perceived food shortage at this period.

4.3 Food item availability

Over one year, 82 different products were available in the sample of 12 HH. Figure 3 shows that food items availability was at its lowest point in September with 65 products (before harvest), and increased gradually from November (end of harvest), till reached a maximum of 75 in March, and then decreased till September.

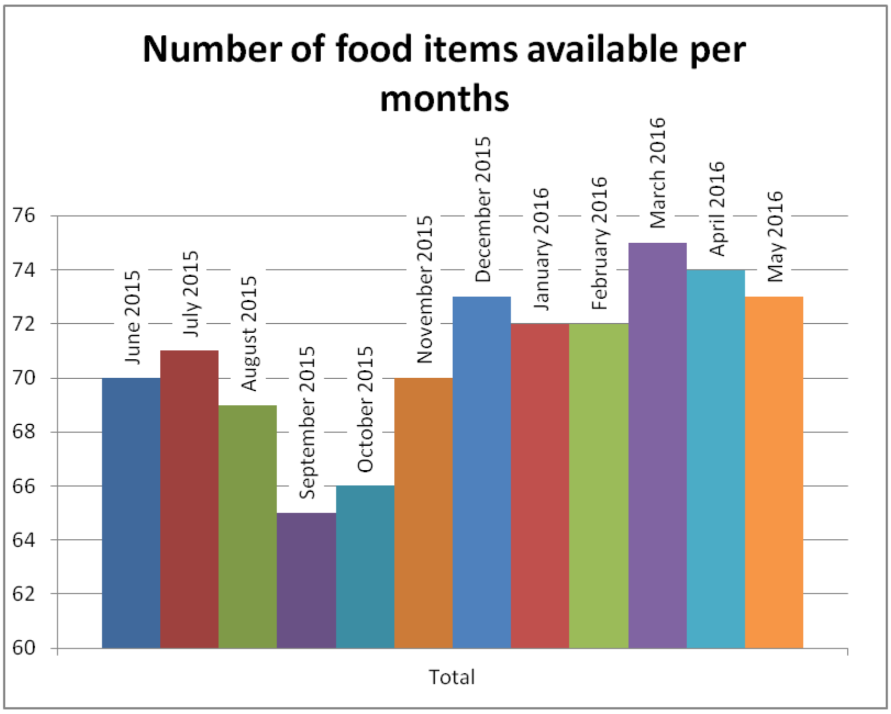

Figure 3: Number of food items available for the 12 households per months, between June 2015 and May 2016.

The mean of products per month was 70.8 products/month (with no regard to the source of origin) and the period of FA (November) had 70 food items available for the 12 HH, and the period of FS (August) had 69 products.

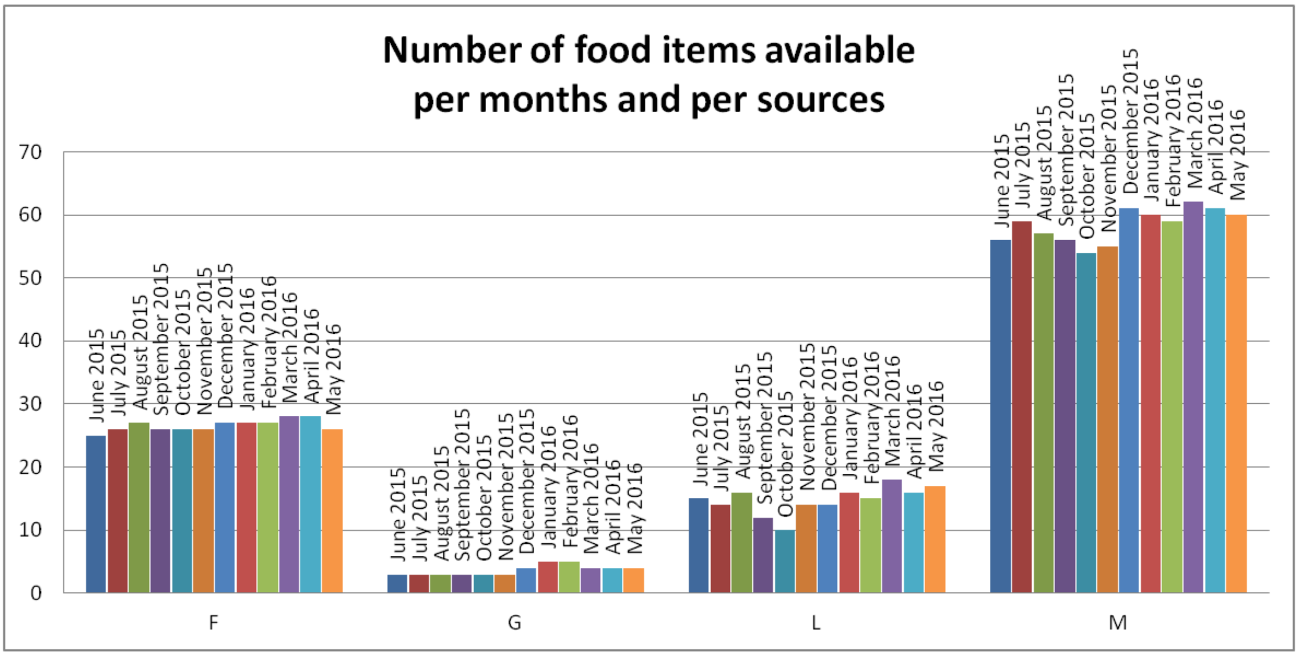

Figure 4: Number of food items available for the 12 households per months regarding their origins, between June 2015 and May 2016.

Figure 4 shows that the sum of F products was constant over the last year and stayed between 24 and 27 products per month. Table 2 shows the different F products and the number of HH (out of the 12) cultivating/raising them. Four species are omnipresent (total HH 11-12), while 12 species are grown by more than 6HH. This reveals certain uniformity in the foodstuffs produced.

Between 10 and 19 L products were available in Yilou over the last year. The diversity was higher between November and May, and then decreased till October. This trend of L product availability was observed with almost all HH, even if there are differences. Table 2 shows the L products that had the easiest access (number of HH close to 12). Moreover Table 3 shows that 7 L products out of 22 are available throughout the year, because once the harvesting time is over most of the HH dry leaves (i.e. baobab, tamarind) and store them for whole-year consumption.

Highest number of food items per month corresponded to M products, with between 54 and 62 different food items each month, which represents about three times the diversity of L products, and two times the diversity of F products. These were mainly purchased after harvest, particularly December through May. Before harvest, the number of food items available decreased from July through October. This finding followed the same trend as the market visit frequency in most HH. Table 2 shows the number of HH that had access to the different M products.

Products offered (G, gifts) to the HH were reported to be quite marginal (5 products). Okra, jute and roselle leaves products were offered on a regular basis over the year, coconut was offered regularly during its seasonal availability, and sardine has been offered only once within the year for a baptism.

Table 2 shows the different sources possible for each products (F + M; L + M; F + G; L + G; G + F + M), the number of HH which has to use different sources, and the colors explain the reason to use different sources (see legend below).

Table 2: Number of HH that consumed products and the different combination of sources.

		F	F+M	M	M+L	L	G	G+F+M	G+F	Total HH
Cereals	**Yellow maize**	10		1						**11**
	White maize			8						**8**
	Pearl millet	10		1						**11**
	White bread			9						**9**
	Rice	1		11						**12**
	Sorghum	10	2							**12**
	Macaroni			11						**11**
Roots and tubers	**Yam tuber**			10						**10**
	Cassava tuber			8						**8**
	Potato	1		11						**12**
Legumes	**Cowpea**	11	1							**12**
	Acacia macrostacchya			3		6				**9**
	Bambara groundnut	10								**10**
Vegetables	**Eggplant**	1	2	6						**9**
	Avocado			3						**3**
	Amaranth leaves	1	1	1						**3**
	Jute leaves	10							1	**11**
	Carrot	1		9						**10**
	Cabbage		1	11						**12**
	Cucumber			12						**12**
	Courgette			8						**8**
	Spinach			1						**1**
	Baobab leaves				2	10				**12**
	Cowpea leaves	12								**12**
	Eggplant leaves	5	2	2						**9**
	Okra	8	3					1		**12**
	Green beans			8						**8**
	Cratevia religiosa					8				**8**
	Kapok			9	2	1				**12**
	Water spinach					5				**5**
	African eggplant	4	4	3						**12**
	Leptadenia hastata					3				**12**
	Onion	5	1	6						**12**
	Roselle leaves	8	3						1	**11**
	Chilli pepper	1		6						**7**
	Sweet green pepper			6						**6**
	Lettuce			7						**7**
	Cassia obtusifolia					11				**11**
	Tomato	1	3	8						**12**

		F	F+M	M	M+L	L	G	G+F+M	G+F	Total HH
Fruits	*Vitex doniana*					3				**3**
	Annona sengalensis			2		1				**3**
	African locust bean			11						**11**
	Banana			11						**11**
	Shea fruit					12				**12**
	Guava			10						**10**
	Diospyros mespiliformis			1		9				**9**
	Jujube			3	1	7				**11**
	Ximenia americana					7				**7**
	Gumvine			3		8				**11**
	Mango			6	3	3				**12**
	Sclerocarya birrea			1		11				**12**
	Orange			12						**12**
	Baobab fruit			3	1	8				**12**
	Lannea microcarpa					12				**12**
	Tamarind				1	11				**12**
Nuts and seeds	Coconut			10			1			**11**
	Groundnut	11	1							**12**
	Sesame	10	1							**11**
	Bikaalga	10	1							**11**
Meat and poultry	Beef	2	3	6						**11**
	Goat	2	4	6						**12**
	Sheep	2	4	6						**12**
	Guinea fowl	9		3						**12**
	Pork			1						**1**
	Chicken	4		2						**6**
Eggs	Guinea fowl egg	3	1	8						**12**
Fish	Carp			7	5					**12**
	Eel			1		1				**2**
	Shrimp			7	1					**8**
	Sardine			2			1			**3**
	Sardinella			12						**12**
	Mackerel			10						**10**
	Catfish			8	2	1				**11**
Dairy products	Cow milk		1	10						**11**
	Powder milk			1						**1**
	Yoghurt			11						**11**
Miscellaneous	Oil			12						**12**
	Dry beef cube			11						**11**
	Black pepper			7						**7**
	Salt			12						**12**
	Soumbala	1		11						**12**
	Sugar			12						**12**

Food shortage | Special event | Seasonal limitation | Bio-physical limitation

Regarding Table 3, most of L products are processed, and then they can be available for the whole year. HH take advantage of it, for example during the month of October 8 L products out of 10 are dry. In addition, the calendar represents the different times of forest products harvest in the area, and it has to be noticed that landscape provides different products every months all year long.

While discussing with HH members, few comments regarding the products availability and different strategies have been identified to cope with problems of FS. Periods of availability and the origins of products for each HH vary in our sample. Depending on the food groups, and various factors, such as income or biophysical conditions, different strategies are adopted and reported below:

Cereals, tuber and legumes:

- Cowpea and sorghum are the basis of the diet, and most HH have enough with their own harvest. Few of them have to buy it on the market during the rainy season (colors of Table 2 legend). Others cannot afford to buy cowpeas, so they rely on the other crops cultivated (i.e. maize and sorghum).

- Access to potatoes, yam and cassava tubers depends on the market availability. Some HH have people from their family close to larger markets, which are charged to access it all year through. Most HH are still dependent on seasonal periods.

- Pearl millet is cultivated in small quantities and reserved to make a special drink called 'zom-kom' during the Tabasky and a type of 'porridge' during the months of cold.

- Most of the cereals, tuber and legumes are cultivated by every HH (see Table 2). Imported cereals such as rice (rarely cultivated) and pasta, which have no seasonal characteristics, are very well appreciated among the population. They are eaten on a regular basis, but less than the crops grow on-farm still as they are expensive products compared with traditional cereals. Others use them only for special events (Christmas or Tabasky) and pasta is one of the first foodstuff they stop to purchase in period of FS due to its higher price.

- *Acacia macrostacchya* seeds are more likely to be stored and consumed for a long time. It is traditionally reserved for special events (weddings), as it is difficult to collect in the landscape, or very expensive.

- Consumption of groundnut, bambara groundnut, or sesame grown on-farm depends on field productivity. If sesame or groundnut are missing, some HH can purchase it ( ). One HH only ate bambara groundnuts during three months during the cold period (December through February). This to keep their reserve of sorghum and cowpea as long as possible and prevent period of severe FS later on n 2016.

Vegetables and fruits:

- Availability of fruits and vegetables is very much season-dependent ( ), except if there is good access to a large market, and only in regards to certain products (i.e. mangoes, tomatoes)

- Depends on the HH bio-physical environment ( ). Some HH have to buy products on the market while others can cultivate them (field located next to river for vegetables, i.e. tomatoes and onions) or collect them on trees in their field (i.e. mangoes, *Annona senegalensis* , etc.).

- Drying products is a widespread strategy after harvesting, and most of the HH preserve food for almost the whole year (okra, jute and baobab leaves, etc.)

- External factors such as early rain influence periods of food availability. Early rain raised the level of the river and flooded gardens on the side of the river, which shortens vegetables period of availability.

- Differences of knowledge between HH concerning post-harvest storage. For instance, few HH can only it eat *Cassia obtusifolia* fresh for a short time as they do not know that it is possible to dry it.

Meat, poultry and fish:

- Fishing period in Yilou is mainly after the months of February, because the level of the river is low enough for women to enter into the water (they do not know how to swim).

- Most of fishes are purchased very frequently all year long, but in very small quantities (especially dried sardinella).

- Regarding meat, it is mainly purchased on the market. Livestock on-farm is used as capital to sell and get an income, but is not produce to feed directly the HH. Exceptions are for special events, such as Tabasky ( ).

- Pork has been reported by only 1HH (other HH are mainly Muslims), and they ate it every months.

- Goat and mutton meat is purchased very often in small quantities, grilled or raw at the market.

- In time of FS, some HH cannot afford meat, because they 'prefer to buy rice instead, as they can have more for the same price' (but they buy fish all year long still). Especially one HH never consumes meat, except for special events.

- Guinea fowl and chicken are most of the time reserved for events, but few HH raise them and can eat them regularly, except during the rainy season, as they lay eggs hatching for the next generation of animals. Guinea fowl eggs are also sold on the market (see below).

Eggs and dairy products:

- Traditions prevent women from eating chicken eggs, so none of the HH consumed chicken eggs (no further explanations has been given).

- The way to raise cattle and guinea fowl could be compared to a zero grazing system. HH have access to milk and guinea fowl eggs mainly during the rainy season.

- The availability of yoghurt was all year long in the shops.

- Only 1 HH reported buying milk powder.

Miscellaneous

- Products such as oil, dry beef cube, sugar, salt, soumbala and sugar were available all year long, except black pepper which does not have a prevalent place in the Burkinabe's cuisine.

Table 3: Calendar of L fruit, vegetables and legumes availability.

Food item		June 2015	July 2015	Aug. 2015	Sept. 2015	Oct. 2015	Nov. 2015	Dec. 2015	Jan. 2016	Feb. 2016	Mar. 2016	Apr. 2016	May 2016
Vegetable	Baobab leaves	■	■	■	■	■	■	■	■	■	■	■	■
	Kapok	■	■	■	■	■	■	■	■	■	■	■	■
	Ipomoea aquatica	■	■	■	■	■	■	■	■	■	■	■	■
	Cassia obtusifolia	■	■	■	■	■	■	■	■	■	■	■	■
	Tamarind leaves	■	■	■	■	■	■	■	■	■	■	■	■
Legume	*Acacia macrostacchya*	■	■	■	■	■	■	■	■	■	■	■	■
Fruit	Tamarind	■	■	■	■	■	■	■	■	■	■	■	■
	Mango	■									■	■	■
	Sclerocarya birrea	■	■	■								■	■
	Gumvine	■	■	■	■								■
	Vitex doniana	■	■	■									■
	Ximenia americana	■	■	■	■	■	■						
	Shea fruit	■	■	■	■								
	Lannea microcarpa	■	■	■									
	Baobab fruit				■	■	■	■	■	■	■		
	Diospyros mespiliformis						■	■	■	■	■	■	
	Jujube						■	■	■	■	■	■	
	Annona senegalensis						■	■					
Vegetable	*Leptadenia hastata*						■	■	■	■	■	■	
	Cratevia religiosa										■	■	■
	Balanites aegyptiaca										■	■	

Indeed food groups are rather specific for each sources. For instance, L products are mainly represented by fruits, leaves (identified as 'vegetables'), and fishes. F products are mainly composed by cereals, legumes (except *Acacia macrostachya* seeds) and meat. Finally, concerning M products they are composed by all types of food groups, and are specific for the dairy products and miscalleneous (oil, salt, etc.).

Table 2 shows that as the 82 products have different period of availability, their sources of origins had to be combined for several reasons:

- Combination of L and M origin: mainly due to seasonal and bio-physical limitations. Certain HH did not have access to specific trees or to the river in their close surroundings, or because on the market products have a longer period of availability than in the landscape. However, certain L products were not available on the market last year, so theirs availability was limited to few HH with access to the specific trees.

- Combination of F and M origin: main reasons are due to special events, seasonal limitations and FS. During special events, such as Tabasky, meat products that are purchased on the market throughout the year, will come from the farm production as few cattle are sacrificed for the event. Otherwise, dairy products, eggs and vegetables also have to be purchased as they have a longer period of availability on the market than on farm. Regarding cereals, legumes, nuts, seeds and some vegetables, they have to be purchased on the market once reserves are empty, and these products are often considered 'essential' in their cuisine.

- G products are mainly products offered from other persons own harvest surplus. However sometimes, even the products offered were not enough to cope with FS, and the HH had to also purchase the product on the market.

These observations provide insights on strategies adopted by sampled HH to cope with FS, seasonal or even, bio-physical limitations (i.e. scarcity of tree). Most widespread or 'safe' option, as evidenced by the amount of M products recorded, is reliance on market access, given the particular context of Yilou and the market celebration every 3 days.

4.4 Nutritional functional diversity

Total nutritional functional diversity (NFD_{tot}) of foodstuffs available last year (2015/2016) represents the sum of all the 'tree branches' of the dendrogram (Figure 5) and is equal to 35.98 regarding the scale on the left side of the figure. This will represent 100% of NFD in this community, and all sub-NFD will be divided by NFD_{tot} to represent a percentage of the maximal NFD. Annex X gives the food name for all the abbreviations.

This dendrogram groups species regarding their percentage of contribution to the dietary requirements of 100g of foodstuff for certain nutrients (nutrient content (100g)/daily requirement intake (DRI)). It is observed that food items on the right side have the highest contribution to the DRI of iron, and the food items on the left side concern vitamin C contribution to the DRI for 100g (except 'soum' which is closer to the iron-rich cluster). Regarding vitamin A, folate, zinc, protein and carbohydrates, the distinction in the dendrogram is less clear as the highest contributions for one of the latters nutrient would always be lower than the highest contributions of another foodstuff regarding iron or vitamin C. For instance, the highest contribution for vitamin C is 290% whereas for

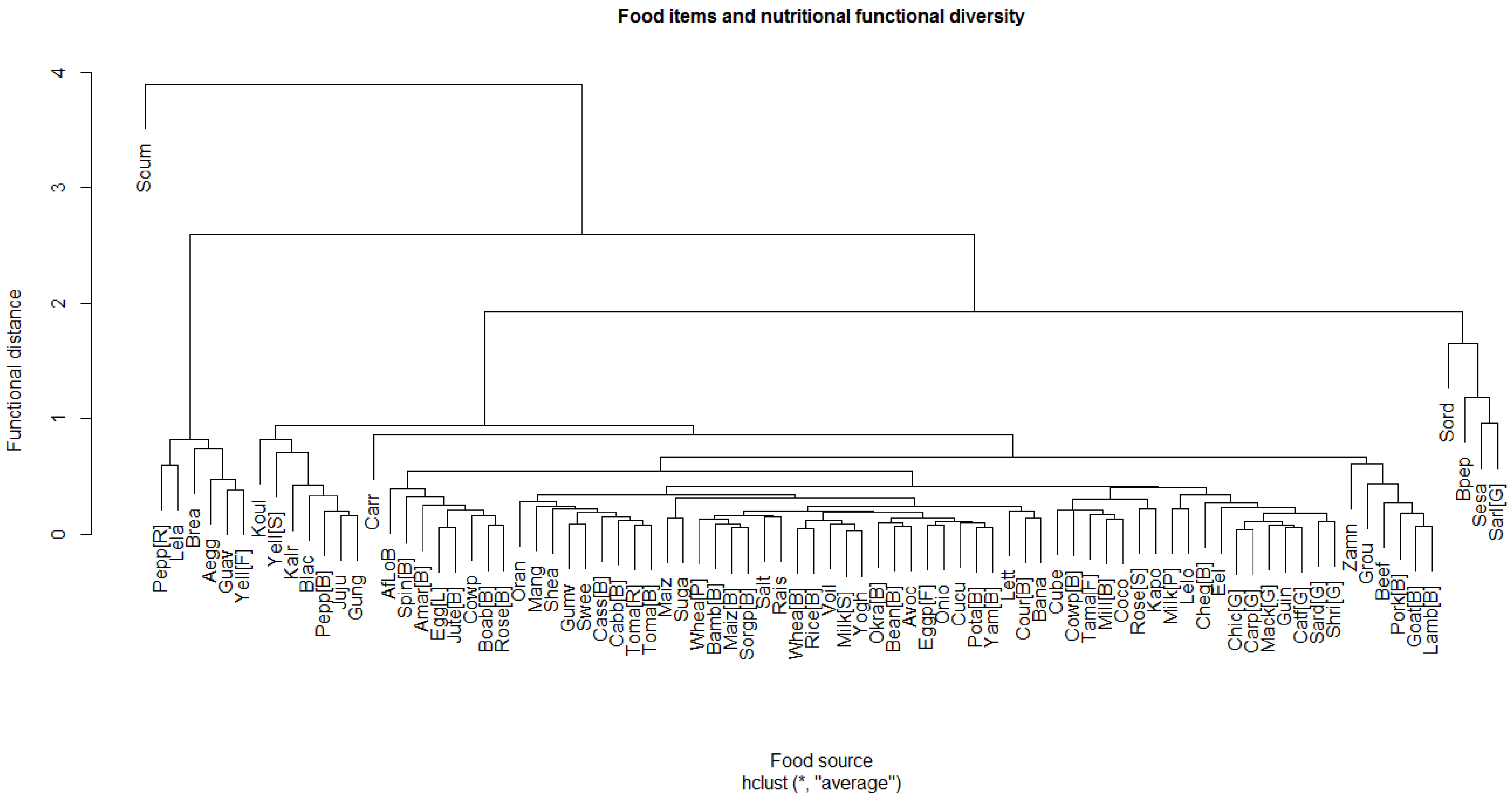

Figure 5: Dendrogram of the total food items available between June 2015 and May 2016.

carbohydrates it is 31%. This can be explained as the DRI for carbohydrates is very high with 325g/day, which is difficult to reach per 100g of food, whereas the DRI for vitamin C is equal to 90mg/day.

The NFD during the lean period (NFD_{FS}) represented 89% of the maximal NFD over one year between June 2015 and May 2016 (NFD_{tot}). In August (month of FS) 69 different products were available in Yilou, which represents 84% of total foodstuffs available (TFA) during the year. The NFD of the abundant period (NFD_{FA}) was with 88%, slightly lower than the NFD during lean period, which means that the diet was more nutrient-rich in period of FS. Moreover, the TFA was higher during FA (85%), which means that the 70 products available in FA together were less nutrient-dense than the 69 products available during FS.

Annex XI reports complete food list during FS and FA, with in blue ( ) the foods that were present during only one of these periods. Seven products were available during FA but not during FS, and 6 other products were available during FS but not during FA. In addition, if the fruit *Sclerocarrya birrea* was removed from the list, the percentage of NFD_{tot} falls to 87.7%, which is lower than in FA. This is the only product not present in FA that can lower the NFD_{FS} below the NFD_{FA}, and it can be explained because the fruit and the seeds are edible, so more nutrients are provided by this food item.

Table 4 shows that between sources, M products always had the largest contribution to NFD_{tot}, whereas L and F products had lower and similar contributions. For F products the contribution to NFD was the same for FA and FS periods, whereas M and L products contribution increased respectively by 3.3% and 2.1% in FS. Contribution of L products to the NFD_{FS} (NFD of the food available in August) was close to 40%, whereas it was around 37% in FA, and it can be explained by an increase from 12 L products (14.6% TFA) to 14 L products (17.1%) available. As a consequence it decreased the contribution of M products to NFD_{FS}, although the number of M products also increased by 2 products. Moreover, L products had a low contribution to TFA (few number of products), whereas they had a substantial contribution to the NFD_{tot}, which means that these products are nutrient-dense. The ratio NFD_{tot}/ TFA shows that for instance in FS, L products are about two times more nutrient-dense, as with only 14 L products available they reach almost the same contribution to NFD_{tot} as 26 F products.

Concerning G products, their contribution to the NFD_{tot} seems to be marginal, especially because during both periods, the products offered are already present at the HH, from other sources. Moreover, G products in period of FS and FA are the same, so no difference of $NFD_{FS;G}$ and $NFD_{FA;G}$ were observed.

Table 4: NFD and food items availability comparisons between food sources.

Indicator	FA_F	FA_M	FA_L	FS_F	FS_M	FS_L	G
NFD_{tot}	33.8%	**74.4%**	**32.8%**	34.4%	**71.1%**	**34.9%**	3.0%
NFD_{FA}	38.2%	**84.1%**	37.1%				3.4%
NFD_{FS}				38.5%	**79.6%**	**39.0%**	3.4%
Total Food Availability	30.5%	65.8%	**14.6%**	31.7%	68.3%	**17.1%**	3.6%
NFD_{tot}/TFA	1.1	1.1	**2.0**	1.1	1.0	**2.1**	0.9

4.5 Correlations between household nutrient diversity and environment biodiversity

NFD of each of the 12 HH has been calculated regarding the overall food they consumed within one year. Then, the sum of the tree branches has been divided by NFD_{tot} in order to compare the between each other, and to appreciate the quality of their diet regarding the NFD total in Yilou, between June 2015 and May 2016. Average NFD_{HH} is equal to 31.3 (SD=2.5), which represents 87% of the NFD_{tot}.

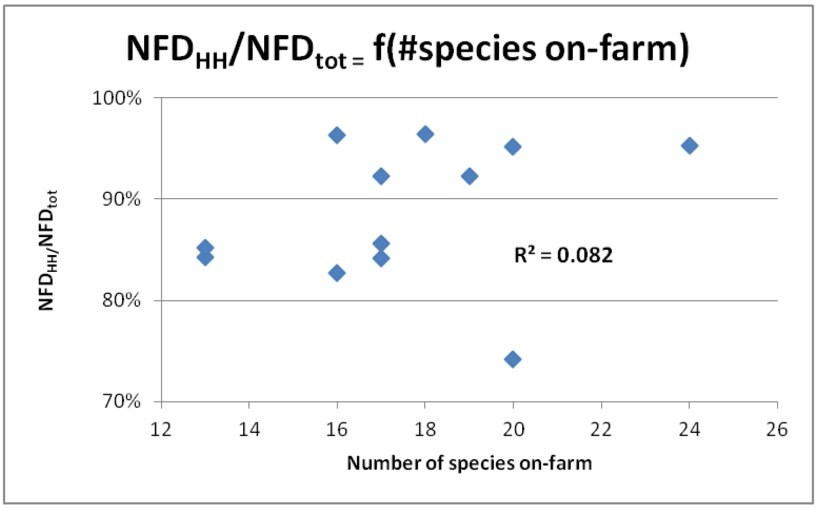

Figure 6: Scatter plot of NFD_{HH} regarding farm production diversity.

The number of species produced on-farm (Figure 6) as well as the number of species from landscape consumed (Figure 7) do not seem to have a correlation with the NFD_{HH}, as their coefficient of determination are respectively equal to 0.08 and 0.10.

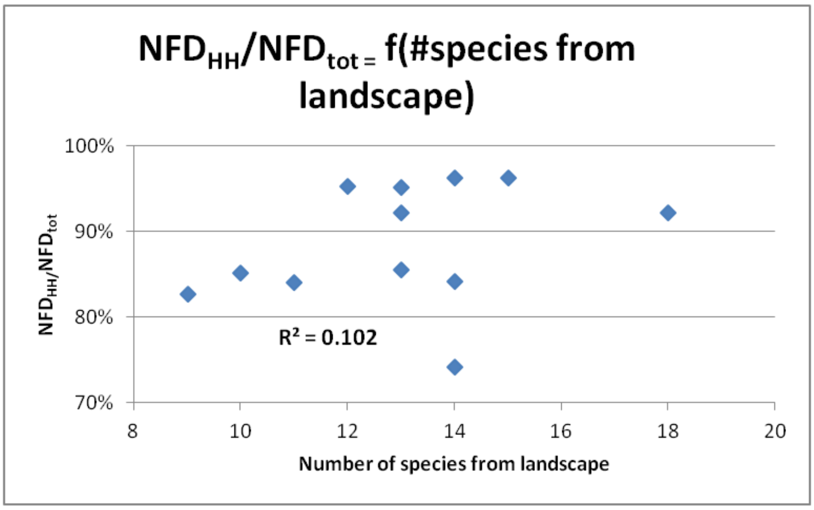

Figure 7: Scatter plot of NFD_{HH} regarding environment biodiversity.

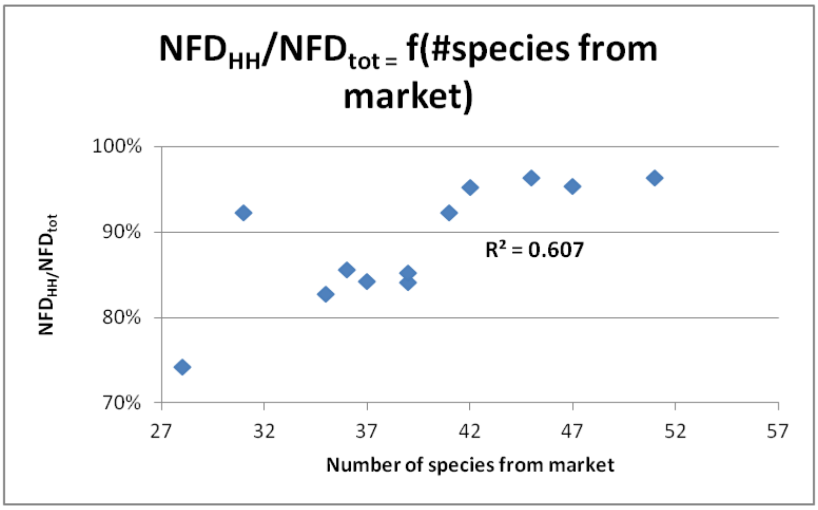

Figure 8: Scatter plot of NFD_{HH} regarding accessibility to market.

Correlations between number of species from the market consumed by the HH (Figure 8), and their NFD_{HH} show to be stronger, even if it is low still.

Moreover, as the number of M products is more important than from other sources, the coefficient of determination is even higher regarding the correlation between the overall diversity of food consumed per HH and their NFD_{HH} (Figure 9).

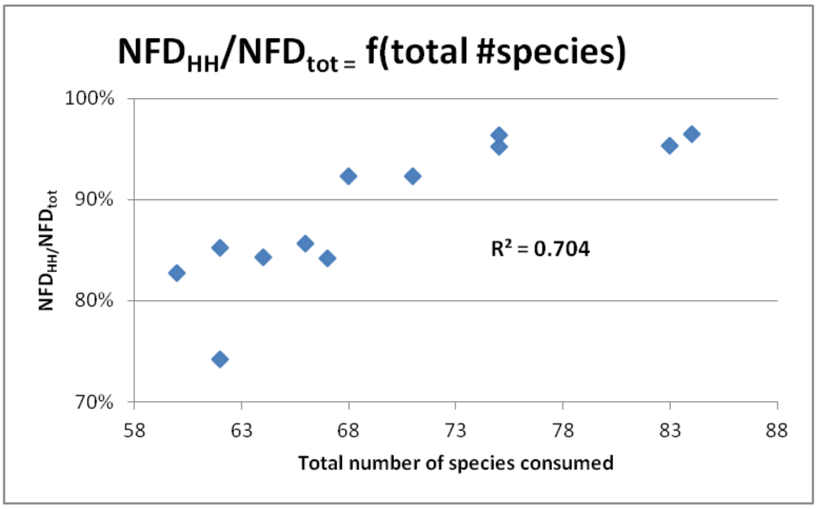

Figure 9: Scatter plot of NFD_{HH} regarding total diversity of products.

Table 5: HH characteristics and coefficient of determination.

HH characteristics	Mean ± SD	R^2
HH size (number of persons)	15 ± 9.5	0.1
Time for cooking/day (min)	156.5 ± 92.7	0.1
Number of woman in charge of meals	2.3 ± 1	0.0
Number of woman cooking /persons fed	0.2 ± 0.1	0.0

In Table 5 have been reported others correlations regarding the HH structure and meal preparation characteristics, but no relations have been found.

4.6 Food sources contribution to energy and specific nutrients intake

Figure 10 shows the contribution of farm, landscape, and market source to intake of energy, iron, zinc and vitamin A during FS and FA. This approach gives a more realistic picture of the dietary patterns, as it takes into account the frequencies of meal consumption, as well as the amount of food consumed.

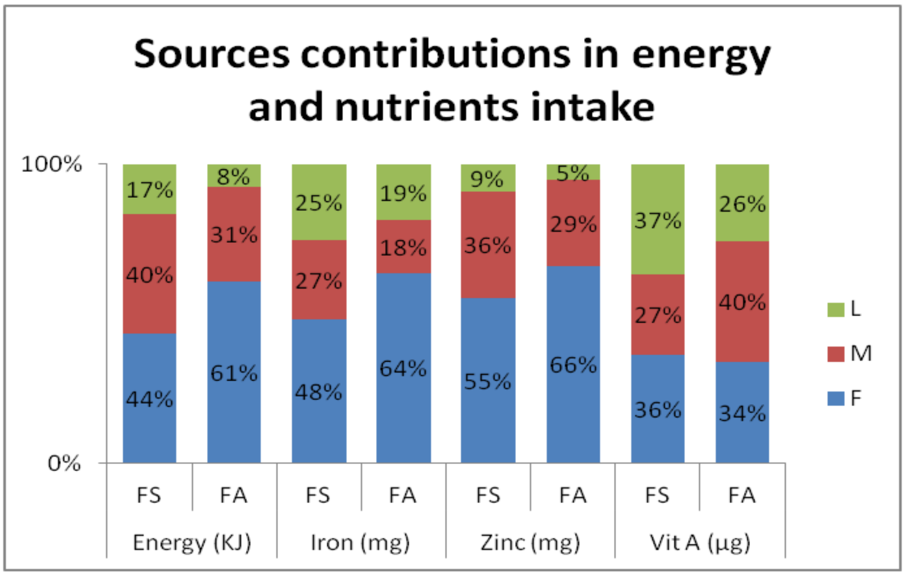

Figure 10: Contributions of each source to the households' intakes of energy, iron, zinc and vitamin A intakes.

The total amount of energy consumed was 8% higher in FA than in FS (Table 6), due to an increase of F products, as their contribution increased from 44% to 61% of the total energy intake. The contribution of M products decreased by 9% between FS and FA when grain storage attics are full again, and HH did not have to buy cowpea anymore, and eat less rice and cassava. L products had a limited contribution to the energy intake, and this was lower for FA than for FS. This can be explained by the increase of total energy intake, and also because there are less fruits in November, which are high in sugar and energy.

Table 6: Amount of energy, iron, zinc and vitamin A intake among the 4 HH between periods of FS (scarcity) and FA (abundance).

Nutrient	Period	Source			Total	Diff. (%)
		F	M	L		
Energy (MJ)	FS	4307	3922	1672	9901	
	FA	6555	3386	828	10769	
	Diff FA-FS	2248	-536	844	868	+8%
Iron (mg)	FS	14245	7890	7473	29609	
	FA	21705	5997	6436	34137	
	Diff FA-FS	7460	-1894	-1037	4529	+13%
Zinc (mg)	FS	7330	4720	1220	13271	
	FA	11576	5029	916	17522	
	Diff FA-FS	4246	309	304	4251	+24%
Vit A (µg)	FS	312212	230613	318705	861531	
	FA	313756	369447	239136	922339	
	Diff FA-FS	1544	138834	79569	60808	+7%

Iron intake was 13% higher in FA than in FS. F products had the largest contribution during both periods, and more of these products were consumed during the FA period. M and L products have similar contribution to iron intake. M products contribution was 9% lower in FA than in FS, mainly because none of the cowpea consumed during FA come from the market (major sources of iron for M products during FS), it all comes from farm production. Surprisingly, meat and fish did not significantly contribute to the iron intake, as their consumption occurs only in small amounts per meal and per person. Contribution of L products to iron intake was 6% lower during FA, which is explained by the absence of certain fruits, which were highly consumed in FS and contain much iron.

Zinc intake was mainly derived from F products in particular cereals and legumes. L products made the smallest contribution to zinc supply. Between FS and FA, the amount of zinc consumed increased by 24%, and this is mainly due to an increase in consumption of F products. Zinc intake contribution from M products decreased between both periods, because as the overall zinc intake increased, the % of zinc intake from M products decrease in FA. Moreover, none of the cowpea consumed during FA come from the market, although it was also the main source of zinc from M products during FS.

An increase of 7% of the overall vitamin A intake was observed between FS and FA. During FS, L products showed to have the main contribution to vitamin A intake and M products the lowest, whereas it is the contrary during FA. Concerning M products, the amount of vitamin A intake during FA is higher than in FS, as some vegetables with high vitamin A content arrive on the market and the consumption of vegetables increase between both periods. Concerning L products, it was observed that they highly contributed to the vitamin A intake during period of FS. However this percentage was lower during FA as fruit consumption decreased, decreasing total amount of vitamin A provided by L products.

4.7 Energy adequacy indicators

During FA, FSR was equal to 0.73 and FSSR to 0.50, while FSR and FSSR were respectively equal to 0.67 and 0.41 during period of FS. The ratios are below 1 during both periods, but are nevertheless higher during FA than during FS. This means that neither products from the farm and landscape together, nor all products consumed were in sufficient amount to meet the energy requirements of the HH in August or November. M (and G) products consumed inside the HH supplied 27% of the energy intake in period of FS, compared with 23% in period of FA. This shows that M products are not the main source of energy during these periods, as it is mainly composed by vegetables, fruit, meat and fish, and does not provide high amount of energy.

5. Discussion

HH perceptions of FS and FA might be related with both variety and amounts of food available during these periods, as the period of FS does not have lowest diversity of food items, and FA not the highest. September had the lowest diversity of products but since most of the HH are Muslims and did Ramadan during this month, most of them only ate 2 meals per day with special dishes for the occasion. This could explain why no HH reported September as period of FS, also because harvest starts during this month so their perception of FS might be alleviate as well.

A study documenting HH strategies to cope with FS in the Sudano-Sahelian region of Burkina Faso, also determined the period of FS regarding 'when cereal granaries become empty until the next harvest' (Koffi et al., 2016). However, Annex XI shows that there are no real differences in food items available for the 12 HH during both periods, except for vegetables and fruits. Indeed some HH asserted that they did not experience scarcity during the last year, so differences were mainly due to seasonal variations instead of problem of FS. However, Table 2 shows that few HH needed to cope with problem of FS by purchasing products on the market, but it does not report the number of HH the most at-risk of food insecurity which could not afford it and had to find other strategies.

The NFD_{FS} and NFD_{FA} reached a high percentage of the NFD_{tot} with 89 and 88% respectively. This can be explained because both periods were close in time (2 months), and also because the HH dried and stored some key foodstuffs to have products available for a long period. Moreover the NFD_{tot} calculated, which is equal to 35.97, is low when compared to other NFD as calculated in Malawi (NFD = 49.25), Kenya (NFD = 64.56) and Uganda (NFD = 68.44)(Remans et al., 2011). Indeed some products reported in the study with high contributions to NFD were not available in this part of Burkina Faso (i.e. pumpkins, mulberries, black jack, peaches, etc.).

F products showed to have a quite constant availability, such as cereals and legumes. This explains the similar NFD_F between both periods, and women emphasized how important it was for them to be able to manage their food reserves over the year. Otherwise, while endangering their HH food intake, the community would label them as 'lazy' persons, which would put additional pressure on them. However, consumption of F products in the 4 HH was higher in FA than in FS and showed an important contribution to energy, iron, zinc and vitamin A intake, especially during FA. Indeed, 3 HH out of 4 recognized that during this period they changed their unit metric (a cup, a dish, etc.) when measuring cereals/legumes to prepare and add for example one additional cup or portion. This could explain why F products change from 44% up to 61% for the energy intake between both periods. Indeed, the number of F products slightly varied between December and April due to the arrival of vegetables such as African eggplants, tomatoes and other leaves, in the field cultivated next to the river. HH with a vegetable garden had a NFD_{HH} on average about 90%, somewhat higher than the average NFD_{HH} (87%) whereas they did not consume more different products from the landscape or the market.

M products showed the highest variety over last year, and for each month. An increase of M products from November till March can be explained because HH get an income from their harvest, and have some time to return to the market after the rainy season, when the field workload is reduced. NFD_M is the highest NFD between sources and periods, and this is emphasized by the stronger correlation (even if it is low still) between the diversity of M products and NFD_{HH}.

M products showed a relatively important contribution to energy and zinc intake in period of FS, and vitamin A during FA (>30%). Regarding energy and zinc intake, their decrease between both periods is mainly due to the increase of cereals and legume (especially cowpea) consumption from F sources. It has to be noticed how one food item such as cowpea, which can be missing in time of FS and might not be affordable to the HH, can make a difference regarding nutrient intakes.

Moreover, M products accessibility may vary between months, years, and especially between HH. For instance, vegetable availability differs only slightly between months as some HH could have access to bigger markets. As a result HH consumed more diverse products (i.e. lettuce, sweet green pepper, etc.), even if this year the garden started to be flooded earlier, shortening availability of some vegetables. In addition a study in Indonesia, Kenya, Ethiopia and Malawi compared HH production diversity and HH dietary diversity (number of food items consumed) (Sibhatu, et al., 2015). It showed that farm production diversity had a small impact on HH dietary diversity, but that off-farm income and access to market was strongly and positively correlated with dietary diversity, and that HH specialized in cash crops production had access to a higher number of products (Sibhatu et al., 2015). Nonetheless, not all HH can afford these products on the larger markets. Therefore relying on M products might not be a sustainable solution and emphasizes the limit between food security and sovereignty (Jarosz, 2014).

However, the type of products available in the outlets can lead to an unhealthy dietary diversification and threaten the health of the diet (Sibhatu et al., 2015). Gomez et al. (2013) define food-value chains (FVC) as the processes to bring food from farms to consumers, and they developed a typology of different FVC. Our observations suggest that in Yilou, two of them coexist out of the four. Products on the local market carried by traditional FVC, as defined by 'traditional traders [which] buy primarily from smallholder farmers, and sell to consumers and traders in wet, mostly local, markets' (Gomez et al., 2013). This FVC provides more diverse products that the wealthier people can have access to.
The other one is a 'modern-to-traditional' FVC, defined as 'Domestic and multinational food manufacturers sell through the network of traditional traders and retailers'. It mainly concerns the products found in the small shops of the village, especially represented by calorie-dense processed/packaged foods, but low in interesting micronutrients (Gomez et al., 2013). The 'modern-to-traditional' FVC in Yilou, carried products such as: vegetable oil, salt, sugar, dry beef cube, yoghurt and milk powder which, except the two latter, are relatively micronutrient-poor.

L products availability over the last year varied between months but 7 out of 18 products are systematically collected, dried, stored and constantly used all year long. Variations between months are mainly due to tree phenology and environmental conditions (floods, early rain, etc.), whereas differences between HH concern their spatial locations in respect to landscape elements. Indeed, the presence/absence of trees or rivers widely influences consumption or source of products, as 9 products can differ from market or landscape (Table 2). Moreover even if NFD_L was relatively low compared with NFD from other sources, the ratio NFD_{tot}/TFA was on average 2 times higher for L products in both periods than for other sources. Indeed even if Figure 7 shows no correlations between NFD_{HH} and the number of L products as number of species are too little, it has to be noticed that on Figure 8, the outlier which has 31 species from the market and a NFD_{tot} around 90% is also the one which has the highest number of L products available. This is especially interesting as L products contribution to the NFD in period of FS is higher than in FA and because they contribute to 37% of vitamin A intake in FS period. In addition, as an example the Food and Agriculture Organization (Food and Agriculture Organization, 2002) gives few examples of food items which could provide more or less the DRI for vitamin A. The comparisons between the food items proposed by the FAO to reach almost the adults DRI, and the availability and affordability in Yilou (Annex XII) shows that only the dark green leaves can play a major role in vitamin A intake between both months. This emphasizes results from previous studies which highlighted that forest foods and wild edible plants (WEP) can provide significant amount of key nutrients all year round (Romanelli, et al., 2006; Vinceti et al., 2013). Moreover, new processing techniques could be implemented to conserve food longer and to increase the nutritional availability in time. For instance, in Ouagadougou a market for dry mango starts to expand (personal observation), this enables the population to eat 'mangoes' and receive vitamin A for a longer period across the year. These kind of initiatives could be proposed in Yilou, and also with other fruits as they are good sources of energy and micronutrients. Moreover, regarding nutrient contribution of products from trees (included in the L products category), most of their fruits contain interesting amounts of vitamin C, but also vitamin A (i.e. *Ximenia Americana)* and folate (i.e. *Vitex doniana*). As a consequence, it would be interesting to integrate more fruit trees in novel farming system designs such as: *Sclerocarrya birrea, Ximenia Americana, Vitex doniana* and *Diospyros mespiliformis*. This is even more relevant as surveys underline that the 12 HH all have access to *Sclerocarrya birrea* trees, otherwise 9 HH have access to *Diospyros mespiliformis,* 7 to *Ximenia Americana* and 3 to *Vitex doniana*. Moreover, baobab leaves showed to be a very widespread food items among the HH, actually consumed year-long, so it might be interesting for the HH to plant more baobab trees nearby their HH, or cultivate them in an intensive way (i.e. low and pruned). Finally, the seeds of *Acacia macrostacchya* showed also to be interesting for its iron content in terms of human nutrition, which could also contribute in the farming systems to increase soil fertility through the fixation of nitrogen. However according to interviewees, it is difficult to collect and cook these seeds because of the thorn on the branches and the long time for preparation. So even if planted nearby the HH, *Acacia macrostacchya* seeds might not be used on a more regular basis, but only on special occasions (i.e. weddings)..

Trade-offs appear between food availability, nutritional interest, labour demand and sustainable food production. Indeed a study in Congo showed that even if environment biodiversity can alleviate the risk of micronutrient deficiencies, and results to a better nutritional health status, a biodiverse environment does not always lead to a better diet (Romanelli et al., 2014; Sunderland, 2011; Vinceti et al., 2013). It is recognized that WEP can supplement staple crops with micronutrients, but they might not be eaten enough to show a real contribution to the diet (Termote et al., 2012). Moreover, this 'modern-to-traditional' FVC which carries mainly new imported products impacted the consumption of traditional products, which leads to a decrease of micronutrient-dense food consumption. In addition, the study showed that living in a highly biodiverse rich environment does not mean that the population uses WEP, and it has been explained by a gap of knowledge regarding WEP use and benefits (Termote et al., 2012; Vinceti et al., 2013). Nonetheless, during surveys two women asserted that they prepared some sauces with certain specific green leafy vegetables at least once a week, even if nobody liked them, because the wise old man of the village taught them that it was good for vitamins intake (no precisions regarding which type of vitamin). This underlines people interest for nutrition and better health through their diet. In Yilou, WEP had an interesting contribution to the NFD regarding their NFD_{tot}/TFA ratio. However their contribution to energy, iron and zinc intake was low and no correlations were found between the NFD_{HH} and the number of species from the landscape. This can be due to the low quantities of products consumed compared with the quantity of M and F products.

Regarding G products, two types of gifts were identified. Concerning 4 food items, they were offered on a regular basis, used very often and contribute to the everyday cuisine (i.e. okra). There were also gifts (such as sardine cans), which are rarely consumed and offered for special event (only for 2 HH out of 12, and only once over the year). Three G products can potentially come from the field, and 5 from the market (see Table 2).

The results do not imply that the 4HH reach their nutrient requirements because the surveys were not detailed enough to assess each person's nutrient intakes and requirements (women, men and child). Figure 10 only represents the percentage of contribution of each source to the nutrient intake. Moreover, regarding iron intake in both periods, the main sources are fruits, cereals, legumes, seeds and vegetables. However, two types of iron coexist: the hematinic and non-hematinic. The first one is present in the blood and the flesh of mammals, poultries and fishes and is well absorbed by organisms (15-35%). The second is mostly found in fruits, vegetables, eggs and milk, but its availability is often less than 5%. As a result, even if the food items reported above have a high contribution in iron intake, they are not well absorbed iron sources for the organisms. Nonetheless factors such as vitamin C (present in fruits) or meat protein (meanwhile eating vegetables) can increase iron bio-availability (Food and Agriculture Organization, 2002). Regarding zinc intake, the main sources in the 4HH diet are from cereals, legumes, and vegetables. However, it is recognized that meat is the main source of bio-available zinc, and the report from the FAO highlights that diet such as in Africa, mainly based on whole flour and cereals, are most of the time zinc-poor diet. The important presence of phytates in these food items prevents zinc absorption by the organism, which increases the risk of zinc deficiency among this population (Food and Agriculture Organization, 2002).

Our study emphasized on the availability and accessibility of the food items in the village of Yilou between June 2015 and May 2015, which includes 2 of the 4 pillars of food security. It also addressed certain dimensions of food sovereignty, in particular the concept of food self-sufficiency. Indeed the FSR and FSSR indicators signify that energy requirements matter to maintain a healthy organism. As seen previously, in both periods the indicators are below one, which means that the 4 HH do not reach their energy requirements during these months from their harvest. It is also observed that 41% to 50% of the energy intake was reach by the sum of products grown on-farm and collected in the landscape. However, the questions remains concerning the 'right [of people] to define their own food and agriculture systems' regarding these results (Jarosz, 2014).

This is emphasized by a report about food security in Burkina Faso, which asserts that the Centre-North region have a high percentage of about 30% of the population facing problems of food insecurity. It is also highlighted that this region shows problems of acute malnutrition (in 2013, 7.6% of acute malnutrition among children) (Programme Alimentaire Mondial, 2014).

Moreover, Figure 10 showed that F products were the main source of energy for all HH, therefore a plausible objective would be to increase yields to meet energy requirements. An option to improve field productivity is to use traditional practices such as woody amendments from native shrubs, to increase organic matter content of the soil (Félix, 2015; Lahmar et al., 2012; Tittonell et al., 2012). This technique is based on farmer's innovations using local vegetation to restore degraded soil, and aims to improve water retention, stimulating biological activity and build-up of soil organic matter. However, one of the main constraints is the scarcity of organic matter resources and trade-offs regarding the use of crop residues (Tittonell et al., 2012). Indeed crop residues are multi-purposes, very valued by farmers, and primarily used as feed for livestock, especially in the dry season (Giller et al., 2002; Lahmar et al., 2012; Tittonell et al., 2012).

Comparison of the FSR and FSSR indicators with another study in East Africa showed that food insecurity was common in areas with annual rainfall under 800mm. In Yilou, the average rainfall last year was 806 mm/year, and according to the article, for this average rainfall the FSR and FSSR would be respectively above 1 and approximately around 0.8 (Rufino et al., 2013). In this study the FSR are between 0.67 and 0.73, while the FSSR are between 0.41 and 0.50, so our results are lower than predictions stated in that other study. This might be explained by the fact that neither alcohol consumption, nor food consumed outside the household (such as street food) were reported in our study. Alcohol does not provide the nutrients present in our trait-matrix to build the dendrogram (but has a significant implication in energy intake), and because present study depicted the food commonly consumed by the HH members in their courtyard. This implies that if external meals are taken into account, M products would most probably have an even higher contribution to household NFD, energy, and nutrients intake.

However, this study has been conducted regarding the year 2015/2016, and remain specifics as according to the farmers, the yield were not very high and external events such as early rain and floods shortened the period of availability of certain products.

Moreover, a limit of the NFD score is that it does not take into account the individual's nutrient requirements, absorption, nor utilization of food items. NFD concept only relies on the theory that dietary diversity is related to nutrient adequacy (Allen et al., 2014; Foote et al., 2004), but NFD represents rather the nutrient availability in a given location (Luckett et al., 2015). In addition, the calendar did not take into account differences in diets within the HH (difference between child, woman, man, etc.) and the food eaten outside or when invited elsewhere. Moreover, this score does not take into account the fact that some food items could be consumed in 'negligible' amounts (i.e. spices, salt...), as the matrix use nutrient contents is computed per 100 g. Future research needs to identify the minimum amount needed to integrate the food item in the matrix (Luckett et al., 2015; Remans et al., 2011). As a result, no interpretation regarding health status of the persons in the HH studied can be done. Moreover, NFD is a relative result that can be compared in different situations, with the highest score as better result. However, no threshold was settled in present study to determine when a diet can be considered 'nutritionally diverse'. This is problematic in the case where policy-makers would want to promote specific recommendations on resource use and management at a larger scale (Luckett et al., 2015).

A limitation of the study is the small number of surveys conducted (n=12). From this, it makes it difficult to find correlations between NFD_{HH} and HH characteristics and also to make recommendations at the village scale only based on our results. Moreover, as it is the food availability at the landscape level which has been assessed, it happened that some food items were only consumed by one HH that had access to larger markets, but was not easily accessible for all HH. However, this foodstuff was also included in the calculations, resulting in small differences between indicators assessed for FA and FS. In addition, most of the persons in the household were speaking

‘Mooré’ (local language), so the help of a translator was needed. Adding this intermediary between the researcher and the interviewee could induce biases in the answers of the interviewees. Moreover the survey was relying on interviewees’ memory of the previous year, and symbolic events during the last year were used instead of using months (i.e. Ramadan instead of the month of September). From this, few imprecisions could happen between months;

Finally, a lack of data can be reported at this moment for the various food composition tables used as references for this study. Particularly finding reliable data on WEPs, combined with problems of nutrient inadequacy in between the tables for the same plants were challenges to properly process our data. Some of the reasons for lacking data in reference tables of nutritional content may include different geographical areas, year of sampling, different methods, etc. When no data could be found, nutrient content was estimated by identifying a plant within the same family from which we could consider had similar nutritional traits, a so-to-say ‘educated guess’. This issue was recurrent especially concerning WEP as their nutritional content has not been well documented so far (Remans et al., 2011). This restrains accuracy of the results and restricts the identification of nutrient-dense WEP. Therefore, no specific recommendations can be provided regarding their consumption even though it has already been highlighted that WEP have a beneficial and non-negligible impact on nutritional status, due to their macro and micro nutrients content (Romanelli et al., 2014; Vinceti et al., 2013). Researches regarding nutritional content of WEPs would emphasize the contribution of landscape elements to diversified and healthy diets. Providing better inventories and more data on composition of different food species and intra-species diversity would ease the identification of nutrient-dense WEP. Additionally results from in-depth ethnobotanical surveys combined with farming systems design approaches would help policy-makers identify and support initiatives to help close the population nutrient gaps while promoting local, accessible, and traditional food, through the mobilisation of local knowledge around natural resources use and management.

6. Conclusion

- ***Research question 1: What were the products available in Yilou over one year between June 2015 and May 2016, and do they have different origins throughout the year?***

Between June 2015 and May 2016, 82 different products were available in Yilou, and periods of availability between months differed for some of them and food sources had to be combined. Indeed relying on the market access and adding products from this source is the most widespread solution to cope with shortened periods of availability of certain products.

- ***Research question 2: Are there significant differences of nutrient diversity consumption in Yilou, between periods of food shortage and abundance of year 2015/2016?***

Between periods of food shortage and food abundance in 2015, the nutritional diversity was not very different, mainly because products in both periods were almost the same, so their availability were not very different neither. Moreover, the hypothesis has been refuted as the NFD of the period of food shortage showed to contribute more to the NFD total in some cases. However, differences were mainly due to the consumption of one product available during the period of food shortage, which was considered as nutrient-dense (i.e. fruit and seed can be consumed, both parts having different nutrient composition). Indeed periods of food shortage and abundance are mainly related with quantities of products consumed (higher in period of food abundance) rather than regarding nutrient-density.

- ***Research question 3: Is one of the food sources (farm, landscape, market or gift) contributing significantly more to the NFD in Yilou, in the year 2015/2016?***

Products from the market had the most important contribution to the NFD total in Yilou between June 2015 and May 2016, as it had the highest diversity of products available (in terms of food groups: meat, vegetables, dairy products etc.) and were the most numerous in number of items. Nonetheless, products from the landscape are fewer than products from the market or farm, but are more nutrient-dense so their NFD is equal to products from the farm in period of food shortage.

- ***Research question 4: What is the contribution of the landscape to micronutrient availability in period of food shortage for the population of Yilou, during the year 2015?***

In period of food shortage, products from the landscape showed a highest contribution to the NFD total in Yilou than during period of food abundance, and lower the contribution of M products. They showed to be more nutrient-dense regarding the ratio between NFD and number of food items. The survey regarding quantities of products consumed and their influence on energy and certain nutrient intakes, showed that products from the landscape have a particularly interesting contribution to vitamin A intake.

- ***Research question 5: Which farm and household characteristics are correlated with NFD of households in Yilou?***

There was a slight correlation found between the NFD_{HH} and the number of products purchased on the market, and therefore the total diversity of products consumed. However no correlations have been found with other household characteristics assessed concerning the number of products grown on-farm or collected from the landscape.

7. Recommendations

Various limitations have been previously reported, and one of them underlines the need for more complete food table composition regarding wild edible plants. A solution would be to sample the products and to work simultaneously with laboratories able to assess the nutrient content in the products. This would enable researchers to identify nutrient-dense species, and would help nutritionists; ecologists and policy-makers promote strategies which integrate agricultural interventions towards better nutrient adequacy.

Indeed, if further studies want to adopt a more nutrition and health-oriented point of view (instead of specifically ecological), the concept of nutrient utilization by the organism should also be integrated. Indeed, it has previously been demonstrated that some products could contain significant amount of certain nutrients (i.e. iron), but this does not mean that it will be absorbed by the organism. Integrating the bioavailability of the nutrients (proportion of a nutrient absorbed from the diet and used for normal body functions) and also by looking at possible synergies between products at the meal level (i.e. Vitamin C-rich products would increase iron availability) would provide more accurate recommendations to improve a person nutritional status.

Regarding the identification of certain household characteristics and the correlation with their NFD, it would be interesting to increase the number of households in the sample to find (or not) stronger correlations. In addition, the strongest correlations found was regarding the number of products purchased on the market. This implies that the NFD of the households could be more related with socio, and especially economical characteristics. As a consequence, further research should perhaps integrate more economic indicators for assessing the correlations with the NFD of the households. Moreover, this study only compared the NFD in periods of food shortage and abundance at the landscape level, but doing this comparison for each individual household, and relating it to economic indicators could add some precisions on factors influencing HH consumption.

Recommendations regarding the results of the study are mainly related with the dependency of the households to the market. Indeed the market showed to have the highest contribution to the NFD as most of the products grow/raise on farm or collected in the landscape are also available on market. This implies that the wealthiest people can access more nutrient-diverse diets. Indeed, sustainably improving yield of farm products, integrating more wild edible plants, and trees and shrubs into farming systems would ease the access for leafy green vegetables to every household. Improving water management through soil conservation techniques (i.e. stone-bunds, contour planting of woody elements, *zaï*) would build a more stable, productive, and resilient system, thereby enhancing livelihoods of households while decreasing their reliance to the market. Trade-offs need to be assessed as well as perceptions of the farmer or shifts and drivers of farming systems trajectory (i.e. external drivers such as artisanal gold-mining).

Finally, it has been observed that women showed interest regarding nutritional knowledge and the link with a better health. It would be interesting if organisations and governments could reach these households to deliver workshops about nutrition, practices to improve their nutritional status and the direct link with their health.

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Annex I: Geographical location of Burkina Faso

Figure 11: Map of Burkina Faso (Source: http://www.indoafrican.org/burkinafaso.htm)

Annex II: Annual rainfall between June 2015 and May 2016 in Yilou

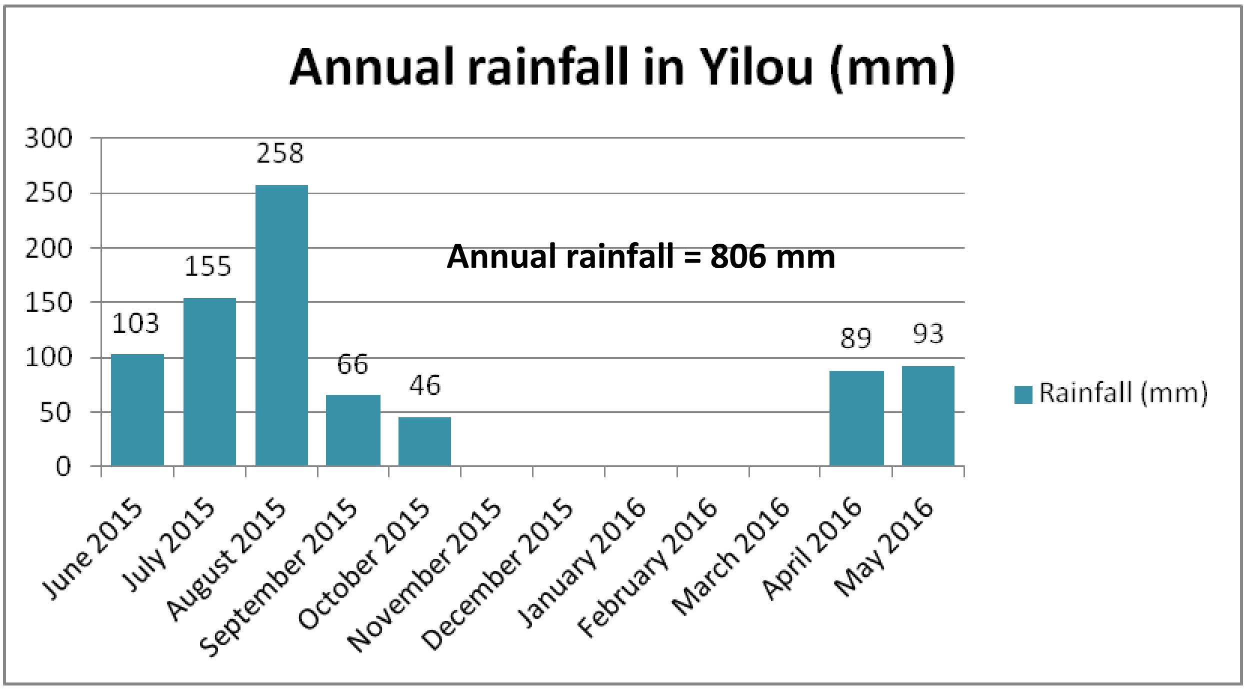


Figure 12: Annual rainfall in Yilou between June 2015 and May 2016

Annex III: Survey household characteristics (translated from French)

Household head : Survey date :

Person inquired :

Link with household head :

Number of persons fed:

		Child			
Men	Women	0-2 y.o.	3-8 y.o.	9-13 y.o.	14-18 y.o.

Number of persons cooking:

	June 2015	July 2015	Aug. 2015	Sept. 2015	Oct. 2015	Nov. 2015	Dec. 2015	Jan. 2016	Feb. 2016	March 2016	April 2016	May 2016
Time spent for cooking/day (min)												
Number of meal/day												
Market frequency/week												

Reason to buy on the market ?
Do you consider your house far from the market ?
Do you sell products on the market ? If yes, which products ?

Annex IV: Survey household calendar (translated from French)

Household head:

Survey date:
Head of inquiry:

Food items	Origin (M/L/F/G)	June 2015	July 2015	Aug. 2015	Sept. 2015	Oct. 2015	Nov. 2015	Dec. 2015	Jan. 2016	Feb. 2016	March 2016	April 2016	May 2016
Yellow maize													
White maize													
Pearl millet													
Bread													
Rice													
Sorghum													
Macaroni													
Yam tuber													
Cassava tuber													
Potato													
Cowpea													
Zamné													
Bambara groundnut													
Eggplant													
Avocado													
Bolombouri													
Boulvaaka													
Carrot													
Cabbage													
Cucumber													
Courgette													
Spinach													

Food items	Origin (M/L/F/G)	June 2015	July 2015	Aug. 2015	Sept. 2015	Oct. 2015	Nov. 2015	Dec. 2015	Jan. 2016	Feb. 2016	March 2016	April 2016	May 2016
Baobab leaves													
Cowpea leaves													
Eggplant leaves													
Okra fruit													
Green beans													
Kalremtouera													
Kapok													
Koulombengro													
Kumba													
Lelomguo													
Onion													
Roselle leaves													
Chilli pepper													
Sweet green pepper													
Lettuce													
Sorda													
Tomato													
Aada													
Barkoudouga													
African locust bean flour													
Banana													
Shea fruit													
Guava													
Gunga													
Jujube													

Food items	Origin (M/L/F/G)	June 2015	July 2015	Aug. 2015	Sept. 2015	Oct. 2015	Nov. 2015	Dec. 2015	Jan. 2016	Feb. 2016	March 2016	April 2016	May 2016
Lela													
Gumvine													
Mango													
'Noisette'													
Orange													
Baobab fruit													
'Raisin'													
Tamarind													
Coconut													
Groundnut													
Sesame													
Bikaalga													
Beef													
Goat													
Sheep													
Guinea fowl													
Pork													
Chicken													
Guinea fowl egg													
Carp													
Eel													
Shrimp													
Sardine													
Smoked, dried sardine													
Mackerel													
Catfish													

Food items	Origin (M/L/F/G)	June 2015	July 2015	Aug. 2015	Sept. 2015	Oct. 2015	Nov. 2015	Dec. 2015	Jan. 2016	Feb. 2016	March 2016	April 2016	May 2016
Cow milk													
Powder milk													
Yoghurt													
Oil													
Dry beef cube													
Black pepper													
Salt													
Soumbala													
Sugar													

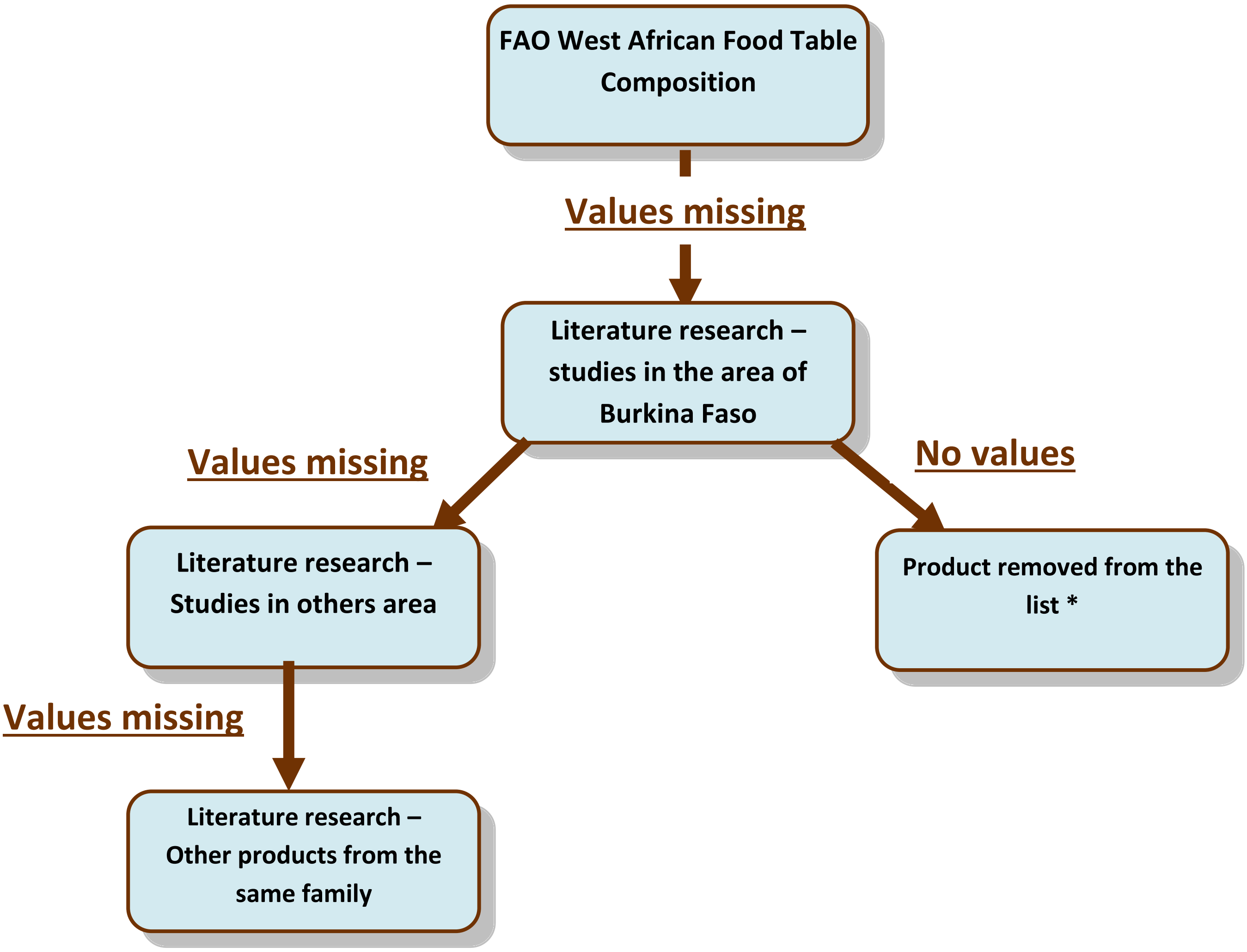
Annex V: Total food list

Food name in English	Food name in Mooré	Scientific name
01 Cereals and their products		
Yellow maize		*Zea mays*
White maize		*Zea mays*
Pearl millet		*Pennisetum glaucum*
White bread		*Triticum spp.*
Rice		*Oryza sativa*
Sorghum		*Sorghum bicolour*
Macaroni		*Triticum spp.*
02 Starchy roots, tubers and their products		
Yam tuber		*Dioscorea spp.*
Cassava tuber		*Manihot esculenta/Manihot utilissima*
Potato		*Solanum tuberosum*
03 Legumes and their products		
Cowpea	Benga	*Vigna unguiculata*
	Zamné (seeds)	*Acacia Macrostacchya*
Bambara groundnut		*Voandezia subterranea*
04 Vegetables and their products		
Eggplant		*Solanum melongena*
Avocado		*Persea americana/Persea gratissima*
Amaranth leaves	Bolombouri	*Amaranthus spp.*
Jute leaves	Boulvaaka	*Corchorus olitorius*
Carrot		*Daucus carota*
Cabbage		*Brassica oleracea var. capitata*
Cucumber		*Cucumis sativus*
Courgette		
Spinach		*Spinacia oleracea*
Baobab leaves	Toedo	*Adansonia digitata*
Cowpea leaves	Bengdo	*Vigna unguiculata*
Eggplant leaves		*Solanum melongena*
Okra fruit	Mana	*Abelmoschus esculentus/Hibiscus esculentus*
Green beans		*Phaseolus vulgaris*
	Kalremtouera	*Cratevia religiosa*
Kapok		*Bombax costatum*
Water spinach	Koulombengro	*Ipomoea aquatica*
African eggplant	Kumba	*Solanum aethiopicum*
	Lelomguo	*Leptadenia hastata*
Onion		*Allium cepa*
Roselle leaves	Bito	*Hibiscus sabdariffa*
Chilli pepper		*Capsicum spp.*
Sweet green pepper		*Capsicum annuum*
Lettuce		*Lactura sativa*

	Sorda	*Cassia obtusifolia*
Tomato		*Lycopersicon esculentum*
05 Fruits and their products		
	Aada	*Vitex doniana*
Sweet apple	Barkoudouga	*Annona senegalensis*
African locust bean flour		*Parkia spp.*
Banana		*Musa spp.*
Shea fruit		*Vitellaria paradoxa*
Guava		*Psidium guayava*
	Gunga	*Diospyros mespiliformis*
Jujube		*Ziziphus spp.*
	Lela	*Ximenia americana*
Gumvine		*Saba senegalensis*
Mango		*Mangifera indica*
	'Noisette'	*Sclerocarya birrea*
Orange		*Citrus sinensis*
Baobab fruit		*Adansonia digitata*
	'Raisin'	*Lannea microcarpa*
Tamarind		*Tamarindus indica*
06 Nuts, seeds and their products		
Coconut		*Cocos nucifera*
Groundnut		*Arachis hypogea*
Sesame		*Sesame spp.*
Fermented roselle red seed	Bikaalga	*Hibiscus sabdariffa*
07 Meat and poultry and their products		
Beef		*Bos taurus*
Goat		*Capra aegagrus hircus*
Sheep		*Ovis aries*
Guinea fowl		
Pork		*Sus domestica*
Chicken		*Gallus gallus*
08 Eggs and their products		
Guinea fowl egg		
09 Fish and their products		
Carp		*Cyprinus carpio*
Eel		
Shrimp		
Sardine		*Sardinella spp.*
Smoked, dried sardine		*Sardinella spp.*
Mackerel		
Catfish		*Synodontis spp.*

10 Milk and their products		
Cow milk		
Powder milk		
Yoghurt		
11 Miscellaneous		
Oil		
Dry beef cube		
Black pepper		*Piper nigrum*
Salt		
Fermented african locust beans	Soumbala	
Sugar		

Annex VI: Procedure of data decisions



*This happened for one product, the leaves of *Balanites aegyptica*.

Annex VII: Species dendrogram construction

- The software RStudio was used to construct a species by trait matrix, as seen in Figure 13. The Food and Agriculture Organization (FAO) developed a West African food composition table (Stadlmayr et al., 2012) which report the nutrient content (per 100g) of diverse foodstuffs currently consumed in this area. When a foodstuff was consumed by at least one household, its nutrient content was divided by the dietary reference intake (DRI) of this specific nutrient in order to standardized and weighing the values (Remans et al., 2011). The 7 nutrients chosen were: carbohydrates, protein, iron, zinc, vitamin A, vitamin C, and folate.

Species	Trait I	Trait II	Trait III
1	10	5	0
2	5	5	0
3	1	0	10

Figure 13: Species by trait matrix (Source: Remans et al., 2011).

Farm	1	2	3
A		1	1
B	1	1	1
C	1	1	

Figure 14: Site by species matrix (Source: Remans et al., 2011).

- RStudio, a site by species matrix was constructed in order to report the absence (=" ") or presence (= 1) of each foodstuff in the household diet.

Species	1	2	3
1	-		
2	0.3	-	
3	0.7	0.7	-

Figure 15: Distance D matrix (Source: Remans et al., 2011).

- From the species x trait matrix (Figure 13), the distance D_{ij} between two species i and j was calculated by RStudio regarding their nutritional traits. The Euclidean formula was used to calculate the distance where there are 7 nutrients assessed and a species distance matrix was constructed (Luckett et al., 2015).

$$\mathrm{D}ij = \sqrt{(i1 - j1)^2 + (i2 \ - j2)^2 + \ldots + (i22 - j22)^2}$$

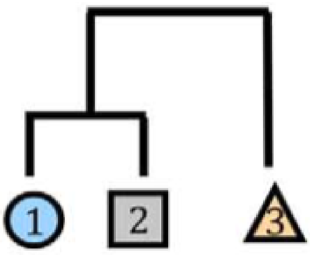


Figure 16: Species dendogram (Source: Remans et al., 2011).

- : RStudio clustered every species into a dendrogram, regarding their nutrient similarities. The total branch length represent the distance between species, as the distance previously calculated will be used as meaningful weights to draw the branches of the dendrogram (Luckett et al., 2015; Podani & Schmera, 2006). This will give an overview of the variety in nutrients content between the different species.

Annex VIII: Example of NFD calculation

Luckett et al. (2015) give an example where they compare the NFD among all HH with the NFD total of one HH (X), the NFD from the market and from the home production of the same HH. Figure 17 shows that the total branch lengths among all HH is equal to 14, and that the one of HH X is 13. From this, the HH NFD = 13/14 x 100 = 93.

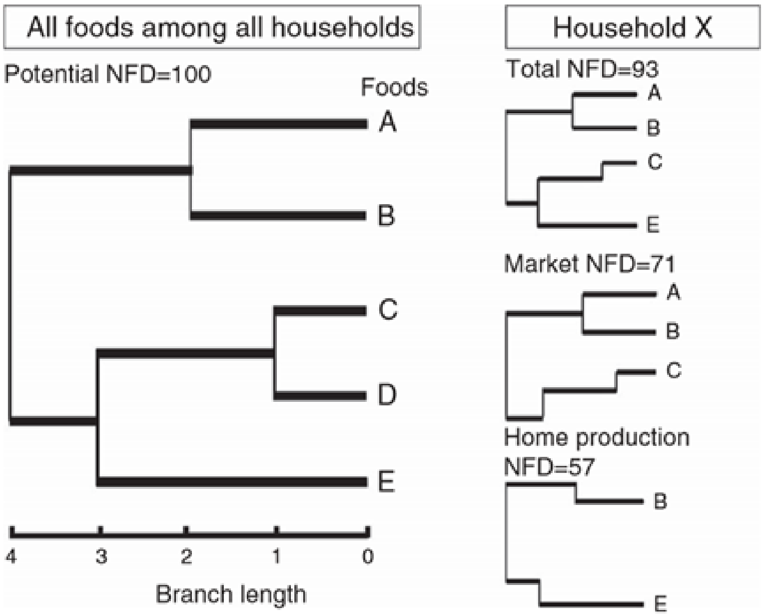


Figure 17: Example of NFD calculation (Source: Luckett et al., 2015).

Annex IX: Survey frequency and weight (translated from French)

Household head :

Survey date:

Head of inquiry:

	Month FS			Month FA		
Food items	Frequency*	Weight (household unit)	Metric weight in g (cup, dish, …)	Frequency*	Weight (household unit)	Metric weight in g (cup, dish, …)

* Fill with frequencies

"1-2 m." = 1-2 times per month; "<1 w." = less than 1 time per week; "1-3 w." = 1-3 times per week;
"4-6 w." = 4-6 times per week; "1-2 d." = 1-2 times per day

Annex X: Food items and abbreviations in species dendrogram.

Food name	Abbr.	Food name	Abbr.	Food name	Abbr.
Bread	Whea[P]	Gumvine	Gumv	Lelomguo	Lelo
Macaroni,	Whea[B]	Jujube	Juju	Gunga	Gung
Yellow maize,	Maiz[B]	Mango	Mang	Kalremtouera	Kalr
White maize	Maiz	Orange	Oran	Lela	Lela
Pearl millet	Mill[B]	Shea fruit	Shea	Sorda	Sord
Rice	Rice[B]	Sweet apple	Swee	Koulembengro	Koul
Sorghum	Sorgp[B]	Tamarind	Tama[F]	Zamné	Zamn
Cassava tuber	Cass[B]	Coconut	Coco		
Potato	Pota[B]	Groundnut	Grou		
Yam tuber	Yam[B]	Dried red roselle seed	Rose[S]		
Bambara groundnut	Bamb[B]	Sesame seeds	Sesa		
Cowpea	Cowp[B]	Beef	Beef		
African eggplant	Aegg	Chicken meat	Chic[G]		
Amaranth leaves	Amar[B]	Goat	Goat[B]		
Baobab, leaves	Boab[B]	Guinea fowl	Guin		
Courgette	Cour[B]	Lamb/mutton	Lamb[B]		
Green beans	Bean[B]	Pork	Pork[B]		
Cabbage	Cabb[B]	Egg	Cheg[B]		
Carrot	Carr	Catfish	Catf[G]		
Leaves cowpea	Cowp	Carp	Carp[G]		
Cucumber	Cucu	Eel	Eel		
Eggplant	Eggp[F]	Mackerel	Mack[G]		
Leaves eggplant	Egg[L]	Sardine	Sard[G]		
Leaves jute	Jute[B]	Sardinella	Sarl[G]		
Lettuce	Lett	Shrimp	Shri[G]		
Okra fruit	Okra[B]	Cow milk	Milk[S]		
Onion	Onio	Powder milk	Milk[P]		
Chilli peppers	Pepp[R]	Yoghurt	Yogh		
Sweet green pepper	Pepp[B]	Vegetable oil	Voil		
Roselle leaves	Rose[B]	Dry beef cube	Cube		
Spinach	Spin[B]	Black pepper	Bpep		
Raw tomato	Toma[R]	Salt	Salt		
Boiled tomato	Toma[B]	Sugar	Suga		
Avocado	Avoc	Soumbala	Soum		
Banana	Bana	Kapok	Kapo		
Baobab fruit	Brea	Black plum	Blac		

Annex XI: Food list for period of FS and FA

		FS	FA
Cereal - Tuber	Bread	X	X
	Cassava	X	
	Pearl millet	X	X
	Potato	X	X
	Sorghum	X	X
	Spaghetti	X	X
	White Maize	X	X
	White rice	X	X
	Yam	X	X
	Yellow maize	X	X
Legume	*Acacia Macrostacchya*	X	X
	Bambara groundnut	X	X
	Cowpea	X	X
	Peanut	X	X
	Sesame	X	X
Vegetable	African eggplant	X	X
	Amaranthus spp.	X	X
	Baobab leaves	X	X
	Bikalga	X	X
	Cassia obtusifolia	X	X
	Corchorus olitorius	X	X
	Cabbage	X	X
	Carrot	X	
	Chilli pepper	X	X
	Courgette	X	X
	Cowpea leaves	X	X
	Cucumber	X	X
	Eggplant	X	X
	Eggplant leaves	X	X
	Ipomoea aquatica	X	X
	Kapok	X	X
	Leptadenia hastata		X
	Okra	X	X
	Onion	X	X
	Roselle leaves	X	X
	Salad		X
	Tomato	X	X

Fruit	African locust bean flour	X	X
	Annona senegalensis		X
	Avocado	X	X
	Banana	X	X
	Baobab fruit		X
	Coconut	X	X
	Diospyros mespiliformis		X
	Guava		X
	Gumvine	X	X
	Jujube		X
	Lannea microcarpa	X	
	Sclerocarya birrea	X	
	Shea fruit	X	
	Tamarind	X	X
	Vitex doniana	X	
	Ximenia americana	X	X
Meat	Beef	X	X
	Chicken	X	X
	Goat	X	X
	Guinea fowl	X	X
	Mutton	X	X
	Pork	X	X
Fish	Carp	X	X
	Catfish	X	X
	Eel	X	X
	Mackerel	X	X
	Sardine	X	X
	Sardinella	X	X
	Shrimp	X	X
Egg	Guinea fowl egg	X	X
Dairy product	Cow milk	X	X
	Milk powder	X	X
	Yoghurt	X	X
Miscalleneous	Dry beef cube	X	X
	Pepper	X	X
	Salt	X	X
	Soumbala	X	X
	Sugar	X	X
	Vegetal oil	X	X

*Annex XII: Quantity of food which provides 500µg Vit A-RAE **

	In Yilou	
	FA	FS
10ml Fresh red palm oil	Not available	Not available
1 small carrot	Not available	Not available
1 small mango	Not available	Not available
1 Egg-size piece of liver	Rarely consumed	Rarely consumed
1,5 cups of chopped dark green leaves	Frequently consumed	Frequently consumed
1 small pawpaw	Not available	Not available
Medium-sized piece of yellow sweet potato	Not available	Not available
1L milk	Low consumption	Low consumption

*RAE means Retinol Activity Equivalents. Vitamin A is found in the nature as a preformed (retinol), in many animal products, or as provitamin A carotenoids, mostly in vegetal foods. As vitamin A is a fat soluble vitamin, several steps are needed before being absorbed and metabolized by the organism, and the conversion rate are different between the two form, as on average 1 IU beta-carotene from food = 0.05 µg RAE. The food item have all been converted in vitamin A-RAE unit as to compare them in between and as it is the most commonly used unit.