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Traditional food consumption and its nutritional contribution in Guasaganda, Central Ecuador.

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FACULTY OF BIOSCIENCE ENGINEERING

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Illustration cover page: "Some traditional foods (*Solanum quitoense* Lam., *Musa* x *paradisiaca* L. and *Citrus limon* (L.) Osbeck) from the *Sacha Wiwua* forest of Guasaganda, and the Andes" (own source)

Illustration last page: "Logo of the biodiversity collaboration project between *Escuela Superior Politécnica del Litoral* and Ghent University" (own source)

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Among the scenes which are deeply impressed on my mind, none exceed in sublimity the primaeval [tropical] forests ... temples filled with the varied productions of the God of Nature. No one can stand in these solitudes unmoved, and not feel that there is more in man than the mere breath of his body.

— Charles Darwin

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Executive summary

Worldwide, nutritionists continue to be confronted with malnutrition so that it is the top public health problem of the 21st century. The Global Nutrition Report of 2016 indicates that one in three people is malnourished either by not eating enough or because of overeating. Health consequences are gigantic and cause the death of millions of people. In Ecuador, the most recent anthropometric data shows that in 2012, 25 % of under-5 year children were stunted (Height/Age < -2 SD) and 8.6 % were overweight (Body Mass Index/Age > 2 SD), whereas 73.9 % of adults had a Body Mass Index higher than 25 which indicates that they were overweight. Malnutrition coexists within the same households, with 13 % of overweight mothers having stunted children. National report of cause of deaths in 2012 shows that dietary-related diseases, such as hypertension and diabetes, were the top second cause of death, killing 4,853 and 3,763 people, respectively. In addition, anaemia (present as a deficit of iron, vitamin B12 and folates) was the cause of approximately 100 deaths in Ecuador during the same year. These figures show that malnutrition in is in Ecuador a big public health issue, just as in other developing countries.

Paradoxically, most Ecuadorians suffering from malnutrition are indigenous people who are also actively involved in the cultivation of indigenous foods. Among them, the prevalence of malnutrition is higher than in other ethnicities (prevalence is presented in *Chapter 1*). In 2012, 42 % of indigenous children were stunted (Height/Age < -2 SD), 17.2 % have vitamin A deficiency (serum retinol < 20 µg/dL), 49.7 % of adults suffered from zinc deficiency (zinc in serum < 65 µg/dL), whereas 15.5 % of indigenous adult women suffered from anaemia (haemoglobin in blood < 12 g/dL). Although indigenous farmers produce foods, availability is not enough as they also face poverty. Indigenous people in Ecuador are the poorest segment of the population. In 2016, 37.4 % of indigenous people living in rural areas lived with less than 84 dollars per month. Sadly, food availability is hampered by environmental changes so that in periods of food shortages indigenous people are vulnerable to food insecurity. The Ecuadorian constitution of 2008 defends the right of indigenous peoples to produce foods by indigenous practices, including hunting and gathering, to feed themselves and the rest of the population, but in reality, little is done to increase the production of indigenous foods.

This thesis is based on the hypothesis that if locally cultivated and wild foods are present and available for consumption, indigenous people are likely to cover a substantial share of the nutrient requirements to prevent malnutrition. Also, we attempt to provide the scientific evidence that highlights the benefits of eating traditional foods (TFs), both cultivated and wild, to get the attention not only from the scientific world but also from policymakers, NGOs, community workers, teachers, voluntary workers and indigenous community leaders. There exist many dimensions, concepts and definitions related to the study of biodiverse diets which needed to be introduced in *Chapter 1*. To prove this hypothesis our research required to specifically study the three core components involved in the functioning of TF production system which are: i) food biodiversity; ii) indigenous people eating behaviour; and iii) nutrient adequacy of the traditional diet. These three components were studied using qualitative and quantitative methodologies and used as core concept the sustainable use of natural resources for food.

We started our research by conducting a systematic literature review of the scientific evidence (40 studies) of the contribution of edible plant and animal biodiversity to human diets (*Chapter 2*). Our results indicated that traditional plants and animals consumed by indigenous people, mainly from farming and wild sources, were contributors (despite the amount) of energy, macro and micronutrients, and dietary diversification. However, the results are limited to the studied areas, and the evidence to attribute a proper nutrition based on the consumption of biodiverse diets is weak. Therefore, we proposed this PhD research on food biodiversity on a specific forest community that is vulnerable to malnutrition. By reviewing the searched papers, we selected the most adequate methodologies to be used in this research. The preparation of the research protocol required the collaboration between researchers at ESPOL and Ghent University. To our knowledge, our review is a valuable input for biodiversity and nutrition studies as it has been, until December 2016, cited 29 times according to Google Scholar.

Our review also revealed the need for a multidisciplinary team to study food biodiversity. In response to the need, a biodiversity research group was created with the collaboration of Ghent University and Escuela Superior Politecnica del Litoral involving nutritionists, ethnobotanists, agronomists, and economists. Consequently, based on botanical, epidemiological and living conditions data, we decided to conduct this study in surrounding farms and villages of Guasaganda, Central Ecuador. The latter was selected as our study area because it is a tropical region with altitudes that fluctuate between 500 and a 1,000 m.a.s.l. which climate allows a high variety of plants and animals to exist. A second reason for choosing the area is the vulnerability of the population of malnutrition, as most of the population are indigenous and poor. Because the inhabitants of Guasaganda are mainly indigenous Quechua an added value of this research is that the author of this thesis shares the same ethnicity and this latter facilitated the data collection and results.

We then initiated our investigations presented in each chapter. In *Chapter 3,* we report all plants and animals that are available for consumption in Guasaganda. We found that TF is composed of 90 plant and 22 animal species, with an additional 14 medicinal plants. From the 90 edible plant species, 41 are cultivated and 49 are wild, being 28 wild plants (out of the 49) present also in some farms (semi-cultivated) inferring domestication. Out of the 22 local animal species, 9 are domesticated, and 13 are wild. We found that at the farms the number of semi-cultivated plant species is significantly higher than the number of cultivated plant foods, with a total mean of 3 ± 1.45 plant species. Traditional farming seems to be solidly based on semi-cultivated plant foods than on crop production. The limited number of plant species at the farms could be that farmers are highly dedicated to milk production.

Furthermore, our curiosity guided us to investigate the factors related to the individual and to the environment that influence indigenous people to eat a combination of cultivated and wild foods, and if this practice is stable or it is changing (*Chapter 4*). Because we suspect that eating behaviour differs with age, we conducted interviews with four different age groups, including men and women. To investigate the behaviour of people we structured our questions based on the constructs of the Health Belief Model which help us to understand the behaviour. We found that in general indigenous people eat TFs because these are linked to health beliefs such as the prevention of dietary related noncommunicable diseases, i.e. diabetes, anaemia and hypertension. Our results show that indigenous peoples of all ages perceive that such diseases would appear if fewer TFs are consumed. Children are aware of being well nourished when eating TFs, whereas adolescents perceive that their bodies get stronger. Adults have interest on the financial benefits of cultivating TFs whereas elderly are culturally linked to indigenous foods. However, there exist personal and environmental barriers that differ for each age group and limit the consumption of TFs. Biodiversity loss, lack of credit that supports traditional food cultivation, and the lack of nutrition education are the top factors, followed by others, that hamper the consumption of a variety of TFs for health. To overcome these barriers the studied community requested to receive interventions that incentive and finance adults to cultivate TFs, and educate young children with healthy nutrition messages in school.

Further research involved an evaluation of the nutritional contribution of locally cultivated and wild foods, to the diet of indigenous women. In *Chapter 5,* we evaluated the nutrient adequacy of the indigenous diet by analysing 260 food-intake records that documented all foods eaten 24-hours before the interview. Because people do not eat the same each day, the interviews were repeated to the same respondents after 14 days to have the average of two-day intake and reduce thereby intra-personal variation. The amount of food consumed together with food composition data enabled us to quantify the intake of energy, water, protein, total fats, carbohydrates, fibre, calcium, iron, zinc, vitamin A and vitamin C. Micronutrients were investigated because these are deficient in indigenous communities according to the last Ecuadorian health survey (Freire *et al*. 2014).

Our results show that during the studied season, 140 different food items were available for consumption, and these were the source of dietary diversity. The 140 food items include 70 TF species (50 plants, 13 animals, and 7 medicinal plants). Median Food Variety Score (FVS) indicated that 23 different foods were consumed during the studied period. Traditional Food Diversity Score (TFDS) showed that about 9 locally cultivated and wild foods, merged, are eaten in a day period. We also observed the diversity by food groups, resulting in a median Minimum Dietary Diversity for Women (MDD-W) of 6, which is higher than the cut-off of 5, and indicates that the diet is adequate in most micronutrients. Medicinal plants contributed to dietary diversification but not in energy or nutrient intake as they are consumed in infusions.

Because FVS, TFDS and MDD-W are proxy indicators of the dietary adequacy, we proceeded to quantify nutrient intakes. To evaluate if the studied women consumed the adequate amount of nutrients, we divided the energy intake and 9 studied nutrients by the Estimated Average Requirements (EAR) to report Nutrient Adequacy Ratios (NAR). EAR was used since it covers the requirements of the 50 % of the population. The NAR for protein, total carbohydrates, fat, iron, zinc and vitamin C was higher than one, meaning that enough or more than the required amount of these nutrients was consumed. Consequently, we calculated the Mean Adequacy Ratio which is the sum of all NAR (truncated to one) divided by 10 (nutrients) and the result was 0.84, suggesting that the general diet is adequate for some of its nutrients.

Using the results from *Chapter 3*, we could sum the consumption of locally cultivated and wild foods (TFs). Our analysis showed that TF consumption contributed to 38.6 % of the total energy intake, and the rest of the energy was supplied by purchased non-traditional foods (not locally cultivated) and foods processed by the industry such as sausages and carbonated drinks. Because data was collected during a heavy rainy season when crops were scarce, we infer that TFs contribute to energy intake, but when TFs are scarce, they have to cope with risk and uncertainty making them vulnerable to food insecurity. Our results show that the more TFs the studied group ate, the more micronutrients were consumed (i.e. calcium, zinc and vitamin c). Also, the studied diet provides with adequate amounts of some of the studied nutrients, but that the traditional portion alone does mainly contribute to micronutrient intake and is, therefore, protective against hidden hunger. Further analysis proved our hypothesis that there is a positive correlation between the amount of

TF consumed and the adequacy of nutrient intake reported as Mean Adequacy Ratio (MAR). This correlation also shows that if TFs are not available, indigenous people are highly vulnerable to food insecurity (MAR=0.66) because of the low food purchase capacity they have.

Additional findings allowed us to analyse other nutrition-related issues. Because our concerns were not only about nutrient intake but also about the prevention of chronic diseases, we statistically compared the mean fruit and vegetable intake with latest recommendations. Total fruit consumption did not reach the 200 g/day recommended for healthy diets (p-value<0.001). Also, the amount of vegetables consumed did not meet recommendations (200 g/day) (p-value<0.001). The latter figures together with the results from *Chapter 3*, indicates that indigenous people require increasing i) TF cultivation or ii) purchase capacity to reach fruit and vegetable intake recommendations for health, according to the pathways proposed by the Bioversity International.

Another concern we had is the apparent shift from traditional foods to industry-processed foods. The analysis of the food intake showed that apart from TFs, indigenous women consume 46 non-locally cultivated foods and 33 industrialised foods which are purchased in nearby markets. Non-locally cultivated foods are consumed in significantly higher amounts than TFs. The combination of TFs and industrialised foods showed us that acculturation is present, but the latter is consumed less frequently. In *Chapter* 4, findings show that despite the health beliefs attached to TF and the negative perceptions to processed foods, indigenous people consume the foods processed by the industry for their convenience and taste, despite their limited purchase capacity. These results indicate that nutrition education should focus on healthy eating choices.

We were also concerned about the amount of red meat consumed because of its relationship with sustainable diets. Therefore, we statistically tested if the consumption of ruminant meat was higher than the maximum 50 g recommended to mitigate Greenhouse Gas Emissions (GHGEs). Mitigation refers to the reduction of GHGEs to levels lower than those reported in 2005.

World enteric methane from cattle, for example, was 75 million tonnes in 2004. Our additional finding shows that the studied women are eating more than the indicated maximum recommendation. Only one person reported eating bush meat, which shows limited overhunting. Therefore, we further suggest that nutrition education should focus on introducing the concept and benefits of sustainable diets, particularly about reducing ruminant meat consumption because of the associated GHGEs from its production; and reducing bushmeat consumption because it is related to the extinction of some species. In *Chapter 6* we present the following general conclusion. When locally cultivated and wild foods are present and available in sufficient amounts for consumption, indigenous people are likely to cover only a limited share of nutrients to prevent malnutrition despite the high preference and health beliefs attached to TF, being the access to non-traditional foods essential to meet full nutrient requirements.

Recommendations for community interventions, future research and policies are also presented in *Chapter 6.* Despite the high availability of foods, both cultivated and wild, there exist barriers to the consumption of TFs which are environmental (availability and access), and individual (knowledge, proud of TF consumption and skills). For the former, increased cultivation of TF for consumption (at the farm or home gardens) and for commercialisation (in nearby markets) is recommended; for the latter nutrition education is recommended. Because both fruit and vegetable consumption did not reach the recommendation and the number of fruit and vegetable species at the farm is low, we recommend that interventions start promoting and giving incentives to increase the cultivation of these food groups, vegetables in particular. Nutrition education should also increase the familiarity towards the taste, preparation and consumption of locally cultivated and wild vegetables by for example cooking workshops. Also, disseminating indigenous knowledge from old people (elders) would increase the cultural value towards TFs.

To know which foods should be best promoted by healthy eating interventions, we identified those foods that were mentioned to be preferred by their taste (*Chapter 4*) and which consumption was confirmed by the eating recalls (*Chapter 5*). These foods include banana (*Musa accuminata* Colla), oranges (*Citrus maxima* (Burm.) Merr.), tree tomato (*Solanum betaceum* Cav.), lemon (*Citrus limon* (L.) Osbeck), papaya (*Carica papaya* L.) and guayaba (*Psidium guajava* L.). The most popularly consumed starchy foods are plantain (*Musa* x *paradisiaca* L.), cassava (*Manihot esculenta* Crantz) and maize (*Zea mays* L.). Beef (*Bos taurus*), chicken (*Gallus Gallus domesticus*) and pork (*Sus domesticus*) are the most preferred meat products, and guanta (*Cuniculus paca*) is the most valued bushmeat. The studied group like to drink infusions from leaves of orange (*Citrus maxima* (Burm.)), lemon (*Citrus limon* (L.) Osbeck), guanabana (*Annona muricata L.*), mastrante (*Lippia alba* (Mill.) N.E.Br ex Britton & Wilson) and lemon grass (*Cymbopogon citratus* (DC.) Stapf).

Ecuadorian policies need to be enforced to intervene and help indigenous populations. Collaboration is necessary between Ministry of Education, Health, Environment and Agriculture. Future policies require specific action plans that promote the sustainable use of natural resources for food. Allocation of resources is needed. Indigenous people require economic incentives and seedlings to cultivate and sell their foods to markets to generate income, improve health and living. A specific strategy would be to increase the 17 % prevalence of women practising traditional farming at home gardens or farms. Infrastructure and salaries are necessary to introduce nutrition-education professionals full-time in schools.

The specific recommendation for healthy and sustainable diets for the studied population is to increase fruit and vegetable consumption (to 200 g/day each group) and decrease the amount of animal protein consumed (particularly ruminant meat up to 50 g/day) preventing thereby chronic diseases and alleviating environmental degradation. The caloric replacement of a share of animal protein by protein from legumes such as beans is recommended. The consumption of locally cultivated plant foods is associated with lower GHGE compared with livestock mitigating global warming, and the consumption of legumes has an effect on reducing LDL cholesterol.

Finally, we recommend the use of a nutrition education handbook that we designed based on the results of this manuscript and which table of content is presented in Table 6.3. This manual can guide local stakeholders or educators through the adequate implementation of future healthy eating educational interventions. It is based on the concept of the sustainable use of natural resources for food and a couple of manuals from other countries which used as reference that use this similar concept.

The author of this thesis reminds the readers that every member of the society can help towards the eradication of hunger and environmental degradation by selecting foods that are produced by peasants using sustainable agricultural practices, especially indigenous farmers. Advocacy of researchers on indigenous eating is required to ensure the existence of indigenous peoples around the world and to ensure that future indigenous generations benefit from their health.

Abstract

In Ecuador, malnutrition affects mainly vulnerable rural people, including ethnic and indigenous minorities, despite the fact that they live in areas characterized by traditional agriculture and collection of wild species in the forest. It is believed that if locally cultivated and wild foods were actually used for consumption, rural people would consume the nutrients required to fight malnutrition.

This PhD research aims to understand the central elements of the traditional food system of an ethnic group in Central Ecuador. By applying qualitative and quantitative research methods, this thesis documents the food biodiversity available for consumption both in farms and from the forest. It further identifies local beliefs that determine the consumption of traditional foods and the barriers for reaching a diversified diet. Finally, diet analysis reflects the nutrient contribution of the traditional food consumed.

Results show the presence of a high number of edible species in the forest which consumption, however, remains marginal, whereas lower species diversity is found in the farms. Food systems, characterized by high species diversity are necessary but not a sufficient precondition to cover energy and nutrient requirements. The amount of food consumed and the economic access to buy non-cultivated foods are equally critical to cover nutrient requirements. Locally cultivated and wild foods are perceived as healthy by the interviewees who also perceive that local food cultivation has economic benefits. Therefore, it is recommended to promote local fruit and vegetable cultivation and consumption to reduce the malnutrition burden in the studied population.

Results of this research have been presented to the local authorities to increase awareness on the community needs and call for action. Currently, a nutrition education manual for primary school children living in Guasaganda is being pre-tested to initiate healthy eating education.

Sammevating

In Ecuador worden voornamelijk mensen van het platteland, inclusief etnische en inheemse minderheden, getroffen door ondervoeding, hoewel zij leven in gebieden met traditionele landbouwpraktijken en bossen waarin zij wilde plantensoorten verzamelen. Het wordt algemeen aanvaard dat de plattelandsbevolking voldoende voedingsstoffen zou opnemen en ondervoeding zou tegengaan indien lokaal geteelde en wilde of onbewerkte voedingsmiddelen zouden worden geconsumeerd.

Deze doctoraatsstudie heeft als doel meer inzicht te krijgen op de hoofdelementen van een traditioneel voedingssysteem van een etnische bevolkingsgroep in het centrum van Ecuador. Met zowel kwalitatieve als kwantitatieve onderzoeksmethodes brengt deze thesis zowel de beschikbare biodiversiteit van boerderijen en bossen voor consumptie in kaart, als ook de lokale overtuigingen en obstakels die de bevolking beletten een gevarieerd en afwisselend dieet te ontwikkelen. Tegelijkertijd toonde een analyse van het dieet de bijdrage aan van de traditionele voedingselementen tot de nutriëntenopname.

Onze resultaten tonen een hoog aantal eetbare soorten in de bossen waarvan de consumptie echter nog steeds beperkt is, terwijl een lager aantal soorten werd gevonden bij de voeding afkomstig van boerderijen. Een hoog aantal beschikbare soorten in het voedingspatroon is een noodzakelijke maar onvoldoende randvoorwaarde om de energie- en nutriëntenvereisten te garanderen. Ook de geconsumeerde voedingshoeveelheden en de economische toegang tot niet-geteelde voeding zijn essentieel om te voldoen aan de voedingsvereisten. Uit de interviews blijkt dat de respondenten beseffen dat lokaal geteelde en wilde voedingsmiddelen gezond zijn en het verbouwen ervan economisch voordelig is. Er wordt daarom aangeraden om de teelt en consumptie van lokaal fruit en groenten te stimuleren om zo de ondervoeding in de bestudeerde bevolkingsgroep te verminderen. De lokale autoriteiten werden op de hoogte gebracht van de resultaten van dit onderzoek om zo het bewustzijn van de noden in de gemeenschap te verhogen en hen op te roepen om over te gaan tot actie.

Momenteel worden handboeken rond voeding voor kinderen uit de basisschool in Guasaganda getest om binnenkort te kunnen starten met opleidingen rond gezond eten.

Resumen

En el Ecuador, la malnutrición afecta mayormente a las personas que viven en áreas rurales, incluyendo a los grupos indígenas que, aunque tienen tierras para practicar la agricultura y están rodeados de bosques donde practican la caza y colecta de especies silvestres. Se cree que, si los campesinos se dedicaran a cultivar o cazar ciertas de las muchas especies que tienen disponibles para la alimentación, estos consumirían los nutrientes necesarios para evitar la malnutrición.

Este estudio doctoral pretende comprender los elementos centrales de un sistema de alimentación de una población ubicada en el Centro de Ecuador. Para lograr este objetivo se utilizaron métodos de investigación cualitativos y cuantitativos, para documentar la biodiversidad de alimentos disponible en las fincas y el bosque, o denominados alimentos tradicionales. También, se identificaron las percepciones locales que influyen en el consumo de alimentos tradicionales y las barreras que impiden el consumo de una dieta variada. Finalmente, el análisis de la dieta local reflejó el aporte de nutrientes de los alimentos tradicionales.

Los resultados demuestran la presencia de un gran número de especies comestibles en el bosque, pero en la realidad, la cantidad que se consume es mínima. Por otro lado, el número de especies en la granja es limitada pero estas especies son críticas para dieta diaria. Esto indica que en sistemas de alimentación donde el número de especies es alto, el número de especies comestibles es una condición necesaria pero no suficiente para cubrir el requerimiento energético y de nutrientes de las personas locales. Lo positivo es que las personas perciben que los alimentos cultivados y obtenidos del bosque son saludables, y además les brinda beneficios económicos cuando son comercializados. Basándonos en nuestros resultados, se recomienda que se promueva el cultivo local de frutas y vegetales para su consumo, esperando así reducir los problemas de malnutrición en la población estudiada.

Los resultados de este estudio ya se han presentado a las autoridades locales haciendo un llamado de atención para que se inicie una intervención. Actualmente, un manual para educación nutricional está siendo socializado en un par de escuelas primarias en Guasaganda para promover la alimentación saludable.

Contents

List of abbreviations and acronyms

CBD	Centre for Biological Diversity
CINE	Centre for Indigenous Peoples' Nutrition and Environment
DDS	Dietary Diversity Score
EAR	Estimated Average Requirements
EC	Ecuadorian Constitution
FAO	Food and Agriculture Organization
FAOSTAT	Statistics Division of FAO
FCT	Food Composition Tables
FVS	Food Variety Score
GEF	Global Environment Facility
GHGEs	Green House Gas Emissions
GIAHS	Globally Important Agricultural Heritage Systems
ha	hectares
INEC	Instituto Ecuatoriano de Estadísticas y Censos
IUFRO	International Union of Forest Research Organizations
IFPRI	International Food Policy Research Institute
MAR	Mean Adequacy Ratio
MDD-W	Minimum Dietary Diversity for Women of reproductive age
MDG	Millennium Development Goals
NAR	Nutrient Adequacy Ratio
NTFP	Non-Timber Food Products
SCAR	Standing Committee on Agricultural Research
SD	Standard Deviation
STROBE	Strengthening the Reporting of OBservational studies in Epidemiology
TF	Traditional Foods
TFDS	Traditional Food Diversity Score
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNISDR	The United Nation Office for Disaster Risk Reduction
USA	United States of America
USAID U.S	Agency for International Development
WCMC	World Conservation Monitoring Centre
WHO	World Health Organization

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Figure 6.2 Pathways which are leading to dietary diversity, food and nutrition security based on food biodiversity (Based on Kennedy *et al*. 2017 with permission). Bigger arrows show higher contributions than thinner arrows

Chapter 1: Justification and study framework

This chapter presents the rationale for this study, and the definitions and theoretical concepts used to construct the research framework. It also lists the objectives of each chapter framed into a thesis outline.

1.1 Background

1.1.1 Justification

During the last decade, reducing both the number of hungry people (Millennium Development Goal (MDG) 1c, and forest loss rate (MDG 7a) have been, amongst the biggest development challenges worldwide according to the United Nations (UN) (BI 2005; Chappell and LaValle 2011; FAO 2013b). Since 2015, Sustainable Development Goal 2 (SDG2) stresses that addressing and operationalising both these goals together, rather than separately, is of paramount importance for reaching sustainable development (UN 2015c; SOFO 2016).

National development plans for developing countries, however, do often fail to combine human and environmental health into their governing principles and practice. Because usually planning focuses on each development goal separately, individual goals are often neglected when concentrating on another. To illustrate this dissociation, a simple observation of undernutrition and deforestation indicators in Latin America from FAO reports shows the problem across years.

Between 1990-92 and 2011-13, the percentage of undernourished Latin people dropped from 13.8 % to 7.1 % (FAO 2013b), with prevalence in 2016 below 5% whereas the numbers are increasing in 2017 (SOFI 2017). The reduction of the number of undernourished Latin people from 66 million to 34 million in about two decades (SOFI 2015), which corresponds to almost the half, was a big achievement as this was the MDG 1c) target. By reaching the latter, human health was ensured, but environmental health was not. Between 2005 and 2010, deforestation in Latin America resulted in 3.6 million hectares (ha) lost per year. This resulted in a total loss of 2 % from the total Latin America forest area in a 5 year period (FAO 2010b; UN 2012). In the latter period (2005-10), Latin America assumed that producing high amounts of foods was necessary to feed the hungry and the growing population. To reach the latter, existing food production systems required an increase in i) commercial agricultural land and pasture surface area; and ii) area for subsistence agriculture (Alder *et al.* 2005; Godfray *et al.* 2010; SCAR 2011; FAO 2012 and 2015b) which was achieved by cutting the forest.

Between 2005 and 2010, the increase in Latin America commercial agriculture was responsible for the deforestation of 3 million ha, whereas subsistence Latin America farming was responsible for the other 0.6 million ha (SOFO 2016). These figures suggest in 2005-10, commercial food production systems were considerably more harmful to forests than subsistence farming. Most of the deforestation that allowed to increase commercial agriculture occurred in the Amazon to produce food for international markets (i.e. cattle, soybean and oil palm) whereas subsistence farming produced foods for the peasant' families and local markets (ibid.). Thus, Latin America deforestation contributed to feeding other countries in higher proportions than to its population.

Ecuador is one Latin American country that undergoes continuous deforestation. Currently, deforestation in Ecuador is driven by i) clearing land for the production of exportables such as bananas, cocoa and coffee; large-scale pastures, and traditional multi-product farms; ii) industrial logging, mining, extraction of fossil fuel and gas; and iii) hydropower and infrastructure, such as roads (Steinweg *et al.* 2016). However, deforestation is mostly driven by the government aims towards economic growth at the expense of natural resources (ibid.), whereas traditional farming has a minimal impact on deforestation and produces food consumed by Ecuadorians. The sustainable development of Ecuador requires producing foods for local consumption that would ensure domestic food security without forest loss.

Policymakers should be aware of the benefits, such as food provision, of forest conservation for securing livelihoods so that policies can efficiently make progress towards SDG2 and promote sustainable food production systems (FAO 2015b; UN 2015b). For the sustainable development of Ecuador, it is imperative that the government supports and encourage the activation of food production systems that have low environmental impacts (Godfray *et al.* 2010; WorldBank 2013), such as traditional and family farming to produce sufficient and diversity of foods (SIISE 2002), and limit further deforestation driven by the agribusiness of exportables.

1.1.2 Terminology and definitions

In 1974, the UN, in line with the Universal Human Rights Declaration, recognised that the reduction of hunger and malnutrition is a critical objective for the progress and development of all countries (UN 1974). In 2000, the Millennium Declaration proposed to halve the proportion of hungry people by 2015 (SOFI 2015). Beyond 2015, UN SDG 2 aims to end hunger and all forms of malnutrition by 2030, through the use of sustainable food production systems (UN 2015c). For a better understanding of how to integrate the fight against malnutrition, and the use of sustainable food production systems towards development, it is essential first to define the terminology used in the field of nutrition and then of food production.

The definition of malnutrition has evolved with development problems worldwide. Several decades ago, malnutrition was defined by Gomez in 1956, as reduced weight in Mexican children when underfed (Gomez 1956). The later author introduced the Weight-for-Age (W/A) indicator and classified malnutrition into three different degrees of severity. This W/A indicator correlated a higher risk of death with a decrease in a child's weight (ibid.). Later, Waterlow (1972) introduced two additional indicators for children, i.e. stunting, that is expressed as Height-by-Age (H/A), and wasting, expressed as Weight-by-Height (W/H) (Waterlow 1972). These last two indicators are sensitive to chronic and acute malnutrition, respectively. W/H is helpful when the age of the child is not known (ibid.). All three indicators were applied to predict death risks of children suffering short or long periods of food shortage. However, these indicators do not consider the death risk when the child is overweight (Gueri *et al*. 1980).

In 1972, the Body Mass Index (BMI) was proposed by Ancel Keys and colleagues based on the work of the Belgian astronomer Adolphe Quetelet (Keys *et al.* 1972). This index is calculated by dividing the body weight (in kg) by the squared height (in m^2) and has specific cut-off values for overweight (BMI>25) and obesity (BMI>30) for adults (ibid.). W/A, H/A and W/H were used for decades as a nutritional status indicator to assess child development in developing countries, whereas BMI was mainly used to evaluate the nutritional status of the population in developed countries. BMI was necessary as western diets are characterised, according to Medical Subject Headings (MeSH terms), by food consumption patterns high on meat, fats and sugars and processed grains. It was in 2000, that Cole and colleagues proposed BMI cut-offs for children's obesity (Cole *et al*. 2000), and in 2007 for thinness (Cole *et al.* 2007). However, Popkin in 1994 already described a transition occurring in developing countries, reporting a double burden of under- and over-nutrition in some countries like Brazil (Popkin 1994). Comparing the BMI of women in Brazil of 1975 with 1997, in the former year there were 2 cases of underweight to 1 case of obesity, whereas in the latter year there were 2 cases of overweight to 1 case of underweight (Monteiro *et al.* 2004). Projections show that for 2015 obesity will affect 12.4% of men and 24.5% of women in Brazil (Abegunde *et al.* 2007). The Lancet presented the emerging issue of overnutrition as a development problem in 2007 showing that Brazil will lose 4.8 billion dollars of their Gross Domestic Product (GDP) by 2015 because of costs related to health problems such as stroke and diabetes (ibid.).

Under- and over-nutrition are known to have adverse effects on health and economic development (Abegunde *et al.* 2007; Black *et al.* 2008). The 2016 Global Nutrition Report written by an independent expert group from institutions such as International Food Policy Research Institute (IFPRI), World Health Organization (WHO), Food and Agriculture Organization of the United Nations (FAO), World Food Program (WFP), among others, uses several indicators for malnutrition that embrace both under- and over- nutrition (IFPRI 2016). Mainly, quantitative indicators are used to evaluate the nutritional status of individuals and population which can be anthropometric and biochemical. Most used anthropometric indicators are stunting (H/A Z<-2SD), wasting (W/H Z<-2SD) and overweight (BMI>2SD) in children, and overweight and obesity (BMI>25 and >30, respectively) in adults. Biochemical blood indicators in children and adults are mostly used to measure deficiencies and include, but are not limited to, the haemoglobin iron-containing protein in blood (g/dL) to assess iron deficiency, serum folate (mg/mL) to measure folic acid deficiency, serum retinol (µg/dL) for vitamin A deficiency, zinc in serum (µg/dL) for zinc deficiency, and glucose blood (mg/dL) to assess diabetes. In this thesis, some of the indicators listed above are used to describe the malnutrition situation of indigenous people in Ecuador using the ENSANUT Health and Nutrition report as a source of prevalences (Freire *et al.* 2014).

The quantitative indicator used in this thesis that quantifies the malnutrition state of the studied population is energy intake reported as kcal/person/day. To assess if the kcal intake of the population is adequate, the mean energy intake was compared with the energy requirement for the studied age and gender group. This indicator, likewise the FAO State of Food Insecurity (SOFI) report uses since 1999, focuses on undernourishment defined as the distribution of dietary energy intake in the population. Energy intake is used in the SOFI as an indicator for malnourishment to measure progress towards development (SOFI 2015), and the State of the World Forest (SOFO) uses it as an indicator of food insecurity. The prevalence of undernourishment in the SOFO 2016 is reported together with a forest change indicator, aiming to measure food insecurity by the assessment of human and environmental health. In SOFO 2016, forest change is reported as the percentage of land that is converted to the forest area and infers a healthy environment. The recent report shows that food security can be increased by halting deforestation (SOFO 2016).

In Latin America, only Costa Rica and Chile progressed towards forest growth and in the reduction of the percentage of hungry people (ibid). SOFO 2016 shows that in Costa Rica there was a reduction of undernourishment from 5.2% in 1990 to <5 % in 2014, whereas in the same period there was an increase in forest area of +7.5 % and a decrease of agricultural land of -9.1 % (SOFO 2016). In Chile, there was an increase of forest land of +16.2 % between 1990 and 2015, and a simultaneous reduction in the prevalence of food insecurity from 9 % to <5 %. These figures show that there could be a relationship between the decrease of food insecurity (malnutrition) when forest land increases (thus biodiversity is preserved) and agricultural land (mostly pastures and arable crops) decreases.

There are other indicators used to assess development, apart from food insecurity, which are based on the concept of dietary diversification as an indicator for diet quality (Hoddinott and Yohannes 2002b; Arimond and Ruel 2004; FAO 2014a). Limited diversity in the diet is a problem among people living in developing countries because their diets are based on staples, and limited fresh fruit and vegetables are consumed (Ruel 2003). Indicators of dietary diversity used in developing countries include the Dietary Diversity Score (DDS), Food Variety Score (FVS), Traditional Food Diversity Score (TFDS) and Minimum Dietary Diversity in Women (MDD-W).

According to a review of dietary quality indexes (Kant 1996), grouping foods as a measure of dietary quality was first reported by Heady *et al.* (1961) based on the main hypothesis that some food groups are correlated to coronary heart disease (Heady 1961; Kant 1996). The review of Kant shows 36 studied since 1961 till 1996, that use, different food grouping methodologies to calculate a dietary quality index and use many validation techniques, but only some studies were conducted among Latin American people. In 1993, DDS was first reported from a National survey (NHANES I, U.S.A) that used 24 hour recalls and 5 food grouping system (i.e. dairy, meat, grain, fruit, and vegetable) (Kant *et al.* 1993). For the calculation, consumption of each food group counts to 1 point to the DDS per person with a maximum of 5 (ibid.). In 2006, the Food and Nutrition Technical Assistance (FANTA) project proposed a Household DDS (HDDS) as an indicator of food access using 12 food groups. For the calculation of HDDS 1 point is given to each food group at household level and then the average for the population is computed using the total number of households surveyed (Swindale and Bilinsky 2006). The concept of food grouping evolved within the FANTA beyond HDDS towards assessing dietary diversity at individual level using Infant and Young Children Feeding Minimum Dietary Diversity in 2008 (IYCF MDD), and Minimum Dietary Diversity for Women of reproductive age in 2014 (MDD-W). Both indicators are dichotomous indicators used as proxy for micronutrient adequacy. For children, foods are grouped into 7 categories, and the threshold of more than 4 food groups is used, whereas for women foods are grouped into 10 categories, and the threshold is more than 5 food groups (FAO/FHI360 2016). MDD-W is the improved version of the Women Dietary Diversity Score (WDDS) proposed by FAO in 2011 which used 9 food groups, and it is not a dichotomous validated indicator as the former one (ibid.).

As an alternative to food grouping for assessing diet quality is to count the number of foods items consumed during a period (Kant 1996). In 1974, counting food items was initially reported as “Food Diversity” based on the hypothesis that the overall diet quality is fundamentally based on the total number of unique foods consumed (Romero de Gwynn and Sanjur 1974). For the calculation, 1 point is given to each food item consumed and a total count of foods per day is computed. Romero and colleague conducted this study in Colombia and used anthropometry to validate their results (ibid.). The review of Kant (1996) shows 5 studies that counted food items as a measure of diet quality being Wahlqvist *et al.* (1989) who proposed the FVS,, when the latter found a correlation between the number of food items consumed with arterial wall index in diabetes II subjects (Wahlqvist *et al.* 1989).

Whether to group or not foods to show dietary quality is a complex desition. A study in Mali that used DDS and FVS to assess the quality of children's diet found that both were correlated with Mean Adequacy Ratio (MAR) (Hatloy *et al.* 1998). Nevertheless DDS showed to be a slightly higher determinant of MAR than FVS (Ruel 2003). In developing countries, Ruel *et al*. 2003 and M'Kaibi *et al*. 2015 have shown positive correlations between DDS and energy intake, suggesting the use of DDS as an indicator for food security. According to the review of Kant (1996) the use of MAR as a diet quality indicator was proposed in 1972 (Madden and Yoder 1972) being one of the first indexes associated with nutrient intake in the field of rural sociology and agricultural economics used for program evaluation of food relief in rural areas (Kant 1996). MAR is an indicator that shows the nutrient adequacy of a diet, with a MAR close to 1 showing a diet adequate for several of the nutrients included in the calculation. The calculation of MAR requires a number of Nutrient Adequacy Ratios (NAR) to be calculated by dividing the nutrient intake of a person by the corresponding recommended dietary allowance of a nutrient for a person according to their age and sex. MAR is the average of the all the NAR (truncated to 1, to avoid that overconsumption of one nutrient disparage for an under-consumed nutrient).

Novelty, to assess the diet diversification of indigenous people (children and women separately) the TFDS was reported by Roche *et al.* in 2008. The indicator is a count of locally cultivated and wild foods which are consumed in a day and recorded by 24 hour recalls. TFDS is computed by giving 1 point to only traditional foods that are locally cultivated and wild (Roche *et al*. 2008). The difference between FVS and TFDS is the source of the food.

In this thesis (*Chapter 5*), DDS and FVS were used to report the degree of diversification of the overall diet. However, because the objective of this study is to assess the contribution of traditional foods, TFDS was used to quantify the number of locally cultivated and wild species consumed in a day, and MDD-W was used as a proxy indicator to assess the quality of the diet regarding micronutrient intake.

As SDG 2 aims for ending all forms of malnutrition using sustainable food-production systems, defining sustainable food production systems is also imperative. There exist two types of food production systems, the conventional and the traditional food production systems, with their involvement in development also changing in time. Conventional food production systems are based on economies of scale which have the main objective of producing large amounts of food with low cost per unit. Conventional agriculture, to produce large amounts of food, does often involve the intensification of only one high-yielding crop in a large extension of land, and the use of machinery, fertilisers and pesticides, including mechanical harvest. Conventional agriculture has, therefore, been identified as the responsible for biodiversity loss (Gabriel *et al.* 2006). Because maximising food production was a significant contributor to the development of industrialised countries the same concept was introduced into developing countries. In Latin America, for example, intensive agriculture was first introduced during the European colonisation and increased with the green revolution late in 1950 (Evenson and Gollin 2003). In that time, the incorporation of conventional agriculture involved the replacement of traditional farming.

A traditional food system is defined in this thesis as a system composed of edibles (which is a synonym of food) from locally cultivated or wild sources that are culturally acceptable consistent with the definition used by the Centre for Indigenous Peoples' Nutrition and Environment (CINE)(Kuhnlein and Receveur 1996). The latter is an independent and multidisciplinary research and education centre for participatory research located in Canada. The CINE studies indigenous communities around the world to address concerns about the integrity, development and sustainability of traditional food systems (CINE, 2016).

More specifically, traditional food systems are based on locally cultivated and wild foods. This thesis focuses on the traditional foods, which include locally cultivated and wild foods in Guasaganda. The term local food refers to the food that has been cultivated or collected/hunted within the geographical area where the rural peasants live and consume these foods. The term localisation is used to emphasise the boundaries and differentiation of a culturally and socially homogeneous locality (in this case Guasaganda) as applied in other rural studies (Hinrichs 2003). Therefore, when food is cultivated or found in the wild and consumed in the same geographical source region, the terminology used refers to local food consumption. When food is not cultivated nor found wild in the area, it is defined as non-traditional local food (BI 2017).

The difference between conventional and traditional food production systems is that although they both produce local foods; the latter uses traditional knowledge applied during farming (traditional farming practices) whereas the former is based on high input agricultural practices and economies of scale (Figure 1.1). Thus, the difference between a conventional and traditional local food is the food system used to produce the food.

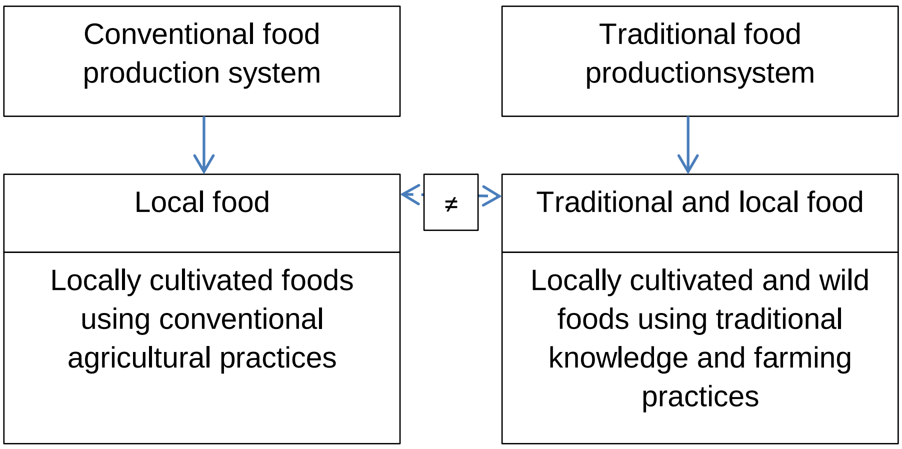

Figure 1.1 Conventional and traditional food system concept used in this thesis. Own source

For example, potatoes are produced in Ecuador and Belgium. Although potatoes were originally domesticated in Latin America, potatoes were introduced to Europe by the Spanish colonisers (Abel 1986). Currently, small indigenous farmers in Ecuador still cultivate potatoes using low input agriculture in small plots and with low yield (also organic), and the harvest is mainly used to feed their families (to fight food insecurity), while the surplus is sold for income generation (to fight poverty) (Paredes and Guerrón-Montero 2014; FAO 2016a). In contrast, Belgium produces large quantities of potatoes whether on large scale or small farms, but both farm scales use fertilisers and mechanical harvest. Additional to conventional farming there exist organic potato growers, for example in Tielt, who also cultivate potatoes in large-scale using mechanisation (VLAM 2016). Most of the Belgian potato production is directed to the processing industry of fries (Belgapom 2016). The production of about 4 million tons of potatoes in 2015 and the use of mechanisation have not only potentially adverse effects on the environment but also to the associated human labour.

In developing countries, the sustainable use of natural resources for food (mainly for subsistence and less for the market) is predominantly managed by indigenous peoples and therefore the term "indigenous food system" is used as a synonym (CINE). Indigenous peoples (many a number of ethnicities) are defined as "those having a historical continuity since pre-colonial years and consider themselves as being from an ethnic group; and they are determined to preserve and transmit to future generations their ancestral territories and ethnic identity as the basis for their continued existence as indigenous peoples" (UN 2004). Sustainable diets are defined as those which are protective and respectful of biodiversity and ecosystems, are culturally acceptable, easily accessible, economically fair and affordable, nutritionally adequate, safe and healthy, while optimising natural and human resources (FAO, 2010). The former terminology is used throughout this thesis following the guidelines of participatory research in indigenous people conducted by the CINE and FAO.

As mentioned above, the definition of traditional-local food includes cultivated and wild species. According to the Convention on Biological Diversity (CBD) the term "cultivated species" is a synonym of "domesticated species" which defines species that initially were wild but by human selection they were noticed, eaten and selected by chance and eventually became domesticated in an evolutionary process to meet human needs (CBD 2014). Wild foods, on the other hand, are defined as non-cultivated species that are gathered from the forest to be eaten (Termote, 2014). According to Nicolai Vavilov, cultivated plants originated from mountain regions of which 8 centres of origin were identified, also called centres of diversity (Harris 1990; Hawkes 1998). This thesis concentrates in one centre of origin, the South-American Andes region (Bolivia, Peru, Ecuador), where many varieties of potatoes, grain crops of the Andes such as quinoa, vegetables, spices and fruits, as well as drugs (i.e. cocaine, quinine, tobacco) in all, some 45 species grow (ibid).

In this study, we also use the term “food biodiversity” defined by the CBD to explore the nutritional indicator for biodiversity on food consumption (FAO 2009). Food biodiversity is defined as the diversity of plants, animals and other organisms used for food, covering the genetic resources within species, between species and provided by ecosystems (ibid.). One objective of this study is to list all local foods present in the forest of Sacha Wiwua (wild foods) and surrounding farms (cultivated foods) which compound the number of TFs and is part of the food biodiversity.

Another term used in this study is “underutilised species”. Since the latter is not a well-defined term, because of geographical, social and economic aspects that influence the definition, we used the glossary of terms used by the CBD for the study of nutritional indicators for biodiversity (FAO, 2009). Therefore, in this thesis, the term “underutilised species” includes a wide range of wild, traditional, indigenous and local foods. Additionally, the term ‘indigenous foods’ is used when describing the foods that are consumed by an indigenous group.

1.2 Traditional food systems

1.2.1 Existing traditional food systems

According to the CINE there exist traditional food systems which are based on up to 400 local food species (Kuhnlein *et al.* 2009), which differ from contemporary food systems relying on approximately 30 food species (FAO 2010f). Because dietary diversification is universally recognised as *the* foundation for healthy eating, the study of traditional food systems, and the diversity of foods (food biodiversity) available for consumption in these systems, is increasing in the nutrition and conservational sciences (FAO, 2017).

Currently, there exist traditional food systems which only subsist because indigenous peoples manage them. The use of traditional knowledge is the most valued item which is transmitted from one generation to the next to assure sustainability of the traditional food system (GEF 2008). It is understood that indigenous peoples safeguard about 80 % of the world biodiverse-rich ecosystems

(GEF 2008), and therefore they are identified as leading actors in biodiversity conservation (FAO 2013a). Currently, research that documents indigenous knowledge on conservation and traditional eating is still needed. Validated instruments to research the latter involving indigenous people are often lacking and could lead to research failure (Halcomb *et al*. 2007). Therefore, researchers require being familiar with the local language and eating culture, having an open mind on TFs and spiritualism, and respect for the holistic value of indigenous peoples' knowledge.

In an effort to conserve indigenous food systems, the CINE has studied 12 traditional systems around the world, namely: Ainu (Japan), Awajun (Peru), Baffin Inuit (Canada), Bhil (India), Dalit (India), Gwich'in (Canada), Igbo (Nigeria), Ingano (Colombia), Karen (Thailand), Maasai (Kenya), Nuxalk (Canada), and Pohnpei (Federated States of Micronesia).

In Latin America, the CINE started in 2004 to document the Awajun ethnic group of Peru. In that year, 93% of the energy intake was supplied by about 223 food species, but nutrition content is known only for 82 species. In other Latin American countries, however, there exist many other ethnicities and TFs that have not been studied (FAO, 2017). It is estimated that 50 million indigenous people practice traditional agriculture on 38 % of the land devoted to cultivation which represents about 60.5 million ha (Koohafkan and Altieri 2010). Indigenous food systems of some Latin American countries produce 41 % of the food that is consumed domestically and, therefore, contribute to food security (ibid.). Also, the high variety of foods produced contributes to dietary diversification (Fanzo *et al.* 2013; Vinceti *et al.* 2013). However, more study on the traditional food systems in Latin American countries is required.

A global report on nutrition indicators for biodiversity updated in 2013, shows that worldwide there exist about 6,000 different foods species that are still consumed, of which approximately 700 were reported in America (Rittenschober and Charrondiere 2013). More importantly, the nutrient content of 350 Latin American foods, including many micronutrient-rich varieties, has been analysed (ibid.). In a recent FAO report for food biodiversity (FAO, 2017), a compilation of the nutrient component of Latin American foods (574 entries) indicates that there is an increasing interest in studying traditional foods. Knowing the nutrient content of foods allows researchers to understand the nutrient contribution of the food consumed. However, nutrition initiatives require that not only the nutrient content and contribution of TFs to be identified but also other aspects, such as benefits and beliefs, because of these factors influence the consumption of TFs.

1.2.2 Characteristics of traditional food systems

For millennia, traditional farmers have developed agricultural practices that allow them to cultivate foods throughout the year from one generation to the next (Koohafkan and Altieri 2010; Iiyama and Dawson 2016). Also, wild foods are managed wisely in traditional systems. Traditional food systems are based on the use of traditional knowledge, and the fact that some traditional food systems still exist is the living proof that traditional knowledge is somehow wise and sustainable (Altieri, 2002). The conservation of traditional food systems not only locally, but also at national and global levels, is imperative to produce food sustainably. Table 1.1 shows the benefits of traditional food production identified by several researchers. In summary, the advantages of producing foods using traditional practices were grouped under the three pillars of sustainability, and conclude that traditional food production has i) environmental, ii) socio-cultural, and iii) financial benefits. All authors conclude likewise that traditional farmers may receive the listed benefits when traditional farming is practised. Consistently, all authors applied the concept of natural resource conservation and management to conclude that traditional food production is sustainable.

Table 1.1 List of the benefits, framed under the 3 pillars of sustainability (environmental, socio-cultural and economic), of traditional farming presented in a number of conceptual models proposed by several authors.

Benefits	Authors
Environmental - Conservation of biodiversity and natural resources - Enhanced food self-sufficiency and sustainability - Natural resources ensured - Reduced environmental vulnerability - Biodiversity utilisation and conservation - Resilience and Continuity - Erosion control, nutrient cycling and microclimatic regulation	(Carney 1998; Altieri 2002; Sthapit *et al.* 2008; Koohafkan and Altieri 2010; Iiyama and Dawson 2016)
Socio-cultural **-** Human well-being and improved capabilities - Available services for religious and spiritual needs - Food culture and dietary diversity - Food security - Conservation of agricultural knowledge - Diet quality - Traditional knowledge, values and cuisine	(Carney 1998; Scoones 1998; Pretty and Hine 2000; Johns and Sthapit 2004; Hartter and Boston 2007; Koohafkan and Altieri 2010; Iiyama and Dawson 2016)
Economic **-**Survival under conditions of economic uncertainties **-**Reduced poverty and increased number of working days -Improved incomes -Provision of goods such as energy, utensils and construction materials - Tree products for income generation	(Pretty and Hine 2000; Sthapit *et al.* 2008; Koohafkan and Altieri 2010; Iiyama and Dawson 2016)

Benefits of traditional agriculture and biodiversity conservation were rather described and conceptualised (Pretty and Hine 2000; Hartter and Boston 2007; Sthapit *et al.* 2008) or illustrated to explain their further link and synergy between traditional farming and human nutrition (Altieri 2002; Johns and Sthapit 2004; Koohafkan and Altieri 2010; Iiyama and Dawson 2016).

Despite the benefits listed in Table 1.1, there exist many disadvantages that traditional food production systems face, particularly in the tropics. Most critical aspects include problems of soil fertility due to nutrient leaching, coping with risk and uncertainty, low labour productivity and the problem of seasonality (Ruthenberg and Ed 1980). However, it is believed that the former problems are managed by traditional farmers using cultural practices such as crop rotation and intercropping (Altieri 2002). Also, peasants cannot compete with large producers due to diseconomies of scale, as the gains from selling TFs are low this induces rural farmers to search jobs in urban areas aiming for higher income (Pretty 2001).

1.3 Main objective

We follow the initiative of the CBD, which aims to strengthen the environmental integrity of agricultural systems to maintain and build sustainable livelihoods. This thesis aims to study the links between locally cultivated and wild foods in TF systems, eating behaviour, and nutrition. The first element of the CBD initiative is the need for scientific documentation of knowledge that explains the links between biodiversity, food and nutrition. This thesis documents locally cultivated and wild food availability, the perceived benefits and limitations of local food consumption and production in TF systems, and nutrient contribution of locally cultivated and wild food consumption in a sample of indigenous people in Central Ecuador.

1.4 Study area and subjects

1.4.1 Ecuador

Ecuador is one of the 17 megadiverse countries of the world (WCMC 2000; CBD 2001). The origin of this high diversity can be explained first by its tropical location, the pronounced presence of the Andean highlands, the influence of the Pacific Ocean's currents on its coasts, the Amazon forest and the uniqueness of the Galapagos Islands. Secondly, there is a huge biodiversity present in 12.8 million ha of forests which represent 42 % of the country's surface area (CBD 2001; FAOSTAT 2014).

Historically, Ecuador together with other three areas, currently known as Colombia, Peru and Bolivia, belonged to the so-called *Tahuantinsuyo* (meaning "the four regions" in Quechua), which was dominated by the Inca Empire. The Inca people used to collect or hunt their foods from the forests whether in the Andes or Amazon (ESPOCH 2011). As part of the Inca culture, Inca people used to practice agriculture on communal land. Inca diets were diversified and seasonal. Many foods such as potatoes (*Solanum tuberosum* L.), oca (*Oxalis tuberosa* Molina), *melloco (Ullucus tuberosus* Caldas*)*, quinoa (*Chenopodium quinoa* Willd.) *chochos (Lupinus albus* L*.)*, and maize (*Zea mays* L.) were cultivated for consumption (ibid.). Cultivation followed cultural and spiritual beliefs, for example, maize is cultivated by women since they are perceived as a symbol of fertility.

Following the Spanish colonisation, indigenous people of Ecuador lost their land and freedom to produce and consume TFs. The European invaders brought wheat (*Triticum aestivum* L.) to be produced extensively and imposed to cultivate maize (*Zea mays* L.) using western methods. Also, the Incas were forced to become Catholic, to speak Spanish and not their native language and to stop adoring "their" mother earth and father sun. The latter pressures caused the loss of the traditional knowledge on food production and consumption (ibid.). Because of intensive wheat (*Triticum aestivum* L.) production, deforestation started, causing a reduction of availability of TFs and importance. Indigenous people adapted their diets to European crops for survival, for example, they began to eat bread. Only a few individuals were able to eat TFs which were produced in the *huasipungo* (piece of land that the Spanish lend to domestic slaves to grow food). Only those hiding deep in the forest were able to maintain their eating culture because they collected TFs that were still available in the forest (Yacelga *et al.* 2004). Reduced availability and isolation might be the starting point to the nutritional problems in Ecuador, such as stunting and wasting.

Additionally, demographic growth and climatic phenomena affected the nutrition situation in Ecuador. In the 90's for example, the Ecuadorian population increased by a 2.1 % whereas food production increased in 2.47% (SIISE 2002). In that decade, the food production was theoretically enough to feed all the population, despite the climatic niño phenomena in 1997-98 that affected the food production (ibid.). However, protein-energy malnutrition was the 6th cause of death of children under 5 years of age. These figures show that the main problem of food insecurity is not the availability of food nor the production capacity of the food system but the limited economic access to buy adequate amounts of foods and diversity of healthy foods (SIISE 2002).

In Ecuador, the last health survey (ENSANUT 2012) shows that undernutrition is still present despite all efforts to reduce stunting (H/A < -2SD) among under-5 children at national levels. In the period of 2004-2012 stunting has reduced by an 8 % since (Figure 1.2a). Additionally, the overweight (BMI > 2SD for children or > 25 for adults) prevalence is increasing both in children and adults (Figure 1.2a and 1.2b). Also, 14 % percent of women (12 to 49 years) are anaemic, reported by the

ENSANUT as haemoglobin (iron-containing protein) in blood < 12 g/dL. Furthermore, 8.5 % of anaemic women of reproductive age are also overweight. Malnutrition coexists in the same household, with 13 % of overweight or obese mothers having stunted (H/A < -2SD) children (Freire *et al.* 2013). The results of the ENSANUT show that under- and over-nutrition manifest differently throughout the life cycle (idib.) However, the statistics department of Ecuador indicates that the second cause of death in Ecuador in 2012 was cardiovascular disease which is correlated with dietary-related risk factors such as hypertension, diabetes and obesity (INEC 2012). Anaemia, caused by the deficit in iron, vitamin B12 and folates, was the cause of death of about 100 people in Ecuador in the same year (ibid.). Inadequate diets are by far the most significant risk factor for the global burden of cardiovascular disease which could be prevented by having nutritious and balanced diets (IFPRI 2016).

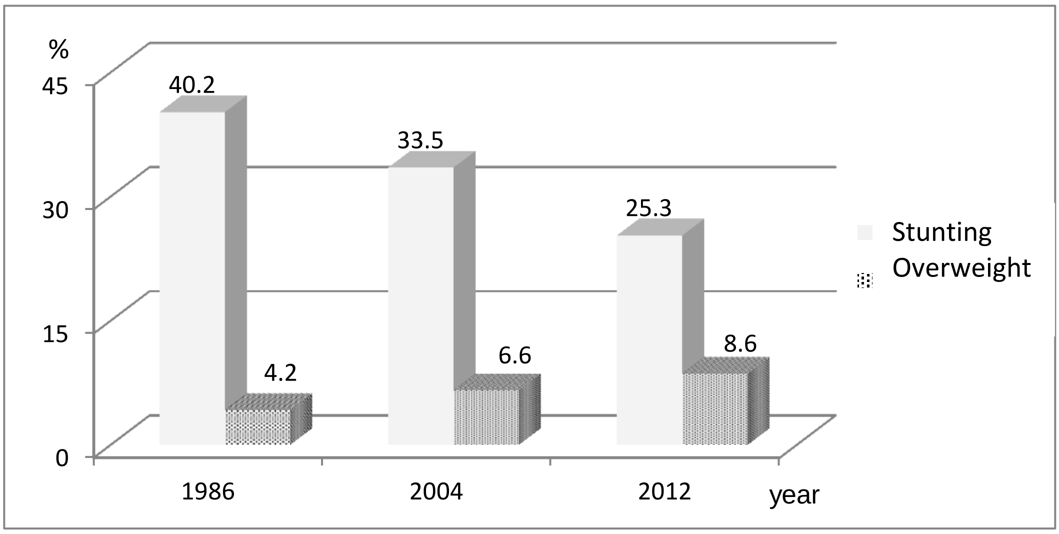

Figure 1.2a Prevalence (%) of stunting (Height/Age Z score <-2 Standard Deviation) and overweight (Body Mass Index > 2 Standard Deviation) in Ecuadorian children, under 5 years old, from 1986 until 2012 (adapted from Freire *et al.* 2013)

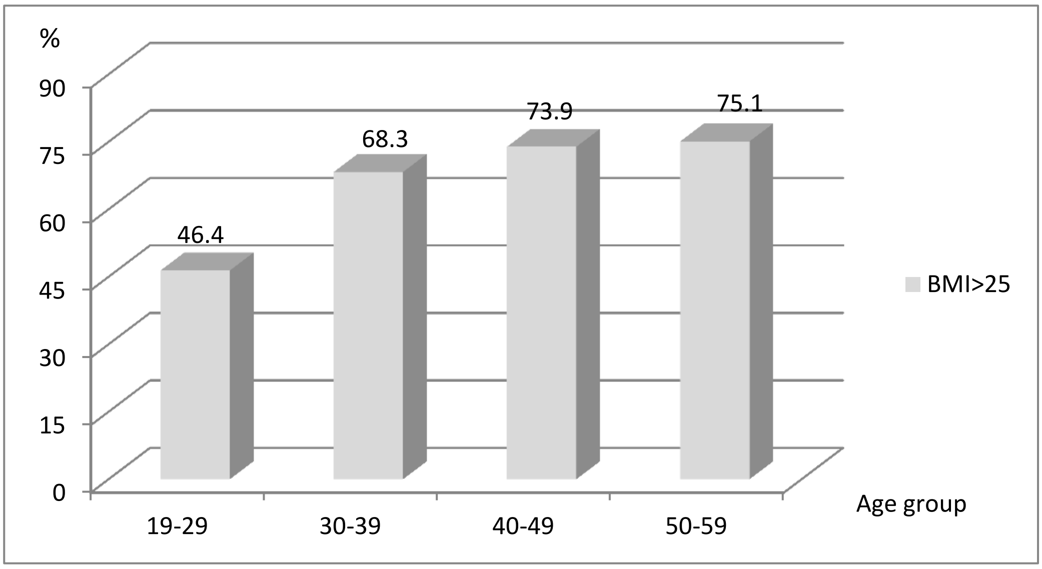

Figure 1.2b Prevalence (%) of overweight (Body Mass Index >25) in adult Ecuadorians in 2012 (adapted from Freire *et al.* 2013)

Currently, the diet of Ecuadorians can contain a combination of foods whether endemic or introduced from other continents. For example, 1,561 edible plant species have been registered, yet only 131 (8%) are cultivated (Van den Eyden and Cueva 2008). Despite the large food resources, Ecuadorian's food production, according to FAO Food Balance Sheets, concentrates on 84 food items with sugarcane, bananas, oil palm, maize, rice, plantains and potatoes as the top 7 crops, and milk, eggs and chicken meat as the top 3 foods of animal source (FAOSTAT 2014). The latter number is higher than for example Belgium's crop production which is concentrated in 48 crops with sugar beet, potatoes and wheat as the top three crops (FAOSTAT 2014). In Ecuador, foods are produced on 7.3 million ha of agricultural land of which 19 % is permanent pastures, 5 % is permanent cropland, and 5 % is arable land (FAOSTAT 2012). There also exists land that is used by indigenous peoples, for subsistence agriculture. However, the amount of land they have, and the number of food species produced by subsistence agriculture has not been estimated.

Change in Ecuadorian land use to increase food production is probably responsible for the high rate of deforestation. Between 2000 and 2008 the country's deforestation rate (-0.66 %) was one of the highest in Latin America with 77,647 of ha lost per year (MAE 2008; Mosandl *et al.* 2008). It has been estimated that such a degree of deforestation also brings an extinction of up to 63 plant species per year (Koopowitz *et al.* 1994). What is currently evidenced by scientists has been well-known by indigenous peoples who have traditionally been working in forest preservation and know that the most important factor in preserving species *in situ* is the integration of conservation into agricultural landscapes to produce foods for subsistence and with limited commercial purposes (Scherr and McNeely 2008).

Ecuador is the first country that in 2008 introduced the concept of food sovereignty in its constitution aiming to promote sustainable agriculture (EC 2008). Food sovereignty is the right of peoples to choose healthy and culturally appropriate food produced through ecologically sound and sustainable methods, and their right to define their food and agriculture systems. It puts those who produce, distribute and consume food at the heart of food systems and policies rather than the demands of markets and corporations. Food sovereignty prioritises local and national economies and markets and empowers peasant and family farmer-driven agriculture, artisanal fishing, pastoralist-led grazing, and food production, distribution and consumption based on environmental, social and economic sustainability (LaViaCampesina 2007). This new strategy promotes peasant farmers in Ecuador to produce foods for the population sustainably fulfilling thereby the food sovereignty concept (Espinel 2016). However, traditional food production in Ecuador is currently limited and neglected.

1.4.2 Guasaganda

This study was conducted in central Ecuador, in the parish of Guasaganda (Figure 1.3a and b). Guasaganda is located between 500 and 1,000 m.a.s.l in the province of Cotopaxi, Canton La Maná. The climate is rather temperate which allows for a wide variety of vegetation and animals. In this area, about 85 plant (Aguilar and Cartagena 2010) and 20 animal (Penafiel D *et al.* 2012) foods have been inventoried as being part of the local diets. In the area, around 4,000 indigenous inhabitants live in the rural villages that surround the forest of *Sacha Wiwua* which is located in Guasaganda (Figure 1.3b). Indigenous people of Guasaganda subsist on the food produced and gathered in their ecosystem. Because of population growth and reduced natural resource and food reserves, malnutrition is a current issue.

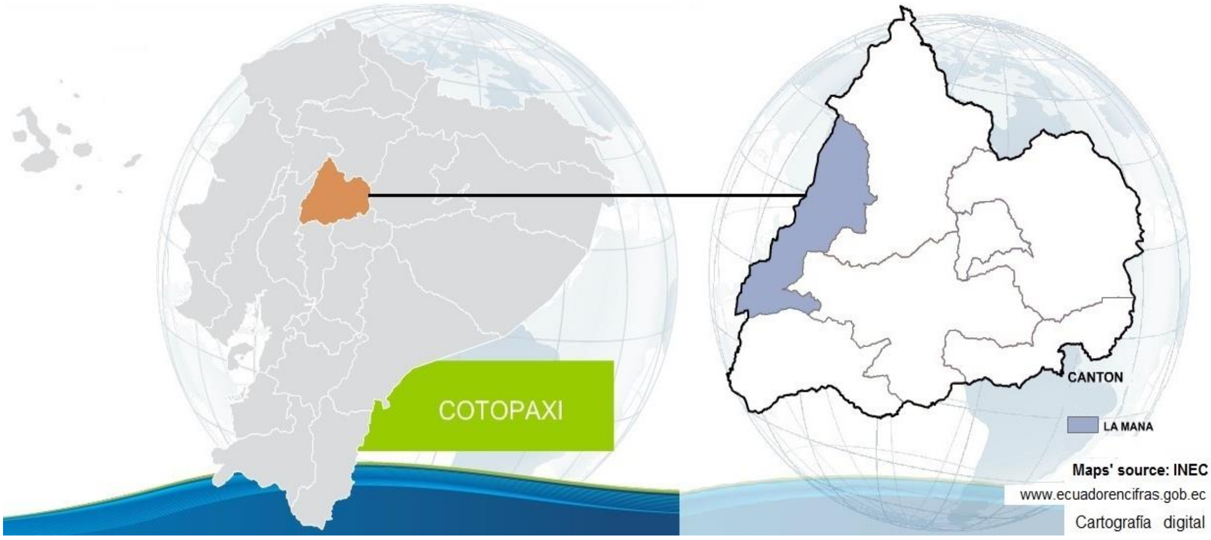

Figure 1.3a Map of Ecuador, Province of Cotopaxi and Canton La Maná (Source: INEC)

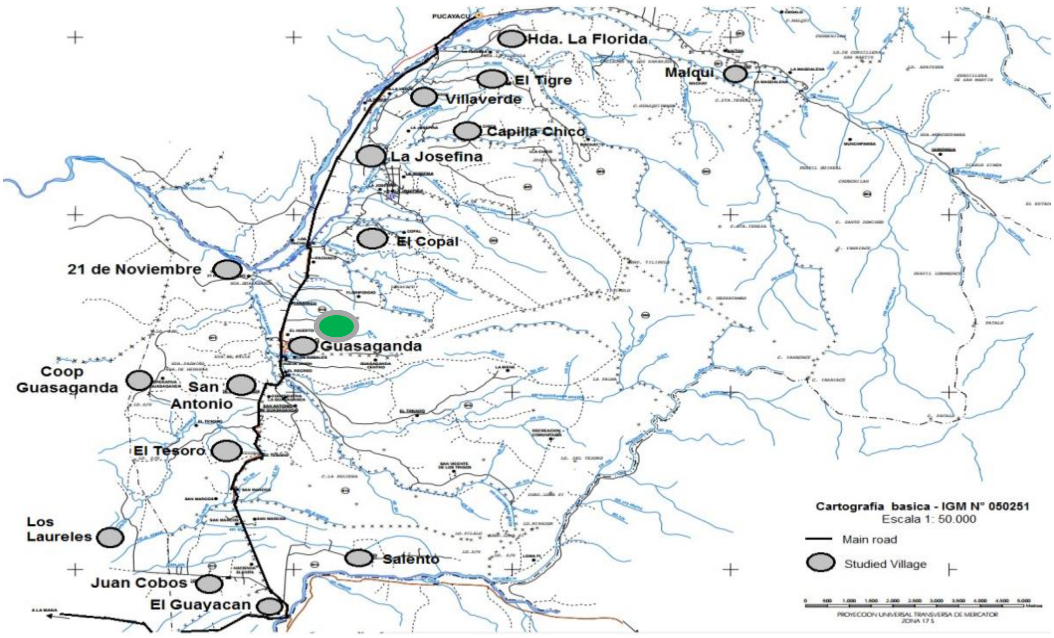

Figure 1.3b Map of Guasaganda and villages included in this study. In green is the location of the *Sacha Wiwua* forest (Source: INEC)

Malnutrition in Ecuador is mostly affecting indigenous people (Yacelga *et al.* 2004; Freire *et al.* 2013). Unfortunately, they are suffering hunger since colonisation up to today. Currently, indigenous people in Ecuador account for 7% (1,018,176 people) of the population. In 2012, 42 % of indigenous children were stunted, whereas 30 % were overweight, which is higher than the figures for children of other

Ecuadorian ethnicities (Figure 1.4). Genetic predisposition in indigenous peoples has been reported and suggests that environmental changes they face are forcing them to change their lifestyle and eating habits (Gracey and King 2009). Also, 17.2 % of indigenous children under the age of 5 have deficiency of vitamin A (serum retinol < 20 µg/dL).

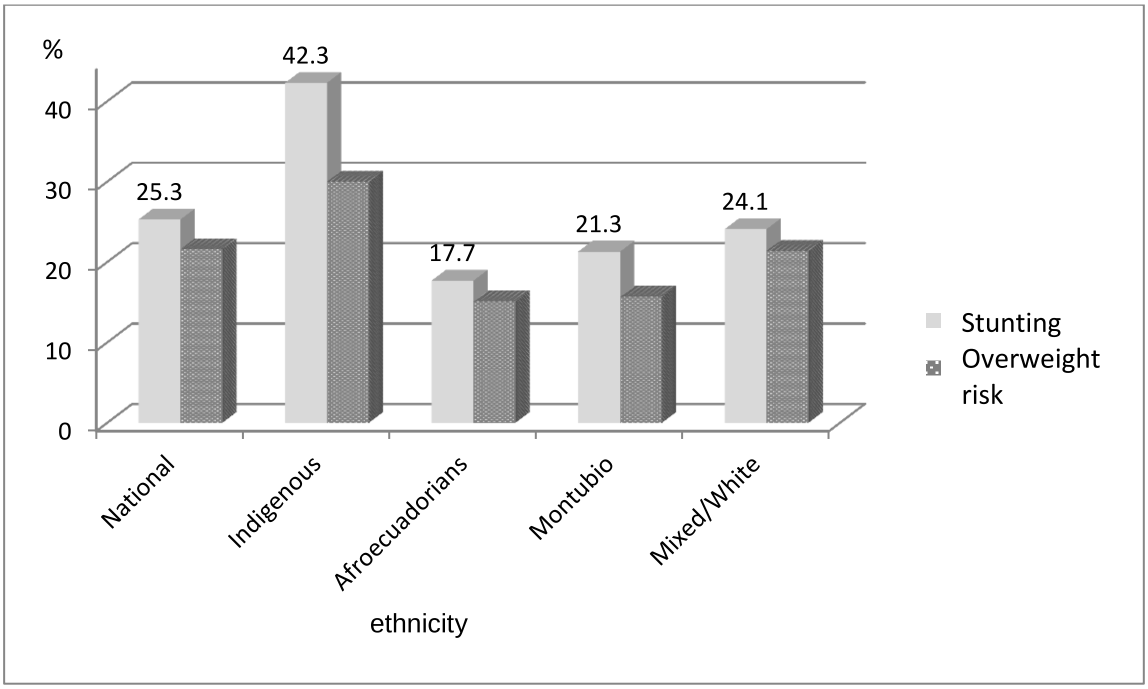

Figure 1.4 Prevalence (%) of stunting (Height/Age Z score<-2 Standard Deviation) and risk of overweight (Body Mass Index between 1 and 2 Standard Deviation) in Ecuadorian children, under 5 years old in 2012 for different ethnicities (adapted from Freire *et al.* 2013)

Indigenous women suffer from anaemia, with 15.5 % of them having haemoglobin levels lower than the reference number of 12 g/dL, whereas 49.7 % of indigenous people have zinc deficiency (Zn < 65 µg/dL) (Freire *et al.* 2013). Also, 16.4% of indigenous people in Ecuador have cholesterol higher than 200 mg/dL, 40% have HDL< 40 mg/dL, 12% have LDL> 130 mg/dL, 12.5% have blood pressure higher than 120/80 mm Hg and 15.7% have metabolic syndrome. Furthermore, it was reported that in a sample of 1,096 indigenous people, 69.3% ate processed/industrialised foods 7 days previous the interview, 41.7% ate fast foods such as French fries, hamburgers, hot dogs and pizzas, and 55.2 % ate packed snacks. The above indicators suggest that indigenous people have unhealthy diets, and that might be the reason for the high prevalence of malnutrition.

Although we do not have the exact malnutrition figures for people of Guasaganda, one of our assumptions is that they are affected by malnutrition just as other indigenous people according to the ENSANUT 2012 (ibid.). One of the most prevalent health problems in Guasaganda, just as for other indigenous communities, is the failure of public health services to reach indigenous people because of their ethnicity and isolation. Having different ethnicity limits indigenous people to process health messages because of the different language used by the health professional in charge (usually Spanish, and keeps indigenous people from eating recommended foods that they are not familiar with because of different eating culture and habits. Also, it was reported that mental illnesses are prevalent among indigenous people which can have an effect on communication (Efstathios 2015). There exist about 32 different ethnicities in Ecuador that account to 7 % of the Ecuadorian population (ibid.). Indigenous people are isolated by choice aiming to protect the Andes or Amazon regions and to get protected from outsiders. Yet, isolation limits the access of health professionals to provide food aid (Yacelga *et al.* 2004). To the knowledge of the author of this thesis, racism does not appear to be a limiting factor to receive health and nutrition interventions. This can be observed by the lower stunting and obesity prevalence of afro-ecuadorians (who speak Spanish and do not live in isolated areas) compared with indigenous people (Figure 1.4). Also, other Ecuadorian rural communities have a higher prevalence of malnutrition compared with urban areas because of the isolation factor and not racism (Freire *et al.* 2013). This study investigated indigenous people in Guasaganda because of their high vulnerability to malnutrition.

1.5 The link between traditional foods, eating and nutrition

Food is a necessity for humankind. Hence, all aspects of food production and consumption are of interest to any scientist not only agronomist or nutritionist but also biologist, sociologist, or anthropologist (Fischler 1988). Researchers of the disciplines above mentioned, however, have often studied foods within the boundaries of only one discipline, difficult to understand the link between food, eating and nutrition (Mintz and Du Bois 2002). Documenting and analysing food production, consumption and nutrition together within a specific food system is a technique increasingly used in biological sciences to increase the understanding of how the food system works (FAO 2013a). Most of the biological research is concentrated on the study of contemporary food systems because it is the most widely used (Sobal *et al*. 1998).

To our knowledge, there are only a few studies that describe (or present an illustration of) the traditional food system of indigenous peoples (Table 1.1), even though their communities are highly vulnerable to nutrition and health problems, as illustrated in Figure 1.4. What exists in literature was written by anthropologists who have been pioneer in providing the cultural understanding of eating TFs (i.e. through studying rituals, beliefs and identities) and particularly the link with food insecurity (Kuhnlein and Receveur 1996; Mintz and Du Bois 2002). Bioscientists, on the other hand, mainly concentrated on listing the benefits/outputs (Table 1.1) of sustainable food production systems. A more recent review of the links between agriculture and nutrition in India, shows how agriculture is disconnecting and non-nutrition sensitive causing malnutrition to be highly prevalent (Gillespie *et al.* 2012).

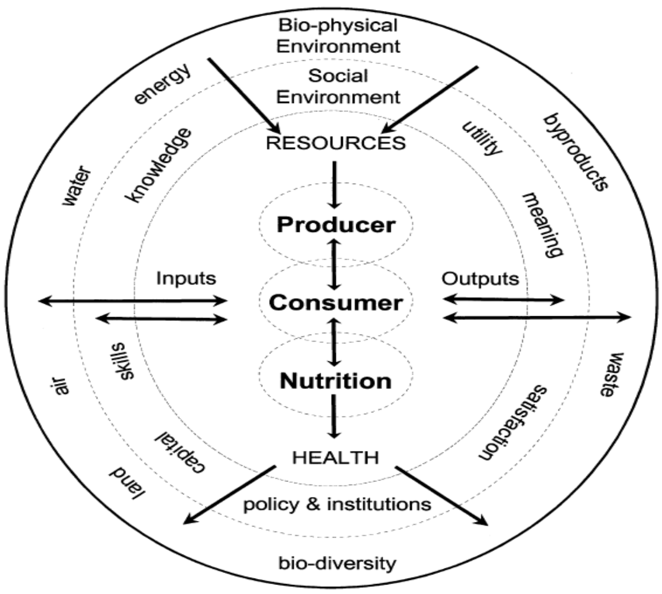

Figure 1.5 An integrated conceptual model for the food and nutrition system (figure used with permission of Sobal *et al*. 1998).

A conceptual model of food production systems which was created after a systematic review of literature and interviews with experts of diverse backgrounds presents a summary of 70 food systems' diagrams (Sobal *et al.* 1998). The model was drawn after a review of systems' theories and a variety of food system's components collected from literature, Delphi method and focus group discussions to identify existing food and nutrition systems among experts. The resulting model mainly describes a contemporary food-nutrition system of industrialised societies. It states that the flow of food can be traced whitin a contemporary food system through nine stages (production, processing, distribution, acquisition, preparation, consumption, digestion, transport, metabolism), and it identifies the producer, the consumer and nutrition as the three core subsystems (Figure 1.5). The integrated model also considers the processes and transformations that occur within the system and relationships between the system and its biophysical and social environments. The resulting system is proposed for research, teaching and practice and, therefore, it was used in this thesis to frame the research objective.

After 1998, food-systems publications consistently identified food production, food consumption and nutrition to be not only the central elements of any food system that affect health (Nugent 2011) but also to be crucial components when analysing the sustainability of any food system (Fanzo *et al.* 2012). Therefore, our study adopted the basic three components of Sobal's model (i.e. the producer, the consumer and nutrition) because these are identified as core elements of most food systems, and also because the study of these elements is imperative to assess the sustainability of the food systems, according to current literature. According to the model there exist a biophysical component that has by-products, water, energy, air, land, biodiversity and also produces waste. This environment is followed by a social component which involves knowledge, meaning, skills, satisfaction, but also capital, policies and institutions. Some or all elements of the biophysical environment enter the food system after produced, then this food is eaten (practicing eating culture). Finally, the consumption of the food by the consumers has an impact on their nutrition and ultimately on health.

Furthermore, we used the pathway number one proposed by Gillespie and colleagues in 2012 to guide our research through the links between subsistence farming and nutrition. The latter authors identified (after their review of 16 documents) that although agriculture can be the primary source of livelihoods for peasants, they tend to suffer from malnutrition and this disconnection is because agriculture is not nutrition-sensitive (Gillespie *et al.* 2012). The pathway links own food production with household calories and micronutrients, individual intake and nutrition outcomes. We used the latter pathway to connect the three elements proposed by Sobal *et al*. (1998) and create thereby the framework for this study.

1.6 Hypothesis and thesis framework

This thesis was framed as illustrated in Figure 1.6 aiming to prove the following general hypothesis: *"If locally cultivated and wild foods are present and available for consumption, indigenous people are likely to cover an important share of the nutrient requirements to prevent malnutrition".*

To elaborate this hypothesis, it was required to identify and define the rationale and concepts associated with the use of natural resources for food (*Chapter 1*). Also, we identified that this hypothesis required the study of the three basic components proposed by Sobal *et al*. (1998) in an indigenous food system. A systematic literature review (*Chapter 2*) on the contribution of local cultivated and wild foods provided us with some evidence that suggested that this hypothesis can be true, and guided us in the selection of the methodology required to prove it.

The three basic elements of study are i) food biodiversity; ii) indigenous consumers; and iii) nutrition after adaptation to indigenous food systems since the original components are specific to contemporary foods systems (Sobal *et al.* 1998). These three elements are studied in *Chapter 3, 4 and 5*, respectively.

1.6.1 Food biodiversity: In *Chapter 3* the hypothesis used was that "*traditional farms that practice traditional agriculture do have a high variety of cultivated and semi-cultivated species that compound a substantial part of TFs*".

The objective of *Chapter 3* is to investigate the number of edible species present on the farm and the forest, having as a general assumption that farms and forest are supplying with foods to the local people. The number of edible cultivated and wild foods present in the farms of Guasaganda and the forest of Sacha Wiwua, respectively, was quantified in a cross-sectional study. *Chapter 3* studies the biophysical environment of Guasaganda using a combination of methodologies. The research question was: How many edible species are present at the farm and forest?

1.6.2 Indigenous people: In *Chapter 4* our hypothesis was that "*there exist environmental barriers that have an effect on the eating behaviour of indigenous people which could affect their health*".

The objective of *Chapter 4* is to describe the individual and environmental factors involved in the consumption of cultivated and wild foods among different age groups. This was documented by a qualitative behavioural study of the socio-cultural context guided by interviews. The research question used was: What are the factors influencing native people to eat a variety of TFs that affect their health?

1.6.3 Nutrition: In *Chapter 5* the hypothesis was that "*if cultivated and wild foods available for indigenous people are consumed in adequate amounts they could suffice for nutrient adequacy and a healthy life"*.

The objective of *Chapter 5* is to correlate the consumption of TFs with nutrient adequacy using adequate indicators assessed by food intake records and to measure dietary diversity. The research question was: Is a diet based on locally cultivated and wild foods nutritionally adequate and diverse?

Chapter 6 presents conclusions about the general hypothesis linking the results from *Chapter 3, 4 and 5* using as reference the pathway of Gillespie *et al.* 2012. Also, it lists the benefits of TF consumption of the studied system. Recommendations for future strategies towards the use of natural resources for food are presented. For future interventions a manual is proposed, for future research recommendations are directed to the use of a combination of biodiversity and nutrition indicators, and suggestions are made for policies.

In this last chapter, a new hypothesis based on some additional findings was elaborated as "*if indigenous people prefer to eat locally cultivated and wild foods that originate from traditional farming and forest, the diet could be associated with low GHGE and therefore sustainable for the environment"*. Dietary indicators to asseses the sustainability of the diet were used from Auestad *et al.* (2015), McMichael *et al.* 2007, Jaramillo *et al*. (2005), Maire *et al*. (2005), Nugent (2011) and Fanzo *et al*. (2012).

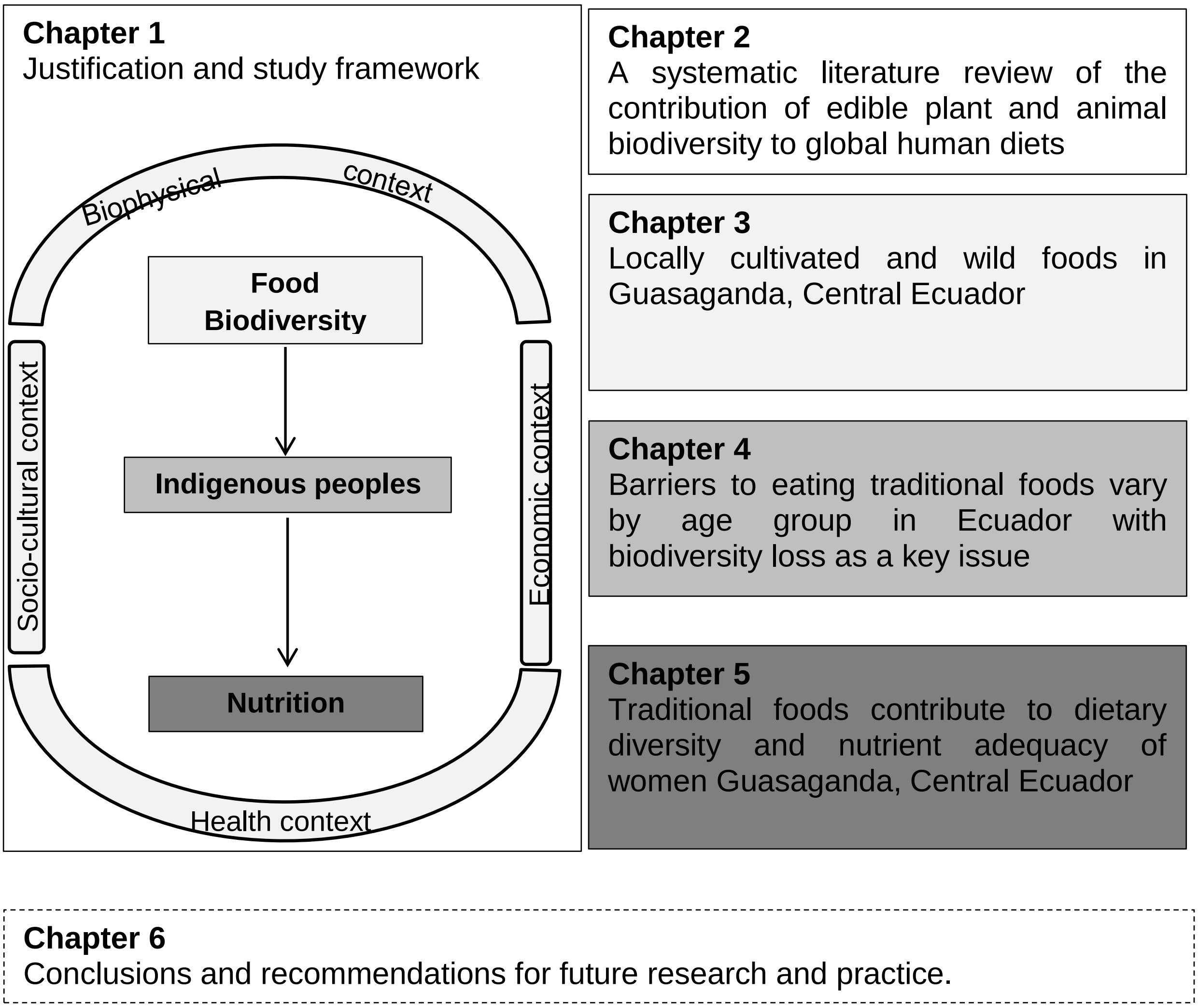

Figure 1.6 Thesis framework

CHAPTER 2: A systematic literature review of the contributions of edible plant and animal biodiversity to global human diets

Based on a research article published as:

Penafiel D, Lachat C, Espinel R, Van Damme P, Kolsteren P. A systematic review of the contributions of edible plant and animal biodiversity to human diets. *EcoHealth*, 2011: 381-399

Abstract

Background: the sustainable use of natural and agricultural biodiversity in human diets can be instrumental in preserving existing food biodiversity more sustainably, address malnutrition and mitigate adverse effects of dietary changes worldwide.

Objective: this systematic review of literature summarises the current evidence of the contribution of plant and animal biodiversity to human diets regarding energy and micronutrient intake and dietary diversification.

Methodology: peer-reviewed studies were collected using 10 databases and predefined search terms. Only primary studies assessing food biodiversity and dietary intake were included, resulting in a total of 40 studies.

Results: seven, fourteen and seventeen studies reported information about energy intake, micronutrient intake and dietary diversification respectively, whereas three studies reported on the three categories together. In general, locally available foods were found to be important sources of energy, micronutrients and dietary diversification in the diet of specifically rural and forest communities of highly biodiverse ecosystems.

Conclusion: current evidence shows local food biodiversity as an important contributor of nutrients to local diets. Findings are, however, limited to populations living in highly biodiverse areas. Research on the contribution of biodiversity to diets of people living in industrialised and urban settings needs more attention. Moreover, instruments that would measure the dietary contribution of local biodiversity are also necessary.

Keywords: nutrition, diet, food, diversity, energy, micronutrient

2.1 Introduction

Biodiversity or biological diversity refers to the variety and variability among all living organisms on earth. Preservation of biodiversity is of paramount importance for sustaining human life. Biodiversity supplies a variety of genetic material that not only directly serves as food, but also contributes to food and nutrition security (Frison *et al.* 2011), and poverty reduction (Frison *et al.* 2005; Johns and Eyzaguirre 2007) whereas is often part of cultural heritage (Wahlqvist 2005). Worldwide, however, biological diversity from wild and agricultural ecosystems is declining (Koopowitz *et al.* 1994). This trend negatively affects livelihoods, particularly for rural people who subsist on foods supplied by local biodiversity.

Currently, about 800 million people suffer from hunger, and many more are deficient in micronutrients (FAO 2015c). In addition, one hundred million of disability-adjusted life years are attributed to chronic diet-related diseases such as cardiovascular disorders and diabetes (Abegunde *et al*. 2007). This double burden of under- and over-nutrition is rapidly increasing in low- and middle-income countries (Monteiro *et al.* 2004). For the latter countries, which highly depend on own food supply, strategies rooted in the sustainable use of biological resources are needed to improve local diets. Unfortunately, the diet of most populations around the world nowadays is based on a limited number of crops (~30) which supply about 95 % of the total ingested energy (FAO 2010f); only a few traditional societies still base their diets on ≥ 200 species (Kuhnlein *et al.* 2009).

Several bioscientists consider that by increasing the number of locally produced fruits and vegetables in the diet, overweight and micronutrient deficiencies could be prevented (Burlingame *et al.* 2006; Flyman and Afolayan 2006; Johns and Eyzaguirre 2006; Englberger *et al.* 2010; FAO 2010c). The promotion of such a biodiverse diet could be a useful and sustainable way to avoid the shift towards energy-dense and non-diversified diets (Kuhnlein *et al.* 1996). Diversified diets have been shown to increase food security (Hoddinott and Yohannes 2002a), to be adequate in diverse nutrients (Ruel 2003; Torheim *et al.* 2004; Steyn *et al.* 2006; Kennedy *et al.* 2007), and to be associated with improved nutritional status (Savy *et al.* 2005).

Several varieties of traditional crops are known to have higher micronutrient content than that of intensively cultivated ones (Burlingame *et al.* 2009; Mouillé *et al.* 2010). The use of local plant and animal varieties in the human diet can also be instrumental to enhance public health since the regular intake of bioactive compounds has been associated with positive health outcomes such as the reduction of serum cholesterol and carcinogen detoxification (Kris-Etherton *et al.* 2002). Additionally, it is imperative to conserve natural biodiversity as a way to meet present and future global food demand (Alder *et al.* 2005; Godfray *et al.* 2010). Sustainable food production can be thus achieved by combining environmental and public health strategies such as policies (Lang *et al.* 2001).

Against a background of continuing biodiversity loss (Koopowitz *et al.* 1994) and dietary changes (Kuhnlein *et al.* 1996) as highlighted above, the Convention on Biological Diversity launched the scientific “cross-cutting initiative on biodiversity and human nutrition” (CBD 2006). Its objective is to mainstream the sustainable use of biological diversity to increase dietary diversity, and to tackle both under- and over-nutrition. The general aim of the initiative is not only to reduce hunger, achieve food security and improved nutrition but also to promote sustainable agriculture which is also the aim of SDG2 (UN 2015c). This initiative acknowledges the need to review current knowledge of the links between biodiversity and human nutrition. Indicators have been proposed to evaluate food composition (FAO 2008) and consumption of food biodiversity (FAO 2010a) to monitor progress towards biodiversity preservation targets. The proposed indicators refered to a list of dietary assessment methodologies which are recommended to be used to document the diversity of plants, animals and other organisms used for food.

To date, however, no systematic literature review on the contribution of biodiversity to human diets is available. Lack of such evidence impairs the development of adequate biodiversity preservation strategies to set benchmarks that include dietary diversity as a key principle. In addition, it is unclear which methodologies are currently applied to measure and document the presence of biodiversity in diets. Because the topic is multidisciplinary, the use of commonly acceptable approaches that combines biodiversity and nutrition evaluation methodologies has made the study of biodiverse diets difficult.

This literature review was necessary for the construction of our hypothesis as summarises the current evidence of the contribution of plant and animal biodiversity to human diets. In this review, biodiversity was conceptualised as presented in *Chapter 1* (FAO 2008 and 2010a). Additionally, we used the word 'food biodiversity' when referring to the diversity of plants, animals and other organisms used for food. The term TF and local foods are also defined in *Chapter 1*.

We systematically reviewed all available information on the dietary contribution of biodiversity in terms of 3 categories:

i) energy intake, as an overall indicator of healthy diets (FAO/WHO 1995), and because of its contribution in reducing energy malnutrition;
ii) micronutrient intake, as a proxy for the prevention of micronutrient deficiencies (FAO/WHO 1998); and
iii) dietary diversity, as a reflection of overall dietary quality and nutrient adequacy (Ruel 2003).

2.2 Methodology

Initially, peer-reviewed articles for this review were searched for in May 2010 in 10 free-access bioscience databases, i.e. IngentaConnect, ISI Web of Knowledge, Science Direct, WorldCat (multidisciplinary databases); Cochrane Library, EMBASE and PubMed (life science, biomedical databases); Bioline International (bioscience database for developing countries), AGRICOLA and AGRIS (agricultural databases). The initial search syntax was based on keywords listed in the manuals of FAO and CBD of biodiversity and sustainable diets (FAO 2010d). The syntax we used was: '(food OR diet OR nutrition) AND biodiversity', combined with wildcards (i.e. *, $), and used indexed terms (i.e. MeSH terms) specific to the respective database. The detailed search syntax for each database is included in Table 2.1.

Then, Google Scholar was used to search for documents using additional keywords to those mentioned above. A second search was conducted in August 2017 to update the first search done in 2010. The 2017 search was conducted only using Science Direct since this database provided most peer review selected papers in the first search. Finally, all searched titles and references were imported into a reference software (Endnote X2, The Thompson Corporation, NY, USA) which was also used to separate all retrieved literature according to 3 categories (i.e. energy intake, micronutrient, dietary diversity). This refinement was conducted for energy and micronutrient intake, and dietary diversification using the keywords ‘energy’, ‘energy intake’, ‘micronutrient’, ‘dietary diversity’, and ‘food diversity’ (Figure 2.1). The main objective of this refinement was for us to make clear statements about the nutrition contribution of biodiversity whether for macronutrients, micronutrients or dietary diversity using as criteria adequate indicators. For instance, authors used kcal as an indicator to report energy intakes, mg or µg for micronutrients and scoring system for dietary diversity. By reading the methodology, we identified if results reported energy intakes, micronutrient intakes or dietary diversification or the three together (for example the documents from the second search). The use of adequate indicators is important to make correct statements about nutrient contribution of foods or food groups in current nutrition research.

Table 2.1 Search strategies used to retrieve documents on biodiversity and its contribution to human diets

Database	Activity	Search term
AGRICOLA	Search (English) (articles)	Database Name: Article Citation Database Search Request: Command = (food OR diet OR nutrition) AND biodiversity
	Refinement (energy)	(food OR diet OR nutrition) AND biodiversity AND energy
	Refinement (micronutrient)	(food OR diet OR nutrition) AND biodiversity AND micronutrient
	Refinement (dietary diversity)	(food OR diet OR nutrition) AND biodiversity AND "dietary diversity"
AGRIS	Search (all fields)	(food OR diet OR nutrition) AND biodiversity
	Limits (language) (articles)	(food OR diet OR nutrition) AND biodiversity; English, Spanish, French, Dutch, Portuguese
Bioline International	Search (all publications)	biodiversity, AND, food
	Refinement (energy intake)	(by hand)
	Refinement (micronutrient intake)	(by hand)
	Refinement (dietary diversity)	(by hand)
EMBASE	Search (limits)	'food'/exp/mj OR food OR 'diet'/exp/mj OR diet OR 'nutrition'/exp/mj OR nutrition AND ('biodiversity'/exp/mj OR biodiversity) AND ([article]/lim OR [article in press]/lim OR [review]/lim) AND ([biochemistry]/lim OR [immunology and hematology]/lim OR [pediatrics]/lim OR [public health]/lim) AND ([dutch]/lim OR [english]/lim OR [french]/lim OR [portuguese]/lim OR [spanish]/lim) AND [humans]/lim AND [embase]/lim
	Refinement (energy)	AND energy
	Refinement (micronutrient)	AND micronutrient
	Refinement (dietary diversity)	AND dietary AND diversity

Table 2.1 Con't

Database	Activity	Search term
IngentaConnect	Search (title/keywords/abstract) in articles	(food OR diet* OR nutrition) AND biodiversity
	Refinement (energy intake)	(food OR diet* OR nutrition) AND biodiversity AND energy
	Refinement (micronutrient intake)	(food OR diet* OR nutrition) AND biodiversity AND micronutrient
	Refinement (dietary diversity)	(food OR diet* OR nutrition) AND biodiversity AND dietary diversity
ISI web of knowledge*	Search (by topic in Web of Science® and Inspec® databases)	(food OR diet* OR nutrition) AND biodiversity
	Limits (publication type and language)	Topic=((food OR diet* OR nutrition) AND biodiversity). Refined by: Document Type=(ARTICLE OR REVIEW) AND Languages=(ENGLISH OR FRENCH OR PORTUGUESE OR SPANISH). Timespan=All Years.
	Refinement (energy)	Topic=((food OR diet OR nutrition) AND biodiversity). Refined by: Document Type=(ARTICLE OR REVIEW) AND Languages=(ENGLISH OR FRENCH OR PORTUGUESE OR SPANISH) AND Topic=(energy). Timespan=All Years.
	Refinement (micronutrient)	Topic=((food OR diet OR nutrition) AND biodiversity). Refined by: Document Type=(ARTICLE OR REVIEW) AND Languages=(ENGLISH OR FRENCH OR PORTUGUESE OR SPANISH) AND Topic=(m*cronutrient). Timespan=All Years.
	Refinement (dietary diversity)	Topic=((food OR diet* OR nutrition) AND biodiversity). Refined by: Document Type=(ARTICLE OR REVIEW) AND Languages=(ENGLISH OR FRENCH OR SPANISH OR PORTUGUESE) AND Topic=(diet* diversity). Timespan=All Years.
	Refinement (food diversity)	Topic=((food OR diet* OR nutrition) AND biodiversity). Refined by: Document Type=(ARTICLE OR REVIEW) AND Languages=(ENGLISH OR FRENCH OR SPANISH OR PORTUGUESE) AND Topic=(food variety). Timespan=All Years.
PubMed*	Search (by topic)	(food OR diet OR nutrition) AND biodiversity
	Limits (English, French, Spanish, Dutch, Portuguese, MEDLINE, PubMed Central)	(food OR diet OR nutrition) AND biodiversity Limits: English, French, Spanish, Dutch, Portuguese, MEDLINE, PubMed Central
	Refinement (energy)	(food OR diet OR nutrition) AND biodiversity AND energy
	Refinement (nutrient)	(food OR diet OR nutrition) AND biodiversity AND micronutrient
	Refinement (dietary diversity)	(food OR diet OR nutrition) AND biodiversity AND (dietary diversity)

*Database used for the second and third search of October 2010, and September 2015, respectively.

Table 2.1 Con't

Database	Activity	Search term
Science direct	Search (all fields)	ALL ((food OR diet OR nutrition) AND biodiversity)
	Limits (subject) (only articles)	((food$ OR diet* OR nutrition) AND biodiversity) Agricultural and biological science, environmental science, Medicine and Dentistry, Nursing and Health professions
	Limits (topics)	((food$ OR diet* OR nutrition) AND biodiversity) AND EXCLUDE (topics, "national park,food web,microbial community,sustainable development,forest management,biological control,fatty acid,soil microbial,community structure")
	Refinements (energy intake)	(((food$ OR diet* OR nutrition) AND biodiversity) AND EXCLUDE (topics, "national park,food web,microbial community,sustainable development,forest management,biological control,fatty acid,soil microbial,community structure")) and energy intake
	Refinements (micronutrient)	(((food$ OR diet* OR nutrition) AND biodiversity) AND EXCLUDE (topics, "national park,food web,microbial community,sustainable development,forest management,biological control,fatty acid,soil microbial,community structure")) and micronutrient$
	Refinements (dietary diversity)	((((food$ OR diet* OR nutrition) AND biodiversity) AND EXCLUDE(topics, "national park,food web,microbial community,sustainable development,forest management,biological control,fatty acid,soil microbial,community structure")) and 'dietary diversity') and dietary diversity AND EXCLUDE(smi, "6845,4972,6776,5819,6035,5995,6806,6963,5163,5836,5161,5934","Journal of Arid Environments,Aquaculture,Estuarine, Coastal and Shelf Science,Marine Pollution Bulletin,Deep Sea Research Part II: Topical Studies in Oceanography, Ecological Economics,Gastroenterology,Molecular Phylogenetics and Evolution,Soil Biology and Biochemistry,Science of The Total Environment,Small Ruminant Research,Ecological Modelling")
The Cochrane library of Systematic Reviews	Search (all text)	(food OR diet OR nutrition) AND biodiversity
Worldcat	Search (keywords, subject title)	'kw:(food OR diet OR nutrition) AND biodiversity'
	Limits (English and articles)	'kw:(food OR diet OR nutrition) AND biodiversity' > 'Article' > 'English'
	Refinement (energy intake)	'kw:(food OR diet OR nutrition) AND biodiversity AND energy intake' > 'Artikel' > 'Engels'
	Refinement (micronutrient)	'kw:(food OR diet OR nutrition) AND biodiversity AND micronutrient' > 'English' > 'Article'
	Refinement (dietary diversity)	'kw:(food OR diet OR nutrition) AND biodiversity AND (dietary diversity)' > 'Article' > 'English'
Second Search in Science Direct 2017	Search syntax	Results found for pub-date > 2010 to 2017 and "((food OR diet OR nutrition)) and biodiversity" AND LIMIT-TO (topics, "specie, agricultural, food, brazil, agriculture, rice") AND LIMIT-TO (content type, "JL,BS","Journal"

We screened articles following the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses and STrengthening the Reporting of OBservational studies in Epidemiology project (STROBE 2007; Moher *et al.* 2009). Initially, only articles in the field of agriculture, biodiversity and nutrition were selected for further screening. Studies on animal nutrition, biofuels, food production simulations and/or modelling, microbiology, soil, and genetically modified organisms together with short communications were excluded. We used reviews as secondary sources for obtaining interesting references to articles which were hand-searched in Google scholar. A second screening was conducted by reading the abstracts' methodology and then selecting only studies on nutritional or dietary assessment of food biodiversity. When the methodology used was not clear from reading the abstract, the full text was reviewed with the help of a second scientist as a method for quality control. Due to time limitation, the documents from the second search were only revised by the first author.

Full-text evaluation of selected articles was carried out independently by the author of this thesis and a second scientist (CL) to reduce bias. When there was disagreement, we consulted a third scientist (PK) for triangulation. All involved scientists have a strong background in nutrition science and are highly familiar with food biodiversity. Eligibility criteria for selection of full papers for further review were i) the study had to be an original study; ii) contribution of wild and cultivated food (plant or animal) biodiversity in the human diet was assessed; and iii) results reported quantitative food or nutrient intakes. Search was done for all years (depending on the coverage of each database) and restricted to English, French, Spanish, Dutch, and Portuguese because the authors could read those languages. This screening approach allowed us to review studies with quantitative results on the consumption of food biodiversity.

We summarised the results in a table which format is recommended by FAO to report nutritional indicators of biodiversity (FAO 2010a). This summary table was used to structure our findings and discuss the results. The results are presented in Table 2.2 for three categories on the contribution of biodiversity to diets (i.e. energy intake, micronutrients contributions and dietary diversity). Table 2.3 presents the results of the second search (2017) that retrieved 7 studies that reported results in all three categories.

Table 2.2 Articles (n= 34) reporting on the contribution of biodiversity to energy intake, micronutrient intake and dietary diversification

Category	**Reference**	**Study design**	**Findings**
Energy intake	Begossi and Richerson (1993)	Randomly selected 12 families in Brazil	Local animal consumption, mainly of fish, contributes 564.1 kcal/person/day
	Kuhnlein *et al.* (2004)	Randomly selected HHs in 3 Canadian arctic regions: 797 in Yukon, 1,007 in Dene and 1,604 in Inuit	Ten to 36 % of total energy intake is derived from traditional foods. Mean total energy intake (kJ/day), and percentage of energy from protein of meals containing traditional foods is higher than from meals without traditional foods
	Mennen and Mbanya (2000)	Convenience sample of one rural and one rural area in Cameroon: 1,058 (HHs) urban and 746 (HHs) rural for survey, 156 people for food-intake study	Ten local foods delivered 52 % (in rural) to 47 % (in urban) of total energy, with cassava providing 10 % of total energy
	Orban *et al.* (2006)	Samples of whitefish *Coregonus lavaretus* in three italian lakes: Bolsena, Bracciano, and Salto	A serving of 150 g of whitefish *Coregonus lavaret*us would contribute 35 % to 40 % of daily recommended protein intake for adults and less than 10 % of the daily recommended fat intake
	Rais *et al.* (2009)	Randomly selected HHs in two areas of India: 349 HHs including 2441 adults in Tarikhet, and 263 HHs including 1729 adults in Ukhimath	Agricultural production contributes 13.6 to 17.8 GJ/year, which is 34 % (Tarikhet) to 52 % (Ukhimath) of required energy per HHs (7 members)
	Rajasekaran and Whiteford (1993)	Randomly selected HHs of 3 groups in India: marginal farmers, permanent labourers and wage labourers: 20% of all HHs, for each group	Local rice-crab production contributes to 32 % (wage labourers) and 23 % (marginal farmers) of Recommended Daily Allowance of protein of resource-poor HHs. 5,820 kcal/day consumed in peak crab season
	Roche *et al.* (2008)	Convenience sample of Peruvians: 49 mothers and 34 children	Traditional diets (all foods, including 1 kg cassava/day eaten by adults and 0.65 kg/ day by children) contribute to more than 90 % of total energy intake

HHs refers to households, kg to kilogram, kcal to kilocalory.

Table 2.2 Con't

Category	Reference	Study design	Findings
Micronutrient intake	Davey *et al.* (2009)	One hundred and seventy-one *Musa* genotypes from Cameroon, Uganda, Hawaii/USA, Philippines and Cambodia.	Eating 100 g/day (fresh weight) of bananas containing the highest pro-vitamin A carotenoids could provide ~95 % of vitamin A Estimated Average Requirements for children, and 47 % for adults
	Englberger *et al.* (2006)	Thirteen *Pandanus tectorius* cultivars from Marshall Islands	Normal consumption patterns (20 to 50 fruit/day by adults and 5 fruit/day by children) of any of the 10 *pandanus* cultivars could contribute to recommended intakes of carotenoids
	Englberger *et al.* (2010b)	Ten banana cultivars from Solomon Islands	Eating 0.4 to 6.6 fruits from 7 Fe'I banana cultivars (characterised by upright bunches) containing high pro-vitamin A carotenoids could contribute to meet estimated vitamin A requirements of adults and pre-school children
	Englberger *et al.* (2009)	Eleven *Pandanus tectorius* cultivars from Micronesia	Normal consumption patterns (up to 50 fruits/day) of *pandanus* cultivars could contribute to meet recommended intakes of vitamin A intake for women
	Englberger *et al.* (2008)	Thirty-four *Cyrtosperma merkusii* cultivars from Micronesia	Consumption patterns of starchy foods (up to 1000g/day), including *Cyrtosperma,* could contribute to meet vitamin A requirements
	Hatloy *et al.* (1998)	Randomly selected 77 Mali HHs with children	Diets with Food Variety Score of 15 and Dietary Diversity Score of 5 were nutritional adequate (Mean Adequacy Ratio of 0.75 including Fe, riboflavin, niacin, vitamin C, Ca, folic acid, and vitamin A)

HHs refers to households, Fe refers to iron, Ca refers to calcium.

Table 2.2 Con't

Category	Reference	Study design	Findings
Micronutrient intake	Kuhnlein *et al.* (2006)	Randomly selected HHs in 3 Arctic regions: 797 in Yukon, 1,007 Dene and 1,604 in Inuit	Inuit diets are nutrient-adequate for Vit A, with 23 % of total Vit A coming from traditional foods: for Dene, Yakon, and Inuit the percentage of cholecalciferol coming from traditional-food portions is 62 %, 54 % and 87 % respectively; whereas for α tocopherol it was 37 % , 24% and 37 %
	Ogle *et al.* (2001a)	Randomly sampled HHs on two regions in Vietnam: 211 (HHs) in Mekong Delta, 103 (HHs) in central highlands. Samples of 28 vegetable species	Naturally occurring vegetables (meaning that these collected from the wild) contribute with 16 (Central Highlands) to 30 % (Mekong Delta) to recommended daily allowance for Vit A, with 5 % to 6 **%** for Zn, and 40 % for Ca
	Ogle *et al.* (2001c)	Convenience sample of ♀ adults in two regions in Vietnam: 211 in Mekong Delta, 103 in central highlands Samples of 16 vegetable species	Fourteen and 21% of total folate intakes is provided by wild vegetables in Central-highlands, and Mekong Delta respectively. From 44 % (Mekong Delta) to 46 % (Central highlands) of the dietary folate is supplied by staple foods (including cassava, rice and sweet potato)
	Roche *et al.* (2008)	Convenience sample of Peruvians: 49 mothers and 34 children	Greater Traditional Food Diversity Scores are associated (partial correlation from 0.38 to 0.64) with higher Fe, thiamine, riboflavin, and Vit A intakes in women and children
	Roos *et al.* (2007a)	Twenty-nine selected fish species in Cambiodia	Local fish availability (50 to 74 g person/day) could contribute to meet 5 % to 15 % of total Vit A Daily Recommended Intake
	Roos *et al.* (2003)	Convenience sample of Bangladesh HHs: 59 fish-producing HHs, 25 non-fish producers HHs	The intake of small indigenous fish species has Nutrient Contribution Ratios of up to 40 % for Vit A, 31 % for Ca, and 9 % for Fe
	Roos *et al.* (2007b)	Convenience sample of 31 Cambodian HHs. Selected 16 fish species	A serving of sour soup meal, containing 49 g *Esomus longimanus*, could contribute to 45 % of daily median Fe requirements
	Singh and Garg (2006)	Six cereals, 9 vegetables and 20 spices in India	Consumption of local spices (25 g/day) contributes to 7.5 % of Daily Dietary Intake for Cr, Fe, Mn and Zn, and 5 % for Cu, P, Se

HHs refers to households, Vit A refers to vitamin A, Fe refers to iron, Zn refers to zinc, Cr refers to chromiun, Mn refers to manganese, Se refers to selenium, ♀ refers to female.

Table 2.2 Con't

Category	Reference	Study design	Findings
Dietary Diversification	Akrofi *et al.* (2008)	Convenience sample of HHs in Ghana: 32 HIV+ and 48 HIV- HHs	Homegardens contribute to Dietary Diversity Score of 6 to 5.8 on HIV- and 6.6 to 6.8 HIV+ HHs, local foods include 9.7 crop species, 2.6 vegetables species, 2.8 fruit species
	Batal and Hunter (2007)	Convenience sample in Lebanon: focus groups with 52 adults: 28 ♀ + 24 ♂; 799 adults surveyed: 48 % ♀ + 52 % ♂	Local recipes are prepared using 10 wild edible plants
	Begossi and Richerson (1993)	12 randomly selected families in Brazil	Local animal consumption of fishermen families is based on 65 foods of animal and plant origin
	Dovie *et al.* (2007)	Convenience sample of randomly selected 45 HHs in South Africa	Mean daily wild edible herb consumption of 0.2 ± 0.05 kg are based prominently on *Cleome gynandra, Cleome monophylla, Amaranthus hybridu, A. thunbergii, Bidens pilosa*, and to a lesser extent of *Cucumis zeyheri*, and *Corchorus tridens*
	Ekesa *et al.* (2008)	Multistage random sampling of 114 HHs in Kenya	Agricultural biodiversity contributes to 48.5 % of dietary diversity of school children. About 46 % of sampled children have a Food Variety Score from 13 to 17, but also 45 % eat less than 12 food items
	Frei and Becker *(*2004)	Convenience sample. Interviews with 36 Philipine HHs	Local diets consist of 51 upland varieties of rice, 13 species of vegetables and 20 species of fruit, with rice being eaten 3 times/day
	Hatloy *et al.* (1998)	Randomly selected 77 HHs with children in Mali	A total of 75 food items compose local diets, in a population with a mean Food Variety Score of 20.5 (consuming at least 13 different foods and a maximum of 29) and a mean Dietary Diversity Score of 5.8
	Kennedy *et al.* (2005)	Randomly selected 313 HHs covering 10 villages in Bangladesh	Consumption of local rice varieties is based on 21 different cultivars
	Lykke *et al.* (2002)	Convenience sample of HHs in 2 areas of Burkina Faso: 8 HHs in Silmogou and 5 HHs in Ningare corresponding to 26 adults in total	Local meals, eaten in a frequency of 1.8 to 2.9 times/day, contain 4.5 to 6.1 food items/meal, and 30 to 45 food items/day. Local diets are based on 52 food items

HHs refers to households, ♀ refers to female and ♂ to male.

Table 2.2 Con't

Category	Reference	Sample design	Findings
Dietary diversification	Nebel *et al.* (2006)	Convenience sample of Italians: 18 adults for the field study 36 elderly for in-depth interview 7 HHs including 22 adults for the food intake study	Local diets consist of 40 wild food species
	Nordeide *et al.* (1996)	Cluster sampling of HHs in 2 areas in Mali: 179 urban and 111 rural for the rainy season, and 148 urban and 102 rural for the dry season. Two focus groups	Local diets include 7 species of green leaves, 11 fruit species, 4 species of roots, one seed and one flower. Also, 26 different fruits used only gathered in rainy season
	Ogle *et al.* (2001b)	Convenience sample of Vietnamese ♀ adults in 2 regions: 211 in Mekong Delta and 103 in central highlands	Women's diets with Food Variety Scores ≥ 21 comprise a higher variety of vegetables than those with low food variety scores (≤15), locally 62 species of vegetables are eaten
	Osemeobo (2001)	Convenience sample of 2 rural markets, 16 settlements, and 1,025 stakeholders in Nigeria	Wild foods ate everyday embrace 27 wild gathered plants, this mostly in rural areas where foods are coming mostly from natural forests
	Passos *et al.* (2007)	Convenience sampling of 459 Brazilian adults	Local patterns of food consumption include 6.6 meals containing fish/week, and 11 fruits/week. A total of 40 fruit-species is eaten
	Pieroni *et al.* (2005)	Convenience sample of traditional eating on Italians: 850 adults for the survey and 86 elderly in the interviews	Seventy-five taxa of non-cultivated and semi-cultivated local food plants and mushrooms are consumed in different frequencies
	Rais *et al.* (2009)	Randomly selected HHs in 2 Indian areas: 349 HHs including 2,441 adults in Tarikhet, and 263 HHs including 1,729 adults in Ukhimath	Local diets consist of 15 species of local field crops (rice, wheat, soybean), ~27 species of local vegetables, ~21 species of local fruits
	Roche *et al.* (2008)	Convenience sample of Peruvians, 49 mothers and 34 children	Traditional diets are based (but not limited to) 10 food items. Mean Traditional Food Diversity Score for women of 9.5 ± 3.5 and 8.7 ± 3.6 for children
	Steyn *et al.* (2001)	Convenience sample of 39 informants eating wild greens, and sample of 32 species in South Africa	Thirty-two wild leafy vegetables are consumed locally. Eight species are eaten in a frequency of 5 to 7 times/week, 8 species are eaten three to 4 times/week, three species are eaten three to 7 times / week; minimum 5 different species eaten in a week

HHs refers to households, ♀refers to female and ♂to male.

Table 2.3 Summary table of studies, from updated search (2017) that reported energy, micronutrient and dietary diversification

Reference	Study design	Findings		
		Energy	Micronutrient	Dietary diversification
Remans *et al*. (2011)	A random sample of 50 to 60 farms on three villages. In total,170 farms of Sub-Saharan Africa were studied	Functional Diversity for all macronutrients is 46.73 ± 9.75	Functional Diversity for vitamins is 41.94 ± 24.48 and for minerals is 32.21±10.56	A total of 77 edible species were reported
Termote *et al.* (2012)	Cross-sectional/convenience sample of villages in Congo, two multiple-pass 24-hour dietary recalls in 363 urban (Kisangani) and 129 rural (Turumbu) women, species identification/ethno botanical investigation	Energy contribution of 14 food groups 45 % of energy comes from roots and tubers in the Turumbu village	Most women in all samples had vitamin A, vitamin C and riboflavin intakes above recommended daily allowance	Consumption of 15 wild edible plants was reported (1 wild yam, two wild nuts, 4 wild leafy vegetable, three wild fruits and 5 wild spices)
Powell *et al.* (2013)	Systematic sampling from a list of HHs with children under five years old provided by village leaders in Tanzania Seven-day food-use questionnaire and two 24-hour recalls Species identification	39.3 % of protein comes from the intake of wild foods foods from the farm contribute with 32.4% and 32.7 % to fat and protein consumption	Wild foods provide a percentage of vitamin A (31.2 %), vitamin C (20.2 %) and iron (19.2 %). Foods from the farms contribute to 69.8 % of vitamin C	Ninety-two species of wild foods were collected from the forest. Food Variety Score of 38 in mothers and 39 in their children (wet season); and 5.5 food groups were consumed per week
Boedecker *et al.* (2014)	Convenience sample of villages in Benin, random selection of HHs, one hundred and twenty women from the Holli ethnic group, two interactive 24-hour recalls	Wild edible plants contribute to less than 1 % of total energy intake	6 mg of cupper is provided by eating wild edible plants, which is 13 % of total cupper intake	13 wild foods were listed per person, and a total of 61 were documented of which 48 were botanically identified. Women Dietary Diversity Score of 5.1 was significantly different to those not eating wild edible plants
M'Kaibi *et al.* (2015)	Cross-sectional study in rainy and dry season. Repeated dietary recalls (24H) were collected from 525 randomly selected households in Kenya, interviewing the mother of pre-school children.	NAR for energy and protein was of 0.36, 0.42, respectively.	NAR higher than 0.7 were reported for B6, C, Thiamine, Folate and Iron.	Agricultural biodiversity accounts for 26 items; 23 domesticated and 3 wild.

Table 2.3 Con't

Reference	Study design	Findings		
		Energy	Micronutrient	Dietary diversification
Bogard *et al*. (2015)	Chemical analysis of fish from single pooled samples of 54 fish, shrimp and prawn species (monsoon season), from local markets and fish landing sites in Mymensingh, Sylhet, Khulna and Cox's Bazar districts in Bangladesh. Also, fish from inland capture and ponds.	The total energy content varied greatly with a range of 267–1020 kJ/100 g; and with 50/g fish intake per day it highly varies.	Consumption of three species of fish and one species of prawn would meet ~25 % of the iron RNI for pregnant women and infants. Fourteen species would meet ~50% of the calcium RNI for pregnant and lactating women, and 18 species that would meet ~50% of the RNI for infants. Three species could potentially contribute >25% of vitamin A RNI for pregnant and lactating women and infants in a standard portion (50 and 25g, respectively). For pregnant women and infants, 13 and 21 species respectively, would potentially contribute >100% of the daily B12 RNI in a standard portion.	55 fish species were analysed for energy, protein, fat, moisture and ash composition, and are assumed to be consumed by adults at 50 g/day and by children at 25 g/day.
Sibhatu *et al.* (2015)	Secondary data from Indonesia (674 farms), Kenya (397 farms), Ethiopia (2,045 farms), and Malawi (5,114 farms). Cross-sectional and cross-country study	NA	NA	Food Variety Score of Indonesia 29.58 (8.11), Kenya 24.68 (4.64), Ethiopia 7.91 (2.31), and Malawi 16.68 (6.72). Dietary Diversity score (pooled) of 7.99 +/- 2.84. Number of healthy food groups 5.51 +/- 1.97 and 6.13 +/- 4.75 crop/livestock species.

2.3 Results

2.3.1 General findings

Figure 2.1 presents the search process, the number of studies initially retrieved, and the number of excluded studies. Finally, a total of 40 studies was selected for this review. We initially retrieved 7, 14 and 17 studies related to energy intake, micronutrient intake and dietary diversification, respectively. Five studies reported findings for two categories. An updated search, in 2017, retrieved six studies which were evaluated based on the three categories. The studies were mainly carried out in areas of high biodiversity in some low- and middle-income countries and focused on the dietary contribution of local foods (whether from wild or agricultural sources) particularly from plant origin (as indicated in Table 2.4). Only 5 studies assessed the contribution of local foods in the diet of populations in high-income countries, being the traditional diet of Canada (Kuhnlein *et al.* 2004; Kuhnlein *et al.* 2006) and Italy (Pieroni *et al.* 2005; Nebel *et al.* 2006; Orban *et al.* 2006) the focus of study. All studies were descriptive and mostly based on convenience sampling.

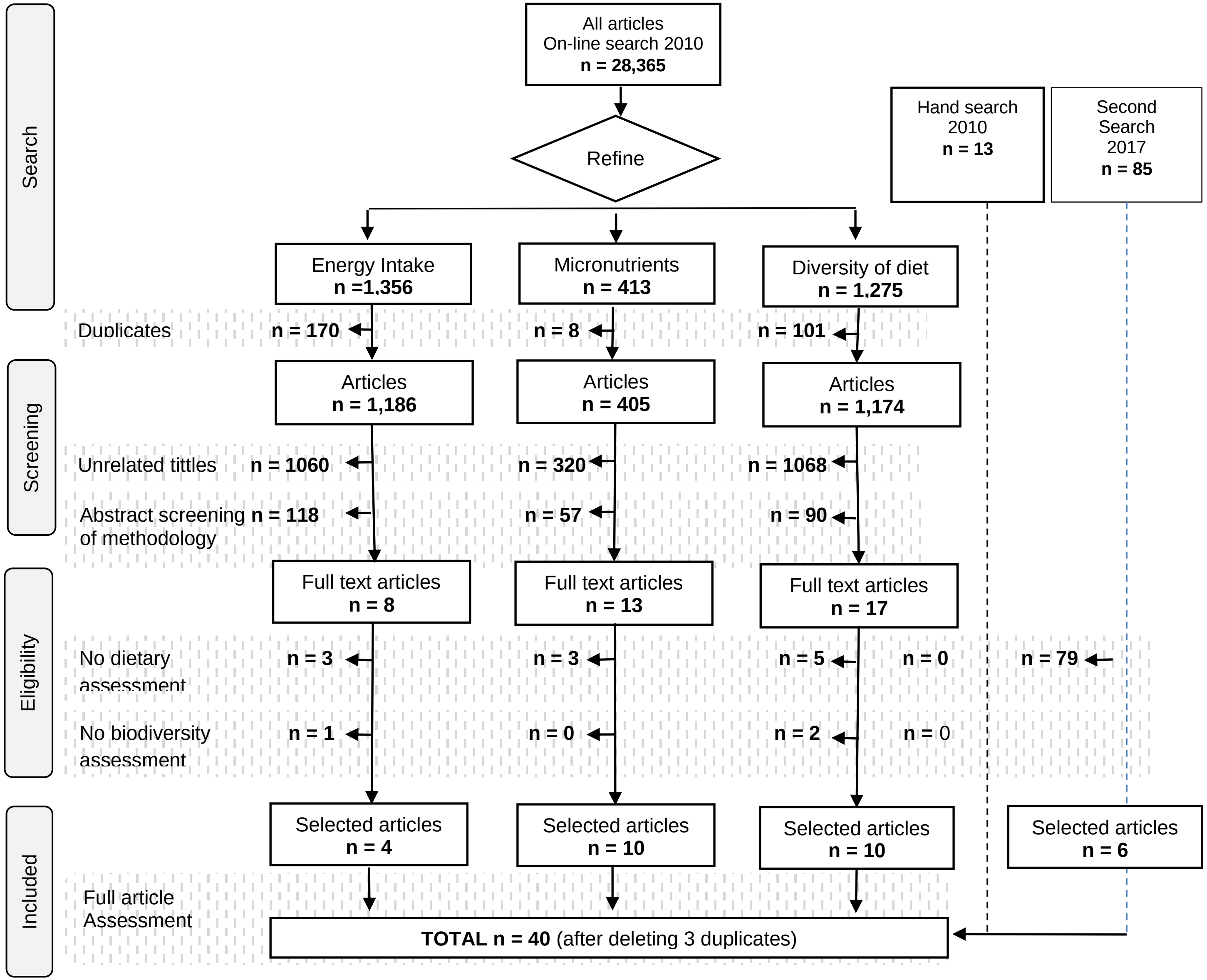

Figure 2.1 Flow diagram of search strategy and selection process of articles on the contribution of biodiversity to human diets. n refers to the number of studies (own source)

Table 2.4 Investigated geographical regions of studies on food biodiversity and diets

Region	Country	Investigated foods	Reference
Africa	Benin	Only wild edibles	Boedecker *et al.* (2014)
	Burkina Faso	All local foods	Lykke *et al.* (2002)
	Cameroon	Local *Musa* cultivars	Davey *et al.* (2009)
		All local foods	Mennen and Mbanya (2000)
	Congo	Wild edibles	Termote *et al.* (2012)
	Ethiopia	Farm foods	Sibhatu *et al.* (2015)
	Ghana	Home garden foods	Akrofi *et al.* (2008)
	Kenya	Only agricultural foods	Ekesa *et al.* (2008)
		All local plants	Remans *et al.* (2011)
		All local foods	M'Kaibi *et al.* (2015)
		Farm foods	Sibhatu *et al.* (2015)
	Mali	Only local foods	Hatloy *et al.* (1998)
		Wild gathered plants	Nordeide *et al.* (1996)
	Malawi	All local plants	Remans *et al.* (2011)
		Farm foods	Sibhatu *et al.* (2015)
	Nigeria	Wild plants	Osemeobo (2001)
	South Africa	Wild edible herbs	Dovie *et al.* (2007)
		Wild edible greens	Steyn *et al.* (2001)
	Tanzania	Wild foods	Powell *et al.* (2013)
	Uganda	Local *Musa* cultivars	Davey *et al.* (2009)
		All local plants	Remans *et al.* (2011)
Middle East	Lebanon	Local wild plants	Batal and Hunter (2007)
North	Italy	Traditional wild-edible plants	Nebel *et al.* (2006)
		Local whitefish	Orban *et al.* (2006)
		Local food plants	Pieroni *et al.* (2005)
	Canada	Traditional Arctic foods	Kuhnlein *et al.* (2004); Kuhnlein *et al.* (2006)
Oceania	Hawaii	Local *Musa* cultivars	Davey *et al.* (2009)
	Marshall Islands	Local *Pandanus tectorius* cultivars	Englberger *et al.* (2006)
	Micronesia	Local P*andanus tectorius* cultivars	Englberger *et al.* (2009)
		Local *Cyrtosperma merkusii* cultivars	Englberger *et al.* (2008)
	Solomon Islands	Local *Musa* cultivars	Englberger *et al.* (2010b)
South America	Brazil	Local animals	Begossi and Richarson (1993)
		Local fruits	Passos *et al.* (2007)
	Peru	Wild edibles	Roche *et al.* (2008)
South East Asia	Cambodia	Local *Musa* cultivars	Davey *et al.* (2009)
		Local freshwater fish	Roos *et al.* (2007a,b)
	Indonesia	Farm foods	Sibhatu *et al.* (2015)
	Philippines	Local *Musa* cultivars	Davey *et al.* (2009)
		Agricultural foods	Frei en Beker (2004)
	Vietnam	Wild vegetables, and staple foods	Ogle *et al.* (2001a,b,c)
South Asia	India	Agricultural products	Rais *et al.* (2009)
		Crab in rice fields	Rajasekaran and Whiteford (1993)
		Local spices	Singh and Garg (2006)
	Bangladesh	Local rice cultivars	Kennedy *et al.* (2005)
		Local small fish	Roos *et al.* (2003)
		Local fish species	Bogard *et al*. (2015)

2.3.1.1 Biodiversity and energy intake

The 7 studies on energy intake reported a variety of outcome indicators including per capita energy intake of local foods (Begossi and Richerson 1993), proportion of total energy derived from local foods (Mennen and Mbanya 2000; Kuhnlein *et al.* 2004; Roche *et al.* 2008), and contributions of locally produced foods to energy requirements (Rajasekaran and Whiteford 1993; Orban *et al.* 2006; Rais *et al.* 2009). None of the studies quantified the energy intake from foods that were identified down to species level, which did not allow us to associate the total energy contribution of the species eaten with the energy requirements.

Studies quantifying dietary intake as percentage of total energy supplied by local foods included Mennen *et al.* (2000), Kuhnlein *et al.* (2004), Roche *et al.* (2008). Moreover, these studies used only common names to refer to the food source. Reported energy contribution from local foods ranged between 10 % to 90 %, whereby the latter was associated with the consumption of about 10 local foods from farms (Mennen and Mbanya 2000), forest (Roche *et al.* 2008) or Arctic areas (Kuhnlein *et al.* 2004). Among these, several local or TFs including (but not limited to) banana, cassava, moose, caribou, seal, and whitefish were found to be essential caloric contributors in the investigated areas.

One study (Begossi and Richerson 1993) reported energy intakes (per capita) from local animal food consumption (mainly fish) and named the species eaten, providing thereby some insight in the relevance of the local fish species to local fishing. However, results are based on intake estimations and are limited to animal consumption, during lunch and dinner time.

Various studies reported the contribution of local foods to the total energy required daily. Results show that from 23% (Rajasekaran and Whiteford 1993) to 52% (Rais *et al.* 2009) of the recommended daily energy intake could be supplied by local foods. These studies, however, were only based on estimated consumption of crab and agricultural products, respectively. Also, one study reported that recommended protein and fat intakes could be reached by eating a serving of local fish per day (Orban *et al.* 2006).

2.3.1.2 Biodiversity and micronutrient intake

Studies on the contribution of local food intake to meet micronutrient recommendations reported nutrient adequacy of diversified diets (Hatloy *et al.* 1998; Roos *et al.* 2003), the proportion of micronutrient intake supplied from local foods (Ogle *et al.* 2001c; Kuhnlein *et al.* 2006; Singh and Garg 2006; Roche *et al.* 2008), and the percentage of recommended intake covered by the regular consumption of local foods (Ogle *et al.* 2001a; Englberger *et al.* 2006; Roos *et al.* 2007a; Roos *et al.* 2007b; Englberger *et al.* 2008; Davey *et al.* 2009; Englberger *et al.* 2009; Englberger *et al.* 2010). The two studies evaluating micronutrient adequacy of local diets were based on actual intake; one used mean adequacy ratio (Hatloy *et al.* 1998) and the other used nutrient contribution ratio (Roos *et al.* 2003) to present results. The latter reported that 31 % and 40 % of the recommended intake of calcium and vitamin A, respectively, was met by consuming small fish species. Hatloy *et al.* (1998) reported Mean Adequacy Ratios (MAR) for 7 micronutrients as well as energy, fat and protein, but did not detail the different food sources. He and his colleagues found that eating a high number of foods (FVS $\geq$ 23) and food groups (DDS $\geq$ 6) is correlated with adequate intakes of micronutrients, mainly vitamin A and C in children.

Three studies evaluated the contribution of TF to micronutrients (Ogle *et al.* 2001c; Kuhnlein *et al.* 2006; Roche *et al.* 2008). Kuhnlein *et al.* (2006) and reported that 87 %, 23 %, and 37 % of total daily intake of cholecalciferol, vitamin A, and tocopherol, respectively, is supplied by TFs. Ogle *et al.* (2001c) reported the contribution of wild vegetables and staple foods to folate only, with values of 21 % and 46 %, respectively, whereas Roche *et al.* (2008) studied the contribution of all TFs to more than one micronutrient (i.e. iron, thiamine, riboflavin, and vitamin A).

Studies focusing on micronutrient composition of some target foods were mainly based on chemical analyses, and used dietary and consumption pattern estimations. The latter was mainly reported as grams of food consumed per day, to report eating contribution to daily recommendations. The study of Davey *et al.* (2009) and those of Englberger *et al.* (2006, 2008, 2009, 2010b) identified several vitamin A-rich *Musa* fruit varieties together with some *Cyrtosperma merkusii*, or *Pandanus tectorius* that could, under normal consumption patterns, potentially contribute to meet dietary recommendations for vitamin A. In addition, Ogle *et al.* (2001a) found that the daily intake of some naturally occurring vegetables can potentially contribute to meet up to 30 and 40 % of the recommended allowances of vitamin A and calcium, respectively. Roos *et al.* (2007a, and b) reported local fish consumption to contribute with 15% and 45% of the daily vitamin A and iron requirements, respectively. The study of Singh *et al.* (2006) showed that the daily intake of a spice mix could contribute with 5 % to 7 % of the recommended daily intake of some micronutrients (i.e. chromium, iron, manganese, zinc, copper, phosphorous, and selenium).

2.3.1.3 Biodiversity and dietary diversity

Studies investigating the contribution of biodiversity to dietary diversification reported mainly the number of food items within the diet (Begossi and Richerson 1993; Nordeide *et al.* 1996; Osemeobo 2001; Steyn *et al.* 2001; Frei and Becker 2004; Kennedy *et al.* 2005; Pieroni *et al.* 2005; Nebel *et al.* 2006; Batal and Hunter 2007; Dovie *et al.* 2007; Passos *et al.* 2007; Rais *et al.* 2009). Also, only a few studies used specific indicators of dietary diversification (Hatloy *et al.* 1998; Ogle *et al.* 2001b; Akrofi *et al.* 2008; Ekesa *et al.* 2008; Roche *et al.* 2008). The number of foods reported as part of any habitual diets varied considerably. The highest reported values included 76 fish and other animal species (Begossi and Richerson 1993), 32 and 62 vegetable species (Ogle *et al.* 2001b; Steyn *et al.* 2001), 26 and 40 fruit species (Nordeide *et al.* 1996; Passos *et al.* 2007), and between 21 and 51 varieties of rice (Frei and Becker 2004; Kennedy *et al.* 2005). We did not find a standard frequency of consumption used, so that studies investigated a wide frequency interval, going from several times per day to few times per year, whereas some indicated seasonal variations (data not shown).

Dietary diversity was reported as Dietary Diversity Scores (DDS), Food Variety Scores (FVS), Traditional Food Diversity Scores (TFDS) and Women Dietary Diversity Score (WDDS). Ekesa *et al.* (2008), Hatloy *et al.* (1998) and Ogle *et al.* (2001b) reported on the level of dietary diversity of local diets using both DDS and FVS. DDS is defined as the number of food groups consumed over a period. To report DDS, food items were grouped under 8 or 12 food groups according to the context. FVS is defined as the total number of food items consumed over a period (usually 7 days). The highest reported value of FVS was 20.5, indicating that about 21 food items were consumed during a week in the investigated area. A more specific indicator used was the TFDS (Roche *et al.* 2008), which is the number of traditional/local foods present in a diet assessed by a 24-hour dietary recall. The indicator showed that diets of Peruvian communities in the Amazon area contain a mean of 9.5 local, wild and cultivated, foods per day.

2.3.1.4 Biodiversity and energy intake, micronutrient intake and dietary diversity

After our publication in 2011 (Penafiel *et al.* 2011), six studies were published reporting different indicators for energy and micronutrient intakes and dietary diversification. Half of these studies conducted systematic plant identification. The focus of three studies was wild edible plants (Termote *et al.* 2012; Powell *et al.* 2013; Boedecker *et al.* 2014), whereas other three focused on farm foods (Remans *et al.* 2011; M'Kaibi *et al.* 2015; Sibhatu *et al.* 2015a). One study focused on small fish species (Bogard *et al.* 2015). Wild edibles are studied because they appear to be nutritionally valuable, a cheap source of micronutrients and are widely available in periods of food shortage (Termote *et al.* 2011). Based on this hypothesis, the contribution of wild edibles to total energy and micronutrient intakes, DDS (using 6 food groups by Termote *et al.* 2012) and WDDS (using 9 food groups by Boedecker *et al.* 2014) is reported. Results show, however, that the contribution of wild foods to macro and micronutrients is marginal. When assessing the contribution of cultivated foods in the farms (crops and livestock) to the diet, novel approaches are lately used, such as the Nutritional Functional Diversity (NFD) by Remans and colleagues, and the regression between production diversity and dietary diversity by Sibhatu and colleagues. The study of Bogard and colleagues used a variety of analytical methods (such as High-Performance Liquid Chromatography, Gas-Liquid Chromatography) to report the macro and micronutrient composition of small fish species (captured and from aquaculture) identified with scientific names, but the intake of the latter was inferred.

Importantly, documenting the food source during the food intake interviews was fundamental to identify if the food was wild or cultivated. Studies on wild foods were done in Africa and focused on interviewing women as they are responsible for TFs cultivation and cooking in the studied countries. Termote *et al.* (2012), Powell *et al.* (2013) and Boedecker *et al.* (2014) resolved that the consumption of wild foods was low, and therefore its contribution to energy and micronutrient requirement was marginal. The contribution of wild foods to requirements was low probably because the infrequent/seasonal and small portions consumed (Termote *et al.* 2012; Powell *et al.* 2013; Boedecker *et al.* 2014). Nevertheless, wild foods were found to contribute importantly to dietary diversity (ibid.).

2.3.2 Additional findings

All the methodologies applied by the different consulted studies estimated the contribution of biodiversity to diets and were very diverse. We identified three different methodological approaches to measure biodiversity in the diet that we categorised as dietary assessment methods (tools that describe or record diets), nutritional assessment methods (tools that estimate nutrient contents of the investigated food items), and local food biodiversity assessment methods (tools to record, identify and list the local edible plants or animals included in the diet). Table 2.5 details the methods used to assess the contribution of biodiversity to the diet.

Table 2.5 Assessment tools (dietary, nutritional and biodiversity) applied by studies exploring biodiversity and its contribution to human diets (n=40)

Assessment	Tool	Reference
Dietary	Focus groups*	Frei *et al.* (2004); Pieroni *et al.* (2005); Batal *et al.* (2007)
	Food frequency questionnaire	Nordeide *et al.* (1996); Mennen *et al.* (2000); Ogle *et al.* (2001a,b,c); Kuhnlein *et al.* (2004); Kuhnlein *et al.* (2006); Ekesa *et al.* (2008)
	Food grouping*	Hatloy *et al.* (1998); Ogle *et al.* (2001b); Frei *et al.* (2004); Akrofi *et al.* (2008); Ekesa *et al.* (2008)
	Intake recall	Begossi *et al.* (1993); Rajasekaran *et al.* (1993); Mennen *et al.* (2000); Roos *et al.* (2003); Kuhnlein *et al.* (2004); Kennedy *et al.* (2005); Pieroni *et al.* (2005); Kuhnlein *et al.* (2006); Passos *et al.* (2007); Akrofi *et al.* (2008); Roche *et al.* (2008), Termote *et al.* (2012), Powell *et al.* (2013), Boedecker *et al.* (2014), M'Kaibi *et al.*(2015),Sibhatu *et al.* (2015)
	Food record/diaries	Mennen *et al.* (2000); Lykke *et al.* (2002); Kuhnlein *et al.* (2004); Kuhnlein *et al.* (2006)
	Food weighing	Hatloy *et al.* (1998); Ogle *et al.* (2001b); Roos *et al.* (2007b)
	Inferred intake/ observations*	Begossi *et al.* (1993); Englberger *et al.* (2006); Orban *et al.* (2006); Singh *et al.* (2006); Roos *et al.* (2007a,b); Englberger *et al.* (2008); Davey *et al.* (2009); Englberger *et al.* (2009); Rais *et al.* (2009); Englberger *et al.* (2010b), Bogard *et al*. (2015)
	Interviews	Osemeobo (2001); Steyn *et al.* (2001); Lykke *et al.* (2002); Frei *et al.* (2004); Nebel *et al.* (2006); Batal *et al.* (2007); Dovie *et al.* (2007); Roos *et al.* (2007b); Rais *et al.* (2009)
	Recipes record	Mennen *et al.* (2000); Ogle *et al.* (2001a); Batal *et al.* (2007); Roos *et al.* (2007b)
Nutritional	Chemical analysis	Ogle *et al.* (2001a); Frei *et al.* (2004); Englberger *et al.* (2006); Kuhnlein *et al.* (2006); Orban *et al.* (2006); Singh *et al.* (2006); Batal *et al.* (2007); Roos *et al.* (2007a,b); Englberger *et al.* (2008); Englberger *et al.* (2009); Englberger *et al.* (2010b), Bogard *et al*. (2015)
	Food composition tables**	Rajasekaran *et al.* (1993); Mennen *et al.* (2000); Ogle *et al.* (2001a,c); Steyn *et al.* (2001); Kuhnlein *et al.* (2004); Kuhnlein *et al.* (2006); Batal *et al.* (2007); Roche *et al.* (2008), Remans *et al*. 2011, Termote *et al.* (2012), Powell *et al.* (2013), Boedecker *et al.* (2014).
Local food biodiversity	Interview (local names)	Rajasekaran *et al.* (1993); Nordeide *et al.* (1996); Hatloy *et al.* (1998); Mennen *et al.* (2000); Ogle *et al.* (2001a,b,c); Osemeobo (2001); Lykke *et al.* (2002); Kuhnlein *et al.* (2004); Kennedy *et al.* (2005); Englberger *et al.* (2006); Kuhnlein *et al.* (2006); Nebel *et al.* (2006); Orban *et al.* (2006); Batal *et al.* (2007); Dovie *et al.* (2007); Passos *et al.* (2007); Englberger *et al.* (2008); Roche *et al.* (2008); Englberger *et al.* (2009); Rais *et al.* (2009); Englberger *et al.* (2010b), M'Kaibi *et al.*(2015)
	Scientific names**	Roos *et al.* (2003); Roos *et al.* (2007a,b), Sibhatu *et al.* (2015)
	Observations/field, market visits (local names) *	Rajasekaran *et al.* (1993); Nordeide *et al.* (1996); Mennen *et al.* (2000); Ogle *et al.* (2001a); Lykke *et al.* (2002); Kennedy *et al.* (2005); Englberger *et al.* (2006); Nebel *et al.* (2006); Orban *et al.* (2006); Singh *et al.* (2006); Dovie *et al.* (2007); Ekesa *et al.* (2008); Englberger *et al.* (2008); Englberger *et al.* (2009); Englberger *et al.* (2010b), Bogard *et al*. (2015)
	Plant / animal identification (scien-tific names)	Nordeide *et al.* (1996); Ogle *et al.* (2001a); Steyn *et al.* (2001); Frei *et al.* (2004); Pieroni *et al.* (2005); Englberger *et al.* (2006); Nebel *et al.* (2006); Batal *et al.* (2007); Passos *et al.* (2007); Akrofi *et al.* (2008); Englberger *et al.* (2008); Davey *et al.* (2009); Englberger *et al.* (2009); Rais *et al.* (2009); Englberger *et al.* (2010b), Remans *et al*. 2011, Termote *et al.* (2012), Powell *et al.* (2013), Boedecker *et al.* (2014)

*considered as indirect assessment, ** obtained from literature

Often, a combination of dietary and nutritional assessments was used (18 studies). Only a few of these studies used a quantified dietary intake assessment (Rajasekaran and Whiteford 1993; Mennen and Mbanya 2000; Kuhnlein *et al.* 2004; Kuhnlein *et al.* 2006; Roche *et al.* 2008; Termote *et al.* 2012; Powell *et al.* 2013; Boedecker *et al.* 2014; Sibhatu *et al.* 2015a). Other studies (Begossi and Richerson 1993; Ogle *et al.* 2001a; Steyn *et al.* 2001; Lykke *et al.* 2002; Kennedy *et al.* 2005; Batal and Hunter 2007; Akrofi *et al.* 2008; Termote *et al.* 2012; Powell *et al.* 2013; Boedecker *et al.* 2014), used a combination of local food biodiversity and dietary assessments, quantifying thereby the intake of local foods and identifying the species involved.

The most frequently applied dietary assessment method was dietary recalls (16 studies), especially on energy intake studies (Begossi and Richerson 1993; Mennen and Mbanya 2000; Kuhnlein *et al.* 2004; Roche *et al.* 2008); followed by food frequency questionnaires (8 studies) which were particularly used to record dietary diversity (Nordeide *et al.* 1996; Ogle *et al.* 2001b; Ekesa *et al.* 2008). Dietary recalls were mostly 24-hour recalls (Rajasekaran and Whiteford 1993; Mennen and Mbanya 2000; Kuhnlein *et al.* 2004; Kennedy *et al.* 2005; Akrofi *et al.* 2008; Roche *et al.* 2008), recalls of specific meals (Begossi and Richerson 1993) and records of various days (Roos *et al.* 2003; Pieroni *et al.* 2005; Passos *et al.* 2007).

Local food biodiversity was mainly documented using a combination of interviews and by field observations (Rajasekaran and Whiteford 1993; Nordeide *et al.* 1996; Mennen and Mbanya 2000; Ogle *et al.* 2001a; Lykke *et al.* 2002; Kennedy *et al.* 2005; Englberger *et al.* 2006; Nebel *et al.* 2006; Orban *et al.* 2006; Dovie *et al.* 2007; Englberger *et al.* 2008; Englberger *et al.* 2009; Englberger *et al.* 2010). These studies belong mostly to the category of dietary diversification. Identification of foods using scientific names was made only in 19 studies which allow identifying which species are important contributors to dietary diversity.

2.4 Discussion

It is of great interest to know in what extent wild and agricultural biodiversity is the key to address the most common nutritional problems in developing countries.

This review presents the available evidence of the contribution of edible plant and animal biodiversity to human diets, information which until now was lacking (CBD 2006). Nutrient contributions, however, appear to be substantial only for specific study areas. We reviewed 40 studies reporting on biodiversity and energy and micronutrient intakes, and dietary diversification. Surprisingly, the number of retrieved studies seems low considering it is a hot topic widely discussed in academia (Johns 2003; Wahlqvist 2003; Frison *et al.* 2006; Toledo and Burlingame 2006; Vinceti *et al.* 2008; Frison *et al.* 2011) and of global public concern.

All information indicated biodiversity to be the mainstay of a variety of plant and animal food products and an important element in local diets. However, this evidence was restricted to highly biodiverse areas and the traditional rural and forest communities. Since the studies concentrated on the diet of people who subsist on locally available foods, the dietary importance of biodiversity is hardly a surprise. It is not surprising that biodiversity investigations have been conceptualised and conducted in areas of high biodiversity, such as tropical forest (Iiyama and Dawson 2016). Results show that a high food biodiversity is necessary but not a sufficient condition to have a biodiverse diet (Termote *et al.*, 2012). A diet based on many species, whether cultivated or wild has shown to be an important contributor to micronutrient intake and dietary diversity (Hatloy *et al.* 1998, M'Kaibi *et al.* 2015, Powell *et al*. 2013, Sibhatu *et al*. 2015). Based on our results we perceive that TFs are a healthy and accessible choice, and therefore the promotion of dietary diversity based on TFs seems imperative for nutritional interventions that aim food sovereignty. However, TF contribution to energy and micronutrient intake is marginal because of the seasonality, under-valorisation, reduced availability and small consumed portions (Boedecker *et al.* 2014).

Answers to the global food security issues of the next generation, however, will require further research and political strategies to feed an increasingly urban population, whether in developed or developing countries. Urbanisation not only leads to loss of arable land, but it also drives intensification of food production systems, mainly intensive agricultural practices (Godfray *et al.* 2010; Agarwal *et al.* 2016). Policy makers will need to carefully consider the role of agricultural and wild biodiversity, local food supply and smallholder agriculture when designing the food system of tomorrow (UN 2010). Our review demonstrates how the current research on biodiversity and diets fails to provide the necessary evidence to design appropriate agro-ecological models on sustainable biodiversity utilisation. However, our results provide with the first evidence to support that a variety of culturally accepted local foods consumed in adequate amount is vital for have healthy diets.

Evidence of biodiversity and energy intake reported mainly the proportion of the total energy supplied by local foods. The latter and all other reported energy outcomes focused on local and TF as essential suppliers of enough calories to the people living in the investigated communities. Daily consumption of local foods is imperative for the food security of people living in traditional or indigenous communities such as rural areas. Nevertheless, the consumption of wild foods was not enough to reach the recommended macronutrient nor micronutrient intakes. People need to be educated towards the consumption of wild fruits and vegetables promoting the benefits of their consumption such as energy and phytochemicals antioxidants) contribution (Bvenura and Sivakumar 2017). Reported outcomes on micronutrient intakes show that regular TF (locally cultivated and wild) consumption in adequate amounts contributes to meet daily micronutrient recommendations. The latter suggests that micronutrient deficiencies can be addressed through local food-based approaches, particularly by the consumption of micronutrient-rich varieties (Tontisirin *et al.* 2002; Krawinkel 2009). Furthermore, the available evidence indicates that diets of people of highly biodiverse areas are diversified by the consumption of a high number of traditional wild (Boedecker *et al.* 2014) and cultivated species (M'Kaibi *et al.* 2015; Sibhatu *et al.* 2015a). It is suggested that seeds and seedlings need to be available for local farmers increasing the availability of TFs (Bvenura and Sivakumar, 2017).

Animal foods were found to be important diversifiers of the diet and to contribute to energy and protein intake. Concerns have been raised, however, on how recommendations should be formulated with regard to the consumption of animal foods. Although animal-source food adds important sources of nutrients to diets of populations in low- and middle-income countries (Allen 2003), the overconsumption of bushmeat in some populations is of current concern (WHO 2003b). Also, environmental concerns have been raised concerning the contribution of the intensive meat production to greenhouse gas emissions, and fisheries on the depletion of oceans (McMichael *et al.* 2007; Bell *et al.* 2009; Godfray *et al.* 2010). In this regard, healthy eating promotion strategies should also incorporate recommendations for sustainable diets. The latter are defined as diets with low environmental impacts, protective and respectful of biodiversity and ecosystems; culturally acceptable, accessible, economically fair and affordable; and nutritionally adequate, safe and healthy (Burlingame *et al.* 2011). A key strategy to promote healthy and sustainable eating portions is to investigate at what level local consumption patterns are sustainable for the environment and to incorporate these into interventions (Auestad and Fulgoni 2015).

Our findings are constrained by the type and nature of the collected information. The reported outcomes varied widely (i.e. many units used to report results and methods to measure intake) and did not allow us to conclude based on the reported outcomes. However, we recommend that when the study design uses randomised sampling, the amount of energy and nutrient intakes from locally cultivated or wild foods can be reported apart to have more precise figures on the contribution of each. When using dietary quality indexes, MAR is a helpful indicator, which needs to be adapted from its original formula by (Madden and Yoder 1972). When calculating the NAR the observed nutrient intake must be divided by its Estimated Average Requirement (EAR) as it is the best estimate for dietary reference intake (which represents 50% probability to cover the nutrient requirements) (Otten *et al.* 2006; Murphy 2008) and not the Recommended Daily Allowance (RDA is 2SD more than the EAR) as originally proposed by Madden and Yoder.

To assess dietary diversification in women, we recommend to use the validated Minimum Dietary Diversity Score for women, merging foods under the 10 required food groups considering the two extra required food categories (i.e. condiments and beverages) (FAO 2014a). MDD-W is a validated proxy dichotomous indicator that performs better than the WDDS to evaluate the micronutrient intake (FAO/FHI360 2016). When establishing the contribution of farm diversity in a single country, a simple count of species within the farm should be compared to a count of species in the diet to avoid that species are underreported when merged into food groups (Berti 2015).

Also, we found that researchers are using a wide variety of methodologies. This could be partially attributed to the use of both biodiversity and dietary assessments by all studies, which we used as pre-condition for the selection of peer review studies. Because it is a multidisciplinary topic, we believe that the use of combined methodologies is necessary to conduct this type of research. As a result, the biggest obstacle for investigating biodiversity and its contributions to human nutrition is the absence of a standardised methodology that quantifies dietary intake of locally produced or wild foods, involves food identification and distinction of species and subspecies, and analyses food composition of the investigated genetic pools. The initiative of FAO on nutrition indicators for biodiversity has given the first step by launching measurement tools and indicators to help to overcome these shortcomings (FAO 2008 and 2010a). To our knowledge, after our review publication (Penafiel *et al.* 2011), the quality of published studies is higher, considering scientist are reporting both biodiversity and nutrition indicators and quantifying dietary energy, micro-nutrient and diversification. The number of evidence reporting biodiversity and nutrition indicators is increasingly contributing to further reviews that show the magnitude of nutrients supplied by local food biodiversity. We find interesting that our review caused a snowball effect resulting in 5 subsequent reviews. The latter focus on biodiversity and nutrition using more specific search terms than ours collecting thereby more evidence of the dietary contribution of cultivated plants or/ and wild plants (Masset *et al.* 2011; Masset *et al.* 2012; Powell *et al.* 2015; Pandey *et al.* 2016; Bvenura and Sivakumar 2017; Jones 2017).

A combination of dietary, health, botanical and agricultural indexed terms and keywords is necessary to retrieve an extensive number of documents which will be refined to increase relevancy to the topic. The use of correct keywords to guide refinement when using several multidisciplinary databases is important to retrieve highly relevant documents for the review. Despite the limited number of studies retrieved in 2011 and updated in 2017 when using the aforementioned search terms, our review must be complemented with similar biodiversity reviews. Mainly, our reviewed articles were mostly indexed under agricultural biodiversity terms. Few studies used quantitative dietary assessments which suggest that research on biodiversity and human nutrition was mainly conducted by botanists and agronomists, and received less attention by nutritionist and health scientists. More recent reviews show an increase in multidisciplinary work which was also a recommendation of our initial review of 2011. The complexity of linking agricultural and health research remains to be a limiting factor when studying the contribution of locally cultivated and wild foods to human nutrition, but research evidence is increasingly showing the efforts to reduce knowledge barriers/gaps. Only future multidisciplinary research, combining appropriate biodiversity and nutritional assessment methodologies, would lead to a better understanding of the dietary contributions of local food biodiversity and diets.

2.5 Conclusion

Biodiversity could contribute to human diets with energy, micronutrient and a variety of foods that count for dietary diversification, particularly in highly biodiverse areas, but strong evidence is lacking. Methodologically, better instruments to quantify the dietary contribution of local biodiversity are needed. A standardised methodology would enable to better substantiate the link between biodiversity and the quality of the diet. Also, using a validated indicator that is measured by following a standard protocol, would allow researchers to make comparisons across countries. More evidence of health benefits associated to highly biodiverse diets would contribute to the design of dietary guidelines which would be based on the concept of sustainable diet. Further research on the contribution of biodiversity to diets of industrialised countries and urban settings is also needed to gain knowledge of biodiversity contributions to other ecosystems.

CHAPTER 3: Locally cultivated and wild foods in Guasaganda, Central Ecuador

Abstract

Background: traditional foods include both wild and domesticated plant and animal species that serve as food in traditional communities, and their availability is key for guaranteeing food security and healthy diets.

Objective: document the number of traditional plants (wild and cultivated), and animal foods (wild and domesticated) found in Guasaganda, Central Ecuador

Methodology: a combination of three methodologies was used: an inventory of plant foods collected from the *Sacha Wiwua* forest (wild plants) and surrounding agricultural land (cultivated), interviews with peasants of 137 farms (cultivated plants), and interviews with 2 different age groups (14 adults and 11 elderly) on animal foods that belong to the food system. Foods were categorised into i) local wild and ii) cultivated, iii) semi-cultivated plant foods; iv) wild, v) domesticated and vi) semi-domesticated animals; and vii) plants used for medicinal purposes.

Results: Forty-nine wild plants and 41 cultivated plants were available for consumption. We also evidenced that 28 wild plants found in the forest were also present in farms (semi-cultivated) showing that domestication is practised. Twenty-two local animal species (13 wild and 9 domesticated) were consumed. Fourteen medicinal plants were consumed. The mean number of plant species at the farms is 3 ± 1.45.

Conclusion: the high diversity of plants and animals available for consumption indicates that traditional diets can be diversified by cultivating and collecting/hunting foods. The main ecosystem service of the forest of Guasaganda is the provision of fruits. Further research should be conducted to document the consumption of the investigated foods, and the nutrient and biochemical content to assess nutrient adequacy of the diet and potential medicinal use.

Keywords: food, fruit and vegetable consumption, nutrition, indigenous people, Ecuador

3.1 Introduction

Tropical forests are biologically diverse ecosystems that contain the highest terrestrial biodiversity per surface area (CBD 2015). They also provide, mainly wild, foods that can contribute to diversified and therefore balanced and healthy diets (Arnold *et al.* 2011; Agarwal *et al.* 2016). Almost 20 % of the global population lives from forest foods. Unfortunately, forests and their biodiversity are quickly disappearing around the world, along with lots of edible plant species that will soon no longer be available for human consumption. Deforestation and the consequent reduction in genetic material that also concerns several food species is affecting diets at local, national and global levels (CBD 2006; Johns and Eyzaguirre 2006; Frison *et al.* 2011).

Forests directly or indirectly supply goods and services that contribute to human nutrition (Vinceti *et al.* 2013; Iiyama and Dawson 2016). To illustrate, 10.9 kg of edible non-timber forest products (NTFPs) were consumed per capita around the world in 2011, with 9.4 kg of NTFPs consumed per person in Latin America alone, whereas only 4 kg/capita were consumed in developed countries (FAO 2014b). Indigenous peoples of Peru get about 90 % of their dietary energy from no less than 200 species collected in the Amazon forest (Roche *et al.* 2008; Kuhnlein *et al.* 2009). In addition, it is estimated that people who consume a high number of Traditional Foods (TFs) have higher intakes of protein, fibre, 6 vitamins and 4 minerals (Roche *et al.* 2008). In the Brazilian Amazon, the consumption of fruits was found to offer an alternative protection from mercury toxicity (from gold-mining activities), as people who consumed 62 fruits in one week exhibited lower mercury intake than those eating mercury-exposed fish (Passos *et al.* 2007). These studies show the invaluable contribution of the Amazon forest to diverse and healthy diets.

One of the adaptation mechanisms that forest people use, when the availability of forest foods is reducing, is to consume annual crops that are cultivated in deforested land (Arnold *et al.* 2011; Nasi *et al.* 2011). Studies on traditional diets show that these contain foods not only from the forest or natural environments (wild foods) but also crops and animals from agricultural production (Kuhnlein and Receveur 1996; Kuhnlein *et al.* 2004; Creed-Kanashiro *et al.* 2009). In the *Usambara* mountains of Tanzania for example, a total of 202 foods is composing the diet, with the forest being the most important source of bushmeat, whereas the farm provides with 82 foods, mainly plant foods (Powell *et al.* 2011). In South-West Nigeria, 27 wild foods and 13 medicinal plants are gathered from natural forests (Osemeobo 2001). In *Buzios* (Brazil), 65 different wild animals are eaten, with fish being the most important source of animal protein (Begossi and Richerson 1993). In the Brazilian Amazon, 40 fruit species are consumed (Passos *et al.* 2007). In two rural districts of *Meru* in Eastern Kenya, 23 cultivated and three wild foods are part of the agricultural biodiversity (M'Kaibi *et al.* 2015).

This study aims to document the number of wild foods that are present in the forest of Sacha Wiwua, Central Ecuador, and foods cultivated in surrounding farms. To know the number of traditional foods (wild and cultivated) is necessary to understand the composition of the traditional food system and use this result for further research to document the diversification of the traditional diet.

3.2 Methodology

Throughout our study, we followed the FAO's guidelines to document underutilised foods and agricultural biodiversity for food and nutrition (FAO 2010e). Because this study required contact with the indigenous community the author of this thesis, who shares the same ethnicity, trained the interviewers and was present in most of the interviews. We used three different methodologies to study 7 food categories. The first method used was an inventory of foods in the forest of Sacha Wiwua, Central Guasaganda. By this approach wild plants (first category) and cultivated plants (second category) were documented. The second methodology used was personal interviews with peasants on cultivated plants and semi-cultivated (third category) present in the farms. The third method used was focus groups with peasants on local wild (fourth category), domesticated (fifth category) and semi-domesticated (sixth) animals that serve as food. Additionally, a seventh category included traditional medicinal plants which emerged from the first two methodologies.

3.2.1 Inventory of forest-plant foods

We collected samples of plants present in the forest of Sacha Wiwua (Central Guasaganda) and surrounding agricultural area to list both wild and cultivated plant foods, respectively. By this method, the first category (wild plants) and the second category (cultivated plants) that serve as food for humans were documented. The inventory was conducted from June to August 2012. The collection of plants and inventory was guided by 5 males and one female local informant who identified the plants with local names and use, and they were our most important source of information. Semi-structured interviews were conducted asking question on the ethnobotanical knowledge. The Ecuadorian Ministry of Environment provided a scientific permit allowing researchers to collect plant samples (Permit N° 03-12IC-FAU-FLO-OPAC/MA).

In the forest (Figure 3.1 a), samples of edible plants were collected in transects in the *Sacha Wiwua* forest and its surroundings (Figure 3.1b) according to literature (Bonham 1989; Elzinga *et al.* 1998). Figure 3.1b shows the transect grid used and mentions the number of grids sampled. Transect sampling was selected because more ground can be inventoried in a period compared with using quadrats, and therefore we combined both methods (Buckland *et al.* 2007). The central transect lines were draw with ropes and measuring tapes. We carefully fixed the transect-lines so that small plants did not overlap the squares.

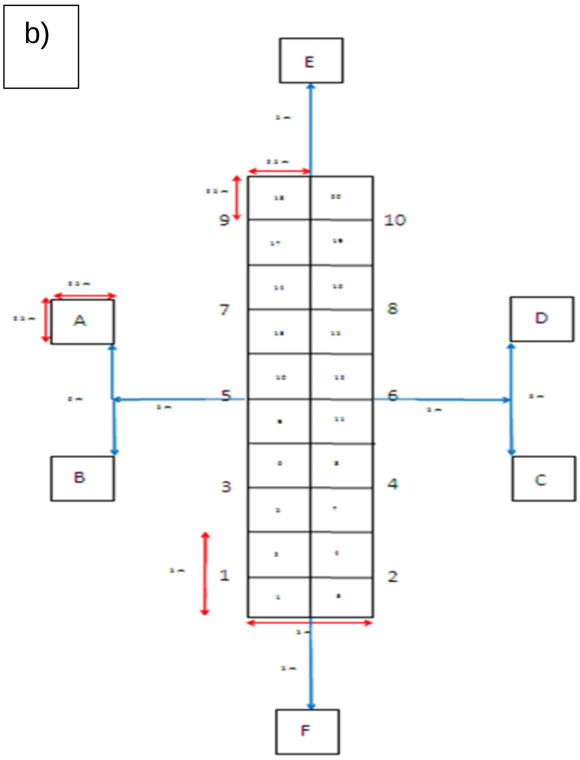

Figure 3.1 a) Photo of *Sacha Wiwua* Forest; b) grid diagram used for the collection of plant samples in the forest of *Sacha Wiwua* (x7) and surrounding agricultural land (x3) in 2012

The sampled forest area involved 1,137.5 m^2 of forest and 375 m^2 of surrounding agricultural land. The forest studied area involved 7 systematic grids formed of 20 central and 6 additional squares (of 2.5 m x 2.5 m each). The latter (from A to F) are located 5 m away from the main grid at the North/South, East/West as shown in Figure 3.1b. There was a distance from grid to grid of a minimum 250 m. Additionally, we subjectively selected three areas around the forest to collect cultivated crops using the interior grid design of 20 squares (of 2.5 m x 2.5 m each also) knowing that around the forest traditional agriculture is practised. Also, it is of our knowledge that the *Sacha Wiwua* forest comprises of 100 ha (forest and agricultural land), therefore, our sampled area covered 0.144% of it.

Each plant found in the transencts was collected and a label was used to record its use (see example in Figure 3.2). Plant samples were collected in duplicate and were prepared *in-situ*. The latter involved drying the leaves in a wooden cabin, and subsequently we placed them between corrugated carton panels and identified them with a unique label. The label listed: country, family, scientific name, author, the area where the plant was collected, a brief taxonomic description, local name, use, name of the botanist who collected the sample, an internal code, and project name. Initial analysis involved identification of collected plants by family and with the collaboration of the local research group who used two books (Gentry 1993; de la Torre *et al.* 2008). Finally, scientific names were confirmed by an herbarium in Quito, Ecuador.

ECUADOR

POLYGONACEAE
Triplaris cumingiana Fisch. & C.A. Mey. ex C.A. Mey.

Det: Felipe Mendoza (ESPOL)

Prov. Cotopaxi, Cantón La Maná, Parroquia Guasaganda; Predio *Sacha Wiwua*.

79° 03' 26'' LW / 2° 08' 59'' LS, BSVp: 579 m.s.n.m: Interior de bosque disturbado. Transectos lineales.

Árbol de fuste recto y copa cerrada, con flores rosadas y fruto con 3 alas.

NV: Fernán Sanchez

Usos: 02 (Alimentos)

Colector: F. Mendoza (ESPOL). Cod. 002 A (013 A)

PROYECTO: "Implementación de un programa de investigación aplicada para el desarrollo agrícola de comunidades rurales en zonas de alta biodiversidad del trópico húmedo occidental de Ecuador". ESPOL, FIMCP-CIR/GHENT UNIVERSITY/ PL-480 /caap.

Figure 3.2 Example of label used for plant identification

The scientific name of each plant was given following the botanical binomial nomenclature and using the official names as provided by the on-line database (www.theplantlist.org, V1.1). The plant use was documented from at least one informant who indicated which part of the plant was edible and whether it was to eat or it has a medicinal use. Apart from documenting plants with edible and medicinal use, we also registered (but are not reported in this thesis) plant species used for animal feed, wood, tools, social or spiritual, toxic, ornamental, beekeeping and environmental protection (a total of 10 uses). According to Aguilar *et al.* (2010) traditional plants with edible use are often inventoried apart from medicinal plants, and it is therefore that we used his recommendations and coded these apart. Also, local informants indicated the plant's edible use according to their traditional perspective (e.g. fruit, vegetable, phloem sap, and starchy food). The importance of using folk classification when studying food biodiversity has been recognised elsewhere (Van den Eyden 2004; Termote 2012). The applied methodology disturbed to the minimum the forest land by collecting only the necessary plant material and following local people who guided us through the forest using existing paths and avoiding ecosystem disturbance. In the results section, foods are listed in alphabetical order according to botanical family and using local names.

3.2.2 Interviews on edible plants at the farm

Another methodology used was conducting personal interviews with peasants on cultivated plants present in their farms. By this method, we documented the number of foods that were cultivated in the farms and semi-domesticated plants. Interviews were conducted from April to June 2011. A convenience sample of 137 farms was studied. All 38 villages of Guasaganda were included in this study reaching 3 to 4 farms per village. We visited the farms and asked at the door for the person in charge of the farm or home garden. By the latter, men (n= 73) and women (n=64) participated in the interviews reducing gender bias. Oral consent was requested to enter the farm. The interviews were guided by a structured questionnaire, with a pre-designed table to write all plants identified as edible by the peasant. The interviewer wrote down the local name of the plant, its use and source. Plant samples were not collected at the farms.

Per farm, the total number of edible plants was reported. Different codes were given to cultivated plants and wild plants. The list of cultivated plants found in the farms was matched with the list of cultivated plants found in the forest using local names. The same was done for wild plants. Those wild plants found in the farms were categorised as semi-cultivated plants (third category).

3.2.3 Interviews on animal foods

This stage of the study was conducted from December 2010 to January 2011. Animal samples were not collected because the legislation in Ecuador does not allow collecting animals or parts of them in forest areas. The protocol for this section of the study was revised and approved by the local *ad hoc* local ethical committee at Escuela Superior Politecnica del Litoral (ESPOL). Interviews were conducted to document all known edible animal species. A convenience sample of 25 people (8 male and 15 female) living in 6 villages of Guasaganda participated voluntarily. Interviewing local people is key to understand food biodiversity as it collects information on the diversity of the ecosystem without disturbing it (Gadgil *et al.* 1993). We requested their participation a couple of days before the interview during visits guided by a local person who was identified by the community as an individual who knows about eating culture (elder). Written consents were obtained from all participants before the interview started.

Participants were grouped into two different age groups, adults from 19 to 56 years and elderly from 56 to 91 years. Interviews were conducted at places familiar to participants, and were recorded by using a Philips digital voice tracer (LFH 0667 DNS) and a microphone. The subjects responded to open-ended questions: i) which are the edible animals that you know are local and can be currently obtained from the forest, rivers or grow on your land? ii) Which foods you know were locally available before but are currently less available or can hardly be found or hunted?. After each question, a free listing exercise was conducted.

3.2.4 Analysis

Qualitative analysis was conducted to the transcripts on animal foods. Interviews were transcribed in English into Microsoft Word document and then imported into NVivo 8 software (QSR, Australia, version 9). To reduce bias, transcripts were coded by the author of this thesis and an additional researcher. The list of animal foods was retrieved by analysing the transcripts using Nvivo 8 using the code “animal food” “wild” and “domesticated”. To report the results, the scientific names of animals were retrieved from the on-line database for Ecuadorian mammals (Burneo and Boada 2012), birds (Freile and Bonaccorso 2011) and freshwater fish (Ramiro 2011) based on the local names and animal description.

Statistical analysis was conducted using S-Plus software (SOLUTIONMETRICS Version 8) to the data obtained from the farms (number of cultivated and semi-cultivated plant foods). Summary statistics were retrieved to observe the central tendency. Kolmogorov-Smirnov tests and box plots were used to examine if the data was normally distributed and if the variances were equal, respectively (data not shown). Since normality condition was not fulfilled and the variances were not equal between groups, a non-parametric test was performed. A non-parametric two sample (Wilcoxon test) one-sided test as used to test if the mean number of semi-cultivated plants was significantly higher than the number of cultivated plants at the farms.

3.3 Results

In total, 112 edible species were documented in this study. This count is the number of locally-available foods of Central Ecuador, Guasaganda reported to the nutritional indicator for food biodiversity for FAO in 2013 (Rittenschober and Charrondiere 2013).

3.3.1 Plant foods

Table 3.1 lists all 90 traditional-local plant species that belong to 35 botanical families which were reported to be edible during the plant inventory. According to our categorisation, 49 plant species were found in the forest and identified as wild, whereas 41 species were found to be cultivated in the farms (identified in grey in Table 3.1). We identified 28 semi-domesticated species which were found in the forest and also in the farms. Also, 4 cultivated edible plants were found in the farms but not in the forest (data not shown). The number of species for each category is illustrated in Figure 3.3.

According to the use reported by participants, out of the 90 plant species, 71 species are eaten as fruits, whereas 7 species as starch source, of only 2 species the phloem sap (the fluid of the plant) is used, 5 species are consumed as vegetables, faba beans (*Vicia faba* L.) as legume, cilantro de monte (*Eryngium foetidum* L.) is used as spice, achiote (*Bixa orellana* L.) as food colorant, coffee (*Coffea canephora* Pierre ex A. Froehner) is used as stimulant, and cacao seed *(Theobroma cacao* L.) is used for chocolate and the aril as fruit. Ninety-one food items add to the list of traditional- local foods since cacao had two uses.

The mean number of plant species present at the farms that serve as food is 3

± 1.45. The mean number of semi-cultivated plants species at the farms that are edible is 2.5 ±1.3, whereas the mean number of plants that are cultivated for food is 1.5 ± 0.8. The mean number of semi-cultivated plants in the farms is significantly higher than the number of cultivated plants with a 95% confidence (p-value<0.001). In average farms have 1.2 cultivated fruits and 1.2 staples; also 1.8 semi-cultivated fruits and 1 semi-cultivated vegetables.

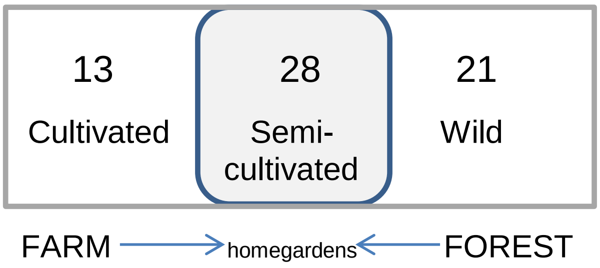

Figure 3.3 Number of locally cultivated, semi-cultivated and wild plants reported as edible in Guasaganda, Ecuador.

Table 3.1 List of traditional plant food species, wild and cultivated, in Guasaganda, Central Ecuador

Botanical family	***Scientific name*** **Author**	***Local name***	**Edible use**	**Plant habitat**
Achariaceae	*Carpotroche longifolia* (Poepp.) Benth.	*Huila*	Fruit pulp	Small tree
Actinidiaceae	*Saurauia tomentosa* (Kunth) Spreng.	*Catón*	Fruit pulp	Tree
Anacardiaceae	*Mangifera indica* L.	*Mango*	Fruit pulp	Tree
Anacardiaceae	*Spondias purpurea* L.	*Obito* *Ciruela*	Fruit pulp	Tree
Annonaceae	*Annona duckei* Diels	*Chirimoya de monte*	Fruit pulp	Tree
Annonaceae	*Annona* sp.*	*Guanábana de monte*	Fruit pulp	Tree
Annonaceae	*Annona cherimola* Mill.	*Chirimoya*	Fruit pulp	Tree
Annonaceae	*Annona muricata* L.	*Guanabana*	Fruit pulp	Tree
Annonaceae	*	*Espinuda*	Fruit	Palm
Apiaceae	*Eryngium foetidum* L.	*Culantro de monte* *Cilantro de monte, Yumbo*	Leaves	Herb
Araceae	*Colocasia esculenta* (L.) Schott	*Papa china*	Starchy corm	Herb
Araceae	*Xanthosoma* sp.*	*Sango*	Starchy corm	Palm
Arecaceae	*Prestoea decurrens* (H. Wendl. ex Burret) H.E. Moore	*Palmito*	Starchy stem	Palm
Arecaceae	*Geonoma interrupta* (Ruiz & Pav.) Mart.	*Chillibo* *Chontilla*	Fruit	Palm
Arecaceae	*Bactris gasipaes* Kunth	*Chontilla* *Chontaduro*	Fruit	Palm
Bignoniaceae	*Cydista aequinoctialis* (L.) Miers	*Bejuco de agua* *Pascuenque*	Phloem sap	Vines
Bixaceae	*Bixa orellana* L.	*Achiote*	Seed colorant extract	Shrub
Cannaceae	*Canna indica* L.	*Atsera*	Starchy corm	Herbaceous
Caricaceae	*Vasconcellea microcarpa* (Jacq.) A. DC.	*Col de monte*	Leaves	Shrub
Caricaceae	*Vasconcellea* sp.1*	*Papaya de monte*	Fruit pulp	Tree
Caricaceae	*Vasconcellea* sp.2*	*Oroyuyo*	Fruit pulp	Tree
Caricaceae	*Carica papaya* L.	*Papaya*	Fruit pulp	Tree
Clusiaceae	*Garcinia sp.**	*Mamey/mango de monte* *Peladera*	Fruit pulp	Tree
Clusiaceae	*Tovomita weddelliana* Planch. & Triana	*Capulí de monte*	Fruit pulp	Tree
Convolvulaceae	*Ipomoea batatas* (L.) Lam.	*Camote*	Starchy root	Guaco
Cucurbitaceae	*Gurania* sp.*	*Zapallo de monte*	vegetable	Guaco
Dioscoreaceae	*Dioscorea trifida* L. f.	*Chambo* *Papa chambo*	Starchy tuber	Guaco
Euphorbiaceae	*Manihot esculenta* Crantz	*Yuca*	Starchy root	Shrub

Table 3.1 Con't

Botanical family	***Scientific name* Author**	***Local name***	**Edible use**	**Plant habitat**
Fabaceae	*Arachis pintoi* Krapov. & W.C. Greg.	*Mani forrajero Pasto forraje*	Seed	Herb
Fabaceae	*Inga* sp.1*	*Guaba de monte*	Aril as fruit	Tree
Fabaceae	*Inga* sp.2*	*Guaba de monte*	Aril as fruit	Tree
Fabaceae	*Inga* sp.3*	*Guaba de monte*	Aril as fruit	Tree
Fabaceae	*Inga vera* Willd.	*Guaba*	Aril as fruit	Tree
Fabaceae	Inga sp.4*	*Guabo común*	Aril as fruit	Tree
Fabaceae	*Inga insignis* Kunth	*Guaba de bejuco Guaba*	Aril as fruit	Tree
Fabaceae	*Inga silanchensis* T.D. Penn.	*Guabo negro*	Aril as fruit	Tree
Fabaceae	*Vicia faba* L.	*Haba*	Legume	Herb
Lauraceae	*Persea americana* Mill.	*Aguacate*	Vegetable	Tree
Malvaceae	*Herrania* sp.*	*Cacao de monte*	Aril as fruit	Tree
Malvaceae	*Matisia giacomettoi* Romero	*Zapote de monte*	Fruit pulp	Tree
Malvaceae	*Matisia* sp.*	*Molinillo Zapote Limón*	Fruit	Tree
Melastomataceae	*	*Obillo*	Fruit pulp	Tree
Moraceae	*Artocarpus altilis* (Parkinson) Fosberg	*Fruta de pan*	Seed	Tree
Moraceae	*Brosimum utile* (Kunth) Oken	*Sandi, cacaolcillo*	Fruit pulp	Tree
Musaceae	*Musa acuminata* Colla	*Orito*	Fruit flesh	Herbaceous
Musaceae	*Musa x paradisiaca* L.	*Plátano verde, barraganete*	Fruit flesh	Herbaceous
Musaceae	*Musa acuminate* Colla	*Guineo de seda, banano*	Fruit flesh	Herbaceous
Myrtaceae	*Syzygium malaccense* (L.) Merr. & L.M. Perry	*Pera costena*	Fruit pulp	Shrub
Myrtaceae	*Eugenia stipitata* McVaugh	*Arazá*	Fruit pulp	Tree
Myrtaceae	*Psidium guajava* L.	*Guayaba, guayabo*	Fruit pulp	Tree
Passifloraceae	*Passiflora* sp.1*	*Granadilla de monte Maracuyá de monte*	Fruit pulp	Guaco
Passifloraceae	*Passiflora* sp.2*	*Granadilla de monte Maracuyá de monte*	Fruit pulp	Guaco
Passifloraceae	*Passiflora foetida* L.	*Badea de monte Enredadera de monte*	Fruit pulp	Guaco

Table 3.1 Con't

Botanical family	***Scientific name* Author**	***Local name***	**Edible use**	**Plant habitat**
Passifloraceae	*Passiflora* sp.3*	*Granadilla de monte Maracuyá de monte*	Fruit pulp	Guaco
Passifloraceae	*Passiflora* sp.4*	*Granadilla de monte Maracuyá de monte*	Fruit pulp	Guaco
Passifloraceae	*Passiflora* sp.5*	*Granadilla de monte Maracuyá de monte*	Fruit pulp	Guaco
Passifloraceae	*Passiflora mixta* L. f.	*Taxo*	Fruit pulp	Guaco
Passifloraceae	*Passiflora edulis Sims*	*Maracuyá*	Fruit pulp	Guaco
Passifloraceae	*Passiflora foetida* L.	*Granadilla de monte Maracuyá de monte*	Fruit pulp	Guaco
Passifloraceae	*Passiflora edulis f. flavicarpa* O. Deg.	*Maracuyá*	Fruit pulp	Guaco
Poaceae	*Saccharum officinarum* L.	*Caña de azúcar*	Phloem sap	Herbaceous
Poaceae	*Zea mays* L.	*Maíz*	Seeds	Herbaceous
Polygonaceae	*	*Hueso de mono Piñuelo Motilon*	Fruit pulp	Tree
Primulaceae	*Clavija* sp.*	*Sacha naranjo Naranjita, pepa de mono, naranjo de monte*	Fruit pulp	Tree
Rosaceae	*Rubus* sp.*	*Mora de monte*	Fruit drupelets	Shrub
Rubiaceae	*	*Maní de monte*	Pod seed	Herba-ceous
Rubiaceae	*Borojoa patinoi* Cuatrec.	*Borojó*	Fruit pulp	Tree
Rubiaceae	*Coffea canephora* Pierre ex A. Froehner	*Café aromático*	Seed	Tree
Rutaceae	*Citrus medica* L.	*Lima*	Fruit pulp	Tree
Rutaceae	*Citrus x limon* (L.) Osbeck	*Limón*	Fruit pulp	Tree
Rutaceae	*Citrus reticulata* Blanco	*Mandarina*	Fruit pulp	Tree
Rutaceae	*Citrus maxima* (Burm.) Merr.	*Naranja*	Fruit pulp	Tree
Rutaceae	*Citrus* sp.1*	*Toronja*	Fruit pulp	Tree
Rutaceae	*Citrus sp.2**	*Toronja*	Fruit pulp	Tree
Rutaceae	*Citrus* sp.3*	*Limón Mandarina*	Pulp juice	Tree

Table 3.1 Cont'

Botanical family	***Scientific name*** **Author**	***Local name***	**Edible use**	**Plant habitat**
Salicaceae	*Casearia quinduensis* Tul.	*Vara blanca* *Naranjito* *Sacha naranjo* *Manglillo* *Naranjo de monte* *Tarquino*	Aril as fruit	Tree
Sapotaceae	*Chrysophyllum argenteum subsp. panamense* (Pittier) T.D. Penn.	*Caimito*	Fruit pulp	Tree
Sapotaceae	*Pouteria multiflora (*A.DC.) Eyma	*Logma*	Fruit pulp	Tree
Sapotaceae	*Chrysophyllum* sp.*	*Cauje*	Fruit pulp	Tree
Sapotaceae	*Chrysophyllum argenteum* Jacq.*	*Caimito*	Fruit pulp	Tree
Solanaceae	*Solanum sesiliflorum* Dunal	*Naranjilla de monte*	Fruit pulp	Shrub
Solanaceae	*Solanum* sp.*	*Naranjilla de monte*	Fruit pulp	Shrub
Solanaceae	*Solanum lycopersicum* L.	*Tomate*	Fruit pulp	Herbaceous
Solanaceae	*Solanum* sp.*	*Naranjilla*	Fruit pulp	Shrub
Solanaceae	*Solanum quitoense* Lam.	*Naranjilla*	Fruit pulp	Shrub
Solanaceae	*Capsicum lycianthoides* Bitter	*Tomate de monte, símbalo, huan huan*	Fruit pulp	Herbaceous
Solanaceae	*Solanum circinatum* Bohs	*Tomatillo* *Tomate de arbol*	Fruit pulp	Sub shrub
Sterculaceae	*Theobroma cacao* L.	*Cacao*	Seed for chocolate Aril as fruit	Tree
Urticaceae	*Pourouma* sp.*	*Uva de monte*	Fruit pulp	Tree

* indicates species that were not fully identified; when a number is added, it refers to another species which was not fully identified but was different from the rest and therefore inventoried apart.
Cells in grey show cultivated plant foods.

3.3.2 Animal foods

Table 3.2 lists all 22 traditional animal species identified as edible, whereas Figure 3.4 shows the number of each category. It includes 8 freshwater fish species, 10 different mammals and 4 fowl. Thirteen species were reported during the open interviews as wild from which 10 were identified as danger of extinction, therefore, less consumed (marked with an asterisk in Table 3.2). Nine species were domesticated and marked in grey in Table 3.2. Only one participant mentioned having a *sahino* in his farm (semi-domesticated) and to be the only person domesticating this animal. Out of the 22 animal species, three fish species (*campeche, cholia and pampanito*) were not identified with scientific names due to the inadequate description during the interviews. The total number of food items of animal origin added up to 27 because chicken, cow and pig had more than one use.

Table 3.2 List of traditional edible animal species consumed in Guasaganda, Ecuador in 2011

English name	*Scientific name*	*Local name*	Food use
Armadillo*	*Cabassous centralis*	*Cachicambo / Ardamillo*	Flesh
Small mouth fish*	*Ichthyoelephas humeralis*	*Bocachico*	Flesh
Campeche fish	Not identified	*Campeche*	
Cavia	*Cavia porcellus*	*Cuy*	Flesh
Chicken	*Gallus gallus domesticus*	*Gallina / Pollo*	Flesh Eggs
Cholia fish *	*Not indentified*	*Cholia*	Flesh
Cow	*Bos taurus*	*Vaca / Res*	Flesh, Liver Stomach
Deer *	*Mazama nemorivaga*	*Venado*	Flesh
Duck	*Cairina moschata domestica*	*Pato*	Flesh
Fox *	*Cerdocyon thous*	*Zorro*	Flesh
Goose	*Not identified*	*Ganzo*	Flesh
Guatuza *	*Dasyprocta punctata*	*Guatuza*	Flesh
Huajia fish *	*Physiculus talarae*	*Pescado Huajia*	Flesh
Paca *	*Cuniculus paca*	*Guanta*	Flesh
Pig	*Sus domesticus*	*Chancho* *Cerdo domestic*	Flesh Liver Intestine
Sheep	*Ovis aries*	*Borrego domestic*	Flesh
Tachuela fish *	*Corydoras hastatus*	*Tachuela*	Flesh
Tilapia fish	*Tilapia mossambique*	*Tilapia*	Flesh
Turkey	*Meleagris gallopavo*	*Pavo*	Flesh
Old lady fish	*Andinocara sp.*	*Vieja*	Flesh
Pampanito fish	Not identified	*Pampanito*	Flesh
Sahino *	*Tayassu pecari*	*Cerdo sahino*	Flesh

* Indicates wild animals reported as undomesticated/hunted, and in danger of extinction
Cells in grey are domestic animals.

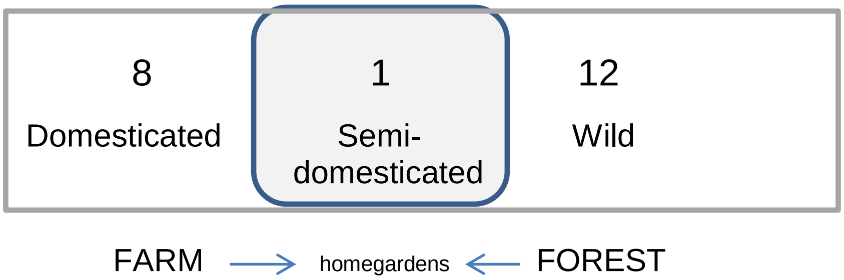

Figure 3.4 Number of locally domestic, semi-domesticated and wild animals reported as edible in Guasaganda, Ecuador.

3.3.3 Additional findings

Plants which are not in the group of wild or cultivated plant foods because their consumption does not provide energy (no intake in grams) were categorised as medicinal plants. The interviewed people often reported plants that were consumed not as food but with medicinal purposes. Mainly, medicinal plants are consumed in the form of infusions and include 14 different plants (mainly the leaves). These drinks are known as "*aguas aromaticas*". Table 3.3 includes all medicinal plants which were found to be collected from the wild (n=7, inventoried in the forest) or to be grown in farms or home gardens (n=7).

Table 3.3 Locally wild or semi-cultivated (in grey) plants with medicinal use in Guasaganda, Ecuador

English name	***Scientific name author***	***Local name***	**Medicinal use**
Basil	*Ocimum basilicum* L.	*Albahaca*	To cure cold, rheumatic pain, inflammation, and blue marks
Lemon grass	*Cymbopogon citratus* (DC.) Stapf	*Hierba luisa*	To cure lungs, to heal blue marks, and for relaxing
Mastrante	*Lippia alba* (Mill.) N.E.Br. ex Britton & P.Wilson	*Mastrante*	To heal stomach pain, for good memory, to cure kidneys
Guayusa	*Piper sp.**	*Guayusa*	To heal headaches, energising
Guanabana	*Annona muricata*	*Guanabana*	To heal fever, and cancer
Balm	*Melissa officinalis* L.	*Toronjil*	To heal stomach pain and gastritis
Mint	*Mentha x piperita*L.	*Menta/Hierba buena*	To heal headaches and to relax
Lemon	*Citrus limon* (L.)Osbeck	*Limon*	For taste and aroma
Mandarine	*Citrus reticulata* Blanco	*Mandarina*	For taste and aroma
Orange	*Citrus maxima* (Burm.) Merr.	*Naranja*	For taste and aroma
Grapefruit	*Citrus sp. **	*Toronja*	For taste and aroma
Valerian	*Valeriana officinalis L.*	*Valeriana*	To relax, to sleep better
Urtica	*Urera sp**	*Ortiga*	To cure headaches,
Urtica	*Urtica sp.**	*Ortiga verde*	stomach pain, fever, inflammations, blue marks and detox.

*food not fully identified down to species level

The traditional diet is composed of mainly three meals and between meals a fruit or a medicinal plant infusion is consumed. The first meal is mainly composed of staple foods which are accompanied by a small portion of protein that can be eggs of cheese, and a drink which can be a mug of milk a plant infusion. The most popular traditional starchy foods for breakfast are plantain (*Musa* x *paradisiaca* L.), cassava (*Manihot esculenta* Crantz) and maize (*Zea mays* L). Plantain is consumed in the morning, prepared as *bolon* (ball of fried plantain with cheese or pork), *tamales* (minced plantain wrapped in plantain leaves and steamed), *patacones* (fried plantain that is crushed in a sunny form), *tortillas (*semioval minced plantain*), majado (*mashed platain*), chifles (*very thin slice of plantain*)* or *asado* (plantain roasted on coal). Cassava is often cooked or fried, whereas maize is usually cooked or used to prepare *tortillas* or *humitas* (minced maize and wrapped in maize leaves).

For lunch, plantain is popularly used as an ingredient in many different soups or *sancochos* (thick soup prepared with meat, chicken or pork that also has traditional vegetables). Plantain is also used as main thickener element of *sango*, *cazuela* and *coladas*. In *sango* and *cazuela* (very thick plantain preparation with pork or seafood prepared in a ceramic pot) and it is accompanied with rice. Also, plantain flour is used to prepare *coladas* (traditional thick drink boiled with milk).

Late in the afternoon people collect fruits from the forest or the farm, and share a couple of them with the family. The most consumed traditional fruits are bananas (*Musa acuminata* Colla), oranges (*Citrus maxima* (Burm.) Merr.), papaya (*Carica papaya* L.), mandarins (*Citrus reticulata* Blanco) and baby bananas (*Musa acuminata* Colla). These fruits are mainly eaten raw and occasionally blended with milk to prepare *batidos* or squeezed to prepare fruit juice. In the evening, food that was left from breakfast or lunch is eaten. At night, a cup of traditional plant infusion is often prepared whether to sleep better, relax or to cure a condition or inflammation based on the medicinal perception as detailed in Table 3.3.

3.4 Discussion

The results of this study demonstrate that many a number of foods (n=112) are available for consumption whether wild, semi-cultivated or cultivated which compound the group of TFs. Also, medicinal plants were perceived as edible and therefore additionally reported (n=14). Indigenous people in Guasaganda, Ecuador can diversify their diets by introducing local wild, semi-cultivated and cultivated foods in their diets. In Guasaganda, people can collect 49 plant foods or hunt/fish 13 species which are present in the natural environment. By practising traditional farming, they can cultivate 41 plant and 9 animal species. This study is the first reporting the availability of food species in the forest of Sacha Wiwua and surrounding farms.

Comparing our study with others on South American indigenous communities (Passos *et al.* 2007; Roche *et al.* 2008; Creed-Kanashiro *et al.* 2009), ours enumerate and identify a higher number of foods. This is problably because our combined methodology used to describe the food biodiversity included all wild, cultivated and semi-cultivated plants and wild, domesticated and semi-domesticated animal foods using scientific and local names. The study of Passos *et al.* (2007) concentrated on the study of traditional fruits in the Brazilian Amazon and used a 7-

day record for only fish and fruit intake. We assumed that recalling only fish and fruit is the reason they only reported 40 fruit species. Otherwise a 7-day record of all foods consumed could result in a higher number of species reported. The study of Roche *et al.* (2008) reported the consumption of 20 TFs in the Peruvian Amazon but did not identify their scientific names, whereas Creed-Kanashiro and colleagues (in 2009) identified 82 TFs in the same Peruvian study of Roche *et al.* (2008) additionally identified foods using scientific names. It is, therefore, important to count species richness after an adequate identification of species using scientific names.

The provision of fruits is an ecosystem service of the Sacha Wiwua forest. Our findings show that indigenous people in Guasaganda have mainly fruits (71 species) available for consumption whereas few staples (7 species) and vegetables (5 species) are available. Because fruits are an important source of micronutrients, it seems imperative to promote the consumption of local wild and cultivated fruits for health (Giridhar and Sridevi 2011).

A body of evidence shows that wild fruits are rich in micronutrients, antioxidants and phytochemicals which are essential for health (Bvenura and Sivakumar 2017). Also, these are culturally acceptable and therefore easy to incorporate into nutrition interventions. Termote and colleagues (2012) reported that consumers of wild edible foods in D.R. of Congo consumed significantly more fruits than non-wild food consumers. Boedecker and colleagues (2014) found likewise that wild-edibles consumers had a significantly higher Women Dietary Diversity Scores than non-wild edible consumers. Yet, the small amount and frequency of consumption of wild edibles were by Boedecker *et al.* (2014) reported minimal contributions to micronutrient intakes. Alternatively, Powel *et al.* (2013) propose that despite wild foods minimally contribute to energy intakes they contribute to micronutrient intakes and dietary diversification.

Despite the total high number of fruit species reported in this study, it is striking to find that there exist a limited number of cultivated fruit species per farm. There are also few vegetables and staples in the farms. Reporting a high food biodiversity in the studied region (defined as the total number of edible species inventoried) was thought to be a necessary condition to find a large diversity of cultivated foods and semi-cultivated foods in the farm, but this latter was not a sufficient condition. A reason for the reduced number of fruit and vegetables species found at the studied farms might be that farmers in Guasaganda are dedicated to bovine milk production (Holswtein, Gyr and Jersey) and therefore pastures (such as *Axonopus scoparius* (Flüggé) Kuhlm., *Paspalum dilatatum* Poir, *Brachiaria decumbens* Stapf) are prevailing (Torres *et al*. 2014) as well as other crops that are only destinated for animal feed and therefore not coded as food. Often, inventories that do not document the farm livestock diversity have a limitation when reporting agricultural biodiversity (BI 2017) as the number of species does not include animal food. Likewise, we did not quantify the number of animal species at farm level, however, we found in the literature the study of Torres and colleagues, which reports that about 600 families are dedicated to milk production in Guasaganda and identified small milk producers having a maximum of 60 cows in up to 80 ha of land producing 3 L of milk per cow/day, whereas big producers work on more than 80 ha with more than 100 cows and produce 8 L of milk per cow/day. With a cost of 30 cents of a dollar per litter when sold directly to the consumer, we assume that the small farmers are more interested in producing milk than in fruit and vegetable cultivation.

The conclusions presented by Torres *et al.* (2014) mention that bovine milk production is important for the food security and income generation of the inhabitants of Guasaganda. From a sustainability perspective, we are concerned in that promoting milk production could increase methane (CH_4) production and increase pasture surface area at the cost of forest area. According to FAOSTAT Ecuador methane production from diary-cattle is 72 kg/cow and 56 kg from non-diary production. Because milk production is the most common income generating activity we, however, recommend that using the portfolio analysis developed by Raes *et al.* (2016) future studies in Guasaganda should analyse the impact of milk production combined with forest conservation and the restoration of pastures and incentive program for tree plantation. Raes with the latter methodology demonstrated that in Southern Ecuador, dairy farmers would increase the amount of land designated for conservation in a risk reduction strategy when receiving cash incentives for forest conservation and tree plantation (Raes *et al*. 2016).

However, the results of Raes showed that the combination of milk production and forest conservation would not eliminate poverty among small farmers because of the low amount of incentives (ibid.). Alternatively, future studies should evaluate if better benefits could be achieved by local farmers when combining milk production with the cultivation of a variety of plant species for household consumption, and if the latter occurs, the legal framework of the incentive programs should be adapted accordingly. A study on farm-biodiversity has shown that the number of species in the farm is correlated with the dietary diversity score of the household in 4 different African countries (Sibhatu *et al.* 2015a). The combination of milk production and traditional farming could be beneficial for small farmers and a potential strategy to increase the number of semi-cultivated and cultivated edible plants species in the farms. A preliminary study in Guasaganda, has positively correlated the annual income with the diversity of species in the farm and agricultural production (Espinel *et al*. 2016). This study can be the starting point for future analysis.

A limitation of our study is that apart from studying the forest and farm, we did not inventory home gardens as an independent niche of edible species. Our results show that home gardens are sites mostly used for cultivation of medicinal foods but also for domestication of wild food species. Because the study of home gardens composition and plant species richness is increasing in tropical countries (Sujarwo and Caneva 2015), research in Ecuadorian home gardens is recommended (Coomes and Ban 2004; Galhena *et al.* 2013). Future interventions in Guasaganda should concentrate on the empowerment of home gardens particularly for the cultivation of vegetables since our results show that only a few vegetables were present per farm.

Additionally, food scientist and nutritionist should study home gardens as a supplier of medicinal plants. Biochemical analysis of medicinal plants is required to identify the bio components responsible for the medicinal properties claimed by indigenous people. For example, leaves extract of *Guanabana* (*Annona muricata* L.) were reported in our results to be used to cure diseases and cancer. A study on Guanabana peel found that extracts have a high antioxidant capacity (reducing free radical content) and a high phenolic content (Restrepo *et al.* 2012). Nineteen components have been identified by gas chromatography-mass spectrometry of oil from *Annona muricata* L. leaves, which has shown in-vitro toxicity on human breast cancer cells (MCF-7) (Owolabi *et al.* 2013). Extracts from the leaves of *Annona muricata* L. was proved to inhibit the proliferation of lung cancer cells attributing this selective cytotoxic effect to cell cycle arrest and programmed cell death through activation of the mitochondrial-mediated signalling pathway without affecting the normal cells (Moghadamtousi *et al.* 2014). Studies done in the same plant family have found that the fruit juice of *Chirimoya* (*Annona cherimola* Mill.) has a high antioxidant capacity when exposed to lymphoma and colon cancer cell lines (Gupta-Elera *et al.* 2011) whereas the leave water-extracts resulted in 90% mortality of cancer cells of lung, liver, colon and breast (Khalifa *et al.* 2013). The latter evidence shows that indigenous knowledge is genuine, although without a scientific background, and that medicinal plants in Guasaganda (Ecuador) could be potentially used to reduce oxidative stress.

3.5 Conclusion

For million years, nature provides to humans with a number of species that serve as food to have energy and micronutrients for a healthy life. In traditional food systems, the forest and the farms supply with species which end on the table of the peasants to feed their families. In our study, however, the number of cultivated species in the farm that are potentially eaten is limited, whereas the number of species collected from the forest, mainly fruits, appear to be higher. Local cultivation of traditional foods and domestication of wild foods is highly recommended. Future research is needed to evaluate if the peasants would have benefited from combining the cultivation of fruit, vegetables and staples with milk production. Medicinal plants are an interesting topic of future research as they are present at home gardens and have a perceived contribution to health.

CHAPTER 4: Barriers to eating traditional foods vary by age group in Ecuador, with biodiversity loss as a key issue

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Abstract

Objective: To document the perceptions of indigenous peoples for the sustainable management of natural resources against malnutrition.

Design: Initially 4 and then 12 interviews were conducted with 4 different age groups.

Setting: Eight rural villages in Guasaganda, central Ecuador, were studied in 2011-2012.

Participants: A total of 75 people (22 children, 18 adolescents, 20 adults, and 15 elderly).

Main outcome measure: Benefits, severity, susceptibility, barriers, cues to action and self-efficacy of traditional-food eating.

Analysis: Qualitative content analysis was done using NVivo software. Initial analysis was inductive, followed by a content analysis directed by the Health Belief Model. Coding was done independently by two researchers, and kappa statistics ($k \geq 0.65$) was used to evaluate agreement.

Results: Healthy perceptions towards traditional foods exist, and these differ by age. Local young people eat traditional foods for its health benefits and good taste; adults cultivate traditional foods that have an economic benefit. Traditional knowledge used for consumption and cultivation of traditional foods is present but needs to be disseminated.

Conclusions and Implications: Nutrition education in schools is needed that supports traditional knowledge in younger groups and prevents dietary changes towards unhealthy eating. Increased traditional-food production is required to address the current economic realities.

Keywords: biodiversity, behaviour, eating, Ecuador

4.1 Introduction

Traditional foods (TFs) are essential in ensuring food security and health of indigenous populations (Wahlqvist 2003; Johns and Eyzaguirre 2006; Koohafkan 2010; Kuhnlein 2010; M'Kaibi *et al.* 2015). In addition, TFs are also consumed by the rest of the population (Paredes and Guerrón-Montero 2014). Changes in the natural environment such as global warming, however, have turned sustainable provision and use of these TFs into a challenge (Campbell *et al.* 2010). In Ecuador, between 2004 and 2012, there was an overall decline of stunting by 8 %; however, the proportion of stunted indigenous children remained high (36 %) (Freire *et al.* 2013). At this same time, overweight in children increased by 2 %, with a prevalence of 25% in indigenous children, three times higher than in children of other ethnicities (ibid.). The simultaneous burden of stunting and overweight is also present in indigenous preschool children, adolescents and adults as reported in the last country's health survey (Freire *et al.* 2014). Preventing indigenous peoples' malnutrition by implementing context-specific interventions is essential to sustainable management of natural food resources (Vinceti *et al.* 2013).

Eating behaviour studies, principally those guided by behaviour theory to know the causes and determinants of a particular behaviour (Brug *et al.* 2005), can offer valuable information to guide the development of healthy eating interventions (Etievant *et al.* 2010). The use of theoretical models to explore and predict eating behaviours is increasingly used for research, mainly because one can identify what needs to be changed and how to motivate the person to promote healthy behaviour. The most commonly used are the Health Belief Model (Becker 1974), Theory of Planned Behaviour (Ajzen 1985), or Stages of Change Model (Prochaska and Diclemente 1986; Buchanan 2004; Lytle 2005). Each model explains that behaviour can be predicted by investigating different factors which influence the behaviour. A review of 29 investigations that used Health Belief Model, for example, identified that "perceived barriers" proved to be the most powerful of the dimensions investigated by the model.

The use of models allows researchers to identify healthy eating factors in different age groups. Factors that contribute to healthy eating in young people include positive attitudes towards consuming healthy foods, education that is targeting action/maintenance behaviour and perceived behavioural control, yet there are many barriers that inhibit, for example, fruit and vegetable consumption (Backman *et al.* 2002; Rasmussen *et al.* 2006). In adults, intentions to eat healthily, as well as social influences such as descriptive norms, are predictors of healthy eating behaviour (Conner *et al.* 2002; Nasi *et al.* 2011). These determinants could be psychosocial (i.e. intrinsic to the individual) or environmental factors (i.e. those surrounding the individual). Thus, interventions can target the person if the problem comes directly from the individual or the environment if external factors are influencing the person. Unfortunately, to our knowledge research on the determinants of eating behaviour has emerged primarily from high-income countries, and therefore it cannot be extrapolated to the unique eating culture of indigenous peoples.

What is known on indigenous peoples is mainly about what they eat, but not on why they eat it. Traditional diets are known to be based on about 200 foods and contribute to ~50 % of total energy intake (Kuhnlein *et al.* 2009). The choice of TFs is influenced by individual and cultural factors that are specific to the population and varies with ethnicity (Kuhnlein *et al.* 2009; Kuhnlein 2010). Investigations on indigenous people, however, have detected that the consumption of TFs is decreasing (Kuhnlein and Receveur 1996). Promoting the consumption of TFs has been used in participatory approaches that aim to promote sustainable/healthy eating habits and increase food security (Englberger *et al.* 2010; Cloete and Idsardi 2013). These studies found that cooking classes, planting material, agricultural incentives (Englberger *et al.* 2010) affordable-indigenous crops and school meals based on indigenous crops (Cloete and Idsardi 2013) can motivate indigenous people of different ages to cultivate, prepare and eat TFs.

Currently, the food habits of indigenous communities are changing (Kuhnlein and Receveur 1996). The specific causes for increasing weight status have not yet been identified and therefore difficult to target (Freire *et al.* 2013). To guide interventions that promote a sustainable consumption of TFs, a comprehensive behavioural study was conducted to identify key determinants of eating behaviour. This study evaluates what indigenous people in Guasaganda (Ecuador) perceive to be the barriers for eating a variety of TFs, how the changes in the local natural environment are affecting the latter, and why traditional knowledge of TF consumption is not broadly transferred.

4.2 Methodology

4.2.1 Participants

The respondents were indigenous people of the rural parish of Guasaganda, which is situated in the province of Cotopaxi (between 250 and 1000 meters above sea level), central Ecuador, and has about 3,900 inhabitants. Because the studied group are indigenous Quechuas the author of this thesis (who shares the Quechua ethnicity) conducted all interviews. Guasaganda was selected due to its high food biodiversity that includes about 85 plant (Aguilar and Cartagena 2010) and 20 animal (Penafiel D *et al.* 2012) food species. Additionally, rural people living in the highlands are the most affected by both stunting and overweight and remain poorly served by nutritional programs (Freire *et al.* 2013).

4.2.2 Study design

This study used group interviews to document opinions and perceived needs about eating TFs in indigenous children (6 to 9 years), adolescents (11 to 18 years), adults (19 to 56 years) and elderly (mainly elders between 56 to 91 years (King *et al.* 2009)). Table 4.1 shows the age range of each studied group. The interview process was conducted by the author of this thesis who followed general guidelines for interviews targeting indigenous and young participants and is of indigenous origin (Krueger and Casey 2000; Smith *et al.* 2002; Gibson 2007; Halcomb *et al.* 2007). Interviews were done in a roundtable format, using a digital voice recorder (Philips model LFH 0667 DNS, The Netherlands) and a microphone. Rather than a simple deductive phase, group discussions were conducted in 2 consecutive parts; the first inductive phase guided the selection of the theory to be used in the second (Hsieh and Shannon 2005).

First Phase (November 2011). This phase aimed to identify the best theoretical model to be used throughout the study (Brug *et al.* 2005) to methodically describe and explain why indigenous people eat a variety of TF. One group discussion per age group was conducted, using open-ended questions (i.e. Why do you eat traditional/local foods?) to maximise unbiased comments regarding eating behaviour.

Second Phase (December 2011 and January 2012). The participants were weighed and measured using a portable scale and a stadiometer (SECA model 877 in kg and 213 in cm) to document anthropometric data to describe the sample. The interviews were conducted until saturation of responses was attained, and the comments were reporting the same determinants from previous interviews, which resulted in 3 interviews per age group. Interviews were conducted using semi-structured questions (listed in Table 4.2) that were framed based on the Health Belief Model (HBM) (Figure 4.1) (Janz and Becker 1984). The latter conceptualizes that a behavior is influenced by a combination of the perceived susceptibility to and severity of an illness (in this case illness caused by malnutrition), the desire to avoid that specific illness and the belief that an action (which has perceived benefits and limited barriers) would help to avoid or relieve the illness. According to this theory, perceptions are subjective ideas linked to behaviour and are the force that guides the action. Also, there exist stimuli (cues to action) and demographic variables such as age and ethnicity that influence the decision to engage in that action (Janz and Becker 1984).

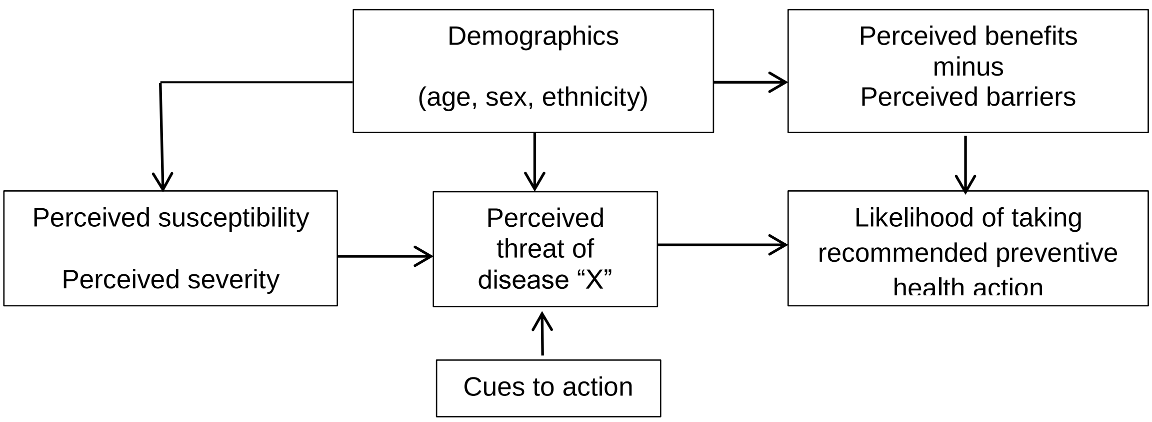

Figure 4.1 Basic elements of the Health Belief Model (adapted from Janz *et al.* 1984)

4.2.3 Recruitment

As the determinants of eating behaviour are different across age groups (Brug *et al.* 2005), interviews were organised with four different age groups. Each interview group had 4 to 6 participants (except for two elderly groups that had 3 participants each). Given the qualitative nature of the study, a convenience sampling of villages meeting a selection criteria was used: easy accessibility by road, dispersed around the forest, ~10 km apart, and having at least five elderly. The 8 villages included in the study (for the second phase interviews) are shown in Figure 4.2.

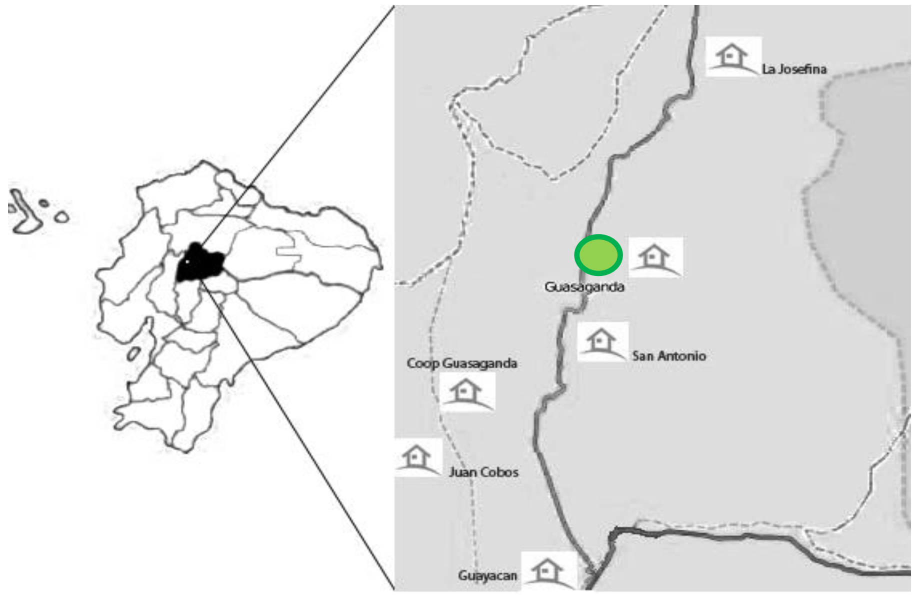

Figure 4.2 Map of Guasaganda villages included in the second-phase interviews. The grey line shows the main road, and the green point locates the Sacha Wiwua forest

The local guide introduced the main researcher, who shares their ethnicity, to the people in those villages more knowledgeable about indigenous eating. Volunteers were grouped according to their age to form homogenous groups. To avoid bias, participants were not discriminated by their gender, background or literacy (Krueger and Casey 2000). To be included in the sample, participants needed to be residents of the area and ≥6 years of age thus ensuring participants were familiar with the topic and had the cognitive ability necessary to respond to the interview questions about what is happening in their environments. Each adult provided written consent, whereas parental consent was obtained for children and adolescents <18 years who wanted to participate. Recruitment and interviews were conducted in local schools (to children and adolescents) and communal meeting places (to adults and elderly).

Research protocols followed the principles of the Permanent Forum on Indigenous Issues (UN 2008) into respecting the rights of the interviewed people, and we received ethical clearance from the *ad hoc* ethics committee of the ESPOL (BIOFOOD FM-007-10 on Nov 15, 2011). Each participant received a bag (containing a notebook, a pencil and a mug) at the end of the interview.

4.2.4 Terminology

The definition of TFs is described in *Chapter 1*. TFs systems were defined as "systems that are composed of foods from the local and natural environment, and that are culturally accepted". Other foods that were not locally cultivated or found in the wild in Guasaganda were referred as "non-TFs". The third category of foods mentioned in this study is commercially produced foods including highly processed foods such as carbonated drinks and packaged potato chips. For this paper, the name of the food was translated into English; otherwise, local food names appear in cursive and between quotation marks. The scientific names of bushmeat were retrieved from the on-line database of *Mamiferos del Ecuador* (Burneo and Boada 2012).

4.2.5 Analysis

To facilitate coding, interviews were translated verbatim into English and written between quotations marks by the author of this thesis, and the Quechua translations were reviewed by an official translator fluent in English, Spanish and Quechua. The author of this thesis received training on eating behaviour research for a year previous this PhD study, resulting in a MSc thesis and a scientific publication. A conventional content analysis (Hsieh and Shannon 2005) of the first-phase interviews showed that the consumption of TF was driven by health beliefs. Therefore, the HBM was selected as the theoretical model for the second phase of the study, and "not eating a variety of indigenous foods" was identified as the risk factor of interest.

Transcripts of respondents from the second interview phase were analysed in NVivo (Version 9, QSR International, Australia, 2008) by age group using content analysis directed (Hsieh and Shannon 2005) by codes from the constructs of the HBM (Figure 4.1). The main codes used were benefits, severity, susceptibility, barriers, cues to action, and self-efficacy. For additional findings new codes (i.e. transition, favourite foods, bush meat, non-traditional and commercially processed foods) were used. To avoid bias, coding was conducted independently by two researchers. Per code, a kappa value retrieved by NVivo was used to objectively evaluate disagreement between researchers. Kappa value of ≥ 0.65 was selected as the threshold for moderate agreement, (Viera and Garrett 2005) and any disagreement ($\kappa < 0.65$) was discussed with a third researcher for final coding. Findings were reported according to the dimensions of the HBM to enable comparisons between age groups. To describe the participants, mean and standard deviation for their age, weight and height were calculated. Also, Body Mass Index was computed, and international cut-offs (Cole *et al.* 2000; WHO 2004; Cole *et al.* 2007) were used to classify their nutritional status according to their age group.

4.3 Results

4.3.1 Participants' age and gender

Table 4.1 lists the age range of each group interview. We interviewed a total of 20 participants in the first phase. The additional 55 participants (23 male and 32 female) in the second phase represented about 2 percent of the population. The BMI status is also presented in Table 4.1.

Table 4.1 Age ranges, weight, height and number of participants (n=75) for each interview phase

Group	Mean age[a] ± SD	Village[b]	n participants' gender phase1	n participants' gender phase2	n participants' BMI status[c]	Average Weight (kg)	Average Height (m)
Children	7.8 ± 0.5	Guasaganda	1♂ + 4♀		-	-	-
	7.6 ± 0.9	Guasaganda		3♂ + 2♀	4 normal, 1 thin	20.9 ± 0.8	1.2 ± 0.1
	7.3 ± 1.2	Juan Cobos		4♂ + 2♀	5 normal, 1 thin	20.6 ± 1.7	1.2 ± 0.1
	7.3 ± 0.5	San Antonio		2♂ + 4♀	5 normal, 1 thin	20.7 ± 0.5	1.2 ± 0.1
Adolescents	15.8 ± 0.5	Guasaganda	4♂ + 1♀		-	-	-
	14.8 ± 2.6	Guasaganda		1♂ + 3♀	4 overweight	58.7 ± 11.1	1.5 ± 0.1
	18.8 ± 0.6	Guasaganda		3♂ + 1♀	4 normal	55.4 ± 7.2	1.6 ± 0.1
	11.2 ± 0.4	El Guayacan		2♂ + 3♀	5 normal	34.8 ± 5.3	1.4 ± 0.1
Adults	35.5 ± 7.9	Hda. La Florida	3♂ + 3♀		-	-	-
	34 ± 10.8	Coop Guasaganda		1♂ + 4♀	2 overweight, 3 obese	68.5 ± 12.6	1.5 ± 0.1
	40.8 ± 12.1	El Guayacan		1♂ + 3♀	2 normal, 1 overweight, 1 obese	61.6 ± 10.5	1.5 ± 0.1
	27.2 ± 6.9	Juan Cobos		1♂ + 4♀	2 normal, 3 overweight	60.9 ± 6.7	1.5 ± 0.1
Elderly	59.8 ± 2.6	21 de Noviembre	1♂ + 3♀		-	-	-
	80.8 ± 12.1	Guasaganda		2♂ + 3♀	2 normal, 3 overweight	60.1 ± 8.7	1.6 ± 0.1
	63.6 ± 4.9	La Josefina		2♂ + 1♀	3 overweight	67.7 ± 2.3	1.6 ± 0.1
	72.6 ± 13	Juan Cobos		1♂ + 2♀	1 normal, 2 overweight	56.9 ± 6	1.5 ± 0.1

[a]participants' age differ from group and therefore these overlap
[b] Geographic position of the villages (with GPS points): Guasaganda 79°09'66"W, 0°48'114"S; Juan Cobos 79°11'810"W, 0°51'596"S; San Antonio 79°09'689"W, 0°48'710"S; Florida 79°05'310"W, 0°43'634"S; El Guayacan 79°09'648"W, 0°53'048"S; Coop Guasaganda 79°09'896"W, 0°48'972"S; 21 de Noviembre 79°12'193"W, 0°46'324"S; La Josefina 79°09'648"W, 0°45'559"S.
[c] Status according to BMI: for children age 6 to adolescent age 18 cut offs from Cole, 2000 and 2007 were used. For adults and elderly, the cut-off for overweight is BMI ≥ 25 and BMI ≥30 for obesity, and 18.50- 24.99 for normal BMI according to WHO, 2004.
- Participants interviewed in the first phase were not weighed nor measured.

4.3.2 Indigenous perceptions of TFs

Table 4.2 lists all determinants of TF eating and includes some quotations.

4.3.2.1 Perceived benefits of eating TFs

In general, indigenous people reported positive perceptions (mostly linked to health), regarding eating a variety of TFs. Children emphasised that TFs were a good source of nutrients whereas adolescents perceived that their body had more vitality by consuming TFs. Adults were more concerned about eating a variety of TFs regularly for disease prevention, and therapeutic reasons. The control of appetite by eating TFs was an important factor mentioned by elderly. A less perceived health benefit was food safety. Adults preferred to eat TFs because the latter were organically produced, ripened naturally, and could be eaten fresh. Additionally, children, adolescents and adults considered indigenous meals to be tasty because their preparation involves mixing a variety of flavours.

Self-production of a variety of TF for consumption was perceived as a benefit mainly by adults, who also indicated that local resources, such as locally produced manure and seeds, were used for this purpose. Elderly associated TF production with a feeling of independence, meaning that they felt empowered by reliance on their land and considered this advantageous as a safety net in difficult times.

Adolescents and adults commented on the economic benefits of producing TF on their land or collecting it from the forest. TFs were perceived as inexpensive, and thus economically accessible. Mainly adults indicated that TFs were sold for cash which then was used to buy foods that are not cultivated on their land or in the area, so as to increase the choice of foods in their diet.

Adolescents focused on the cultural significance of TFs indicating that "*good*" TFs were eaten because their grandparents used to eat them. Adults also indicated that TFs were eaten when feeling nostalgic about the past or when being far from their indigenous community.

Table 4.2 Determinants, interview questions (framed from the Health Belief Model) and some discourse quotes of traditional-food eating of indigenous children (n=17), adolescents (n=13), adults (n=14), and elderly (n=11) of Guasaganda, Ecuador

HBM constructs *Interview Question*	**Determinants**	**Discourse quote**
Perceived benefits *Why is it good to eat a variety of indigenous foods? What is the benefit?*	**Health Benefit**	
	Nutrition	"Because it is healthy for our body", "There exist local foods that are very healthy"[children]
	Medicinal	"Here at the farms, foods are healthy. We live healthily. We do not have to go regularly to the doctor", "We rarely get sick" [adults]
	Vitality	"Because my body feels better … stronger", " The benefit is that … every time we eat various local foods, my body has more energy … and we are healthy"[adolescents]
	Appetite control	"And if we eat diversely, we eat with more pleasure… because we have more appetite", "Because we have to get nourished and not be hungry !", "But if we eat variedly … taro, cassava and other things and switch … we eat with pleasure … and we fill the stomach" [elderly]
	Food Safety	"Because we cultivate it ourselves with no chemicals", "It is all organic, … other people feed their chicken with pellets; we feed them with plantain" [adults]
	Taste	"I eat the food! I like to eat …. I like to eat *pear* and *cassava*", "Because I like it", "I like to eat salad with cucumbers… with tomato.. and … all vegetables" [children] "Eating always the same … has the same flavour", "It is different … it tastes different", "different flavours" [adolescents] "By eating the same every day we get bored £", "Varied is better", "It is tastier … to eat varied" [adults] "G*uayaba* is from here also … for juice. Tasty ! … Oranges too" [elderly]
	Food Production	
	Own cultivation	"We do not need to buy traditional foods. We have everything here" [adults]
	Self-reliance	"It is NICE to go … and collect a taro, or a cassava, from the plant! take it home, prepare it, cooking it … this is better than to go and buy something that has been stored. Our foods are fresh !" [elderly]
	Local inputs	"We know ourselves how it is produced, because we do it", "We grow it in soil that it is not polluted, and we do not use chemicals" [adults]
	Economic benefit	
	Low cost	"Chickens are also for selling …", "It is cheaper", [adolescents]
	Revenues	"My son in law cultivated … four blocks and he just sold it" "Cassava, oranges, mandarins … everything grows! for example, I used to cultivate A LOT of papaya … I harvested a LOT of papaya, and I used to sell it in Pucayacu and they send it to Latacunga" [elderly]
	Cultural significance	"It maybe because my grandparents ate … for example *guanta* … for holydays … something cultural", "For baptism, a pig is slaughter house, and 30 to 40 chickens … and all the guest eat good" [adolescents]

Table 4.2 Cont'

HBM constructs *Interview Q'*	**Determinants**	**Discourse quote**
Perceived Barriers *What does not allow you or your family to eat regularly different indigenous foods?*	**Biodiversity loss**	"Because there was a diversity of trees … but by cutting the trees, all fauna was lost … all fauna !", "In the river back there.. There used to be a lot of fish" [children] "There used to be animals that they (referring to the grandparents) used to catch and … they did not have to buy … they cooked them" [adolescents] "In the past, there were more animals … nowadays, there are a few … they are rare", "We eat mainly domestic animals, raised at home … on the other hand, those (referring to wild animals) are animals from the forest", "In the past … because I remember my mother had local chicken, turkey … everything, and eggs" [adults] "Fish, in the past there was a lot of fish !", "It is a luxury to eat those. Before, it was common to eat those animals (referring to *guatuza* and *paca*). Before ... here was all forest, and therefore there were a lot of those wild animals. I believe it was really healthy meat! In the past there were no places where to buy, not close, not around" [elderly]
	Low production Farming and land	"It is better to have a piece of land with … traditional plants", "The bad thing is that not everyone grows traditional foods", "Not everyone has land", "Our piece of land in not enough", "If one has some money to invest in the land… here everything grows !", "Some cannot invest in land" [adults]
	Pest and diseases	"The *guayaba*, and also the *hawaii papaya* … but they all get diseases and it does not produce as before", "Passion fruit … but it also has worms. It seems the technique is missing to … do it better", "Suddenly there was a diseases … they call it 'fungi' … and from then, it started … we stopped with the cassava and started with the grass" [elderly]
	Migration	"They migrate, instead they could cultivate onions, potatoes, faba beans, cebada …sheep, pigs for food, and they do not to move to Quito to work as loaders", "Young people work for money! And they can grow pigs, cattle, birds … they can make money, but they need to invest." [elderly]
	Low purchasing power	"Because there is no money", "Money is needed" [children] "Well, every day we eat more or less diverse … only rich people eat … for example, good" [adolescents] "There was a time, a bunch of plantain cost 1 dollar …", "But then, it cost five or six dollar the bunch ... then, nobody could buy it, it was too expensive", "Well, money. If we would have money we could eat as we want … all that is needed, but there is not enough money… We have to eat what is available [adults] "poverty" [elderly]
	Availability Seasonality	"It depends on the season of the fruit; it is not available all the time. Oranges or Araza. All fruits are seasonal" [adults] "Oranges and mandarins … are seasonal" [adolescents]
	Transition to non- traditional foods	"My father buys pears, apples … and many other fruits that are not produced here", "yes, we do not eat the same than our grandparents … now we eat rice, back then they ate other things" [children] "For example, at the city… all is fried, and fried and fried … therefore they live sick. But not here! [adults] "About traditional foods nowadays our children say 'that was before, but now it is not possible'" [elderly]

Table 4.2 Cont'

HBM constructs *Interview Question*	**Determinants**	**Discourse quote**
Perceived Barriers	**Cooking person**	
	Absence	"The meals prepared by mommy are healthy", "We cook .. in her place (refereeing to their mothers), but not traditional foods", "Because she goes to work £", "When my mum is sick, my father cooks" [children]
	Time limitation	"Few time to cook" [adolescents] "It is a bit more difficult to cook the plantain … it takes more time" [adults]
Perceived Severity *What would happen to you or your family if you do not eat a variety of indigenous foods regularly?*	**Health risk**	
	Health issues	"I could get sick", "Some people get diseases, and pain (pointing to his belly)" [children] "… when eating only 1 or 2 foods, and the same foods next day … they (referring to his son) say 'no, no, no … I would feel weak", "And then … diseases come because they (referring to his son) are weak. The blood gets weak, it is … is '*chulla*' (meaning "alone" in Quechua), like water, men feel weak and stay in bed" [elderly]
	Physical problems	"By eating cassava everyday … we do not have energies to do the things we like", "Our bones do not receive enough calcium … and I could not even move" [adolescents]
	Low appetite	"Because … we do not get bored. If we eat the same foods we get bored" "I do not cook for them the same and the same … otherwise, they do not want to eat" [elderly]
	Hunger	"Other people eat something fast (for breakfast) … like coffee and bread. If we eat that we get hungry. Here at the farms we are used to eat cooked plantains, cassava, potatoes" [adults]
	Death	"We could die" [children] "It would affect to our health. We would not be nourished … it is not worth it … we would be only surviving from simple foods [adults]
Perceived Susceptibility *Do you feel it is possible that you get diseases, or the negative health condition mentioned above by not eating a variety of indigenous foods? Why?*	**Distant Susceptibility**	"Anyway, nature is … changing. Not because we live in a farm we will always be healthy", "It can happen to us too. The environment is changing. We are not fully protected", "One gets anaemia by not eating healthily", "we are poor, but we eat healthy" [adults] "Our children! They … they do not eat what we ate in the past. They are always sick! They are weak; they are not strong like us"," I thank God … when I get up and when I go to sleep … that I have a bit of everything to eat. One morning I eat some foods, the next day other foods, and so on ... varied. And I can also eat well … with a full stomach and go to work!" [elderly]
	Highly Susceptible	"It happened to my brother … he was weak and with headache and he fainted … there (pointing to the yard of the school)", "I heard … people could get sick" [children] "My classmate … used to eat only chips and cola … and then he got leukaemia" [adolescents]

Table 4.2. Cont’

HBM constructs *Interview Question*	**Determinants**	**Discourse quote**
Cues to action *What do you think it can help you to eat more diverse indigenous foods?*	**Nutrition education** School education	“You would have to come and teach us that oranges are good, that they are healthy for our body and contain vitamin C” [children] “People to teach us” [adolescents] “One way is to educate children at school. I believe the government assign money to give them breakfast at school … I think that by giving milk, one litre at 30 cents … if they give half a litre of boiled milk, they would get USED to it and … they won’t need any other food in the day. Milk is a good food ! it needs promotion. They like better cola than milk. We are all failing! we are all … ALL” [elderly]
	Cooking classes	“At the farm we know … but it would not hurt to receive some seminars … by a technician”, ”it would be good to … receive … an intervention”, “to know how to cook £ ji ji, to prepare different recipes” [adults]
	Sustainable eating	“They have to learn to eat what WE HAVE! but with care” [elderly]
	Pride to eating traditional foods	“Guatuza ... people used to eat that before with pride, but now I do not know if they do… they should learn” [elderly]
	Financial help Cultivation	“To cultivate indigenous plants … to eat”, “to buy the seedling (planting material) for us”, [adolescents]
	Credit for farming/land	“We need more land … there is no land where to cultivate … sometimes, there is just a piece of land next to the home … and that is it” [adolescents] “Well, if you want to live from the farm, investment is needed. It is not that easy.” [adults] “I need money to invest and to hire a worker … for help. Money is needed!” , “There should be … an easy way to get credits, easier .. to raise pigs, cattle, birds … for selling, but investment is needed”, “Once, a woman came to visit and ask for some seeds … I gave her three cassava tubers for no cost! It is BEAUTIFUL to share … with those who do not have” [elderly]
	Income generating Activities	“Providing jobs” [adolescents] “Sometimes, if we would have jobs …”, “Jobs to eat better” [adults]
	Biodiversity conservation	“To grow more trees”, “To take care of nature”, “To do not pollute the rivers” [adolescents]
Self-efficacy *Do you feel able to prepare and eat meals containing different types of indigenous foods? Why or why not?*	**Cooking skills**	“I sometimes prepare salads”, “I can warm up the soup”, [children] “yes, I can cook these”, “yes, as long as we cultivate it” [adolescents]

All comments are between quotation <“”> marks. Ellipsis <…> means pause, exclamation marks <!> are used for emphasis, for smile a pound sing <£>, and high voice tone was transcribed in <UPPERCASE>. Researcher’s notes are between brackets <( )> and the age group was identified between square brackets <[ ]>.

4.3.2.2 Perceived barriers to eat TFs

Several environmental factors hampered the consumption of a variety of TFs. Elderly were highly concerned by the loss of biodiversity. TFs, bushmeat mainly, were perceived to be currently less available than when the interviewed elderly were young adults. Elderly were very critical of non-indigenous peoples' agricultural and hunting practices. Deforestation was mentioned as the first barrier of TF-availability; the second was overhunting.

The main concern of adults was the low availability of TF due to seasonality and dietary transition away from TFs. Furthermore, adults perceived there was a general preference for picking and eating traditional fruits as they became ripe, rather than waiting for the full harvest to become ripe.

Another concern presented by adults and elderly was the limited production of TFs in the area. Adults perceived that this was mainly due to scarce time for farming or money to purchase more land to produce TFs. For example, plantain is traditionally-cultivated in the area but those who do not have enough land they have to purchase plantains from neighbours or markets to cover energy intakes. Elderly mentioned that the outbreak of pest and diseases on their plantations and animals, along with increasing migration of indigenous farmers to urban areas for a non-farming job were some reasons for abandoning traditional farming.

Another factor limiting the consumption of TFs, according to adults, was the low purchasing power of the indigenous population. Respondents who were not producing foods for their households mentioned that they needed money to purchase TFs at the local markets; however, cash-generating activities other than farming were rather limited. Children indicated that within the indigenous population, mothers, in particular, were skilled in cooking TFs. When mothers were not at home (absent) or had limited time, TFs were not served.

4.3.2.3 Perceived severity and susceptibility to diet-related realth problems

Eating a limited variety of TFs was perceived to have negative health effects. Responses varied in levels of severity, such as death, health issues (e.g. anaemia, leukaemia, cholesterol, gastritis, diabetes, and low immune response), physical problems (e.g. overweight and weakness), low appetite, and hunger. Children and elderly mainly commented on the latter adverse health conditions. However, elderly did not feel vulnerable to illness although they mentioned that “others” could get ill. Adults did not believe they could get ill or malnourished by not eating a variety of TFs, yet they believed their appetite could increase.

4.3.2.4 Self-efficacy to eat TFs

The perception of self-efficacy (the feeling of having control over whether or not one eats TFs), was linked principally to cooking skills. Adults and elderly responded positively to possessing the necessary skills for cooking and preparing traditional meals. Children and adolescents perceived a lack of knowledge when it came to cooking TFs.

4.3.2.5 Cues to action

Receiving nutrition education in school was indicated by most children and adolescents to be the cornerstone to keeping traditional healthy eating habits and increase dietary diversity. They also considered that informants not from the community, such as health or nutrition professionals, were useful channels for disseminating healthy eating messages. Elderly suggested that traditional healthy-eating knowledge must be transferred to the children. Elderly stressed that the consumption of TF must be promoted along with a sense of pride for indigenous foods. Adults further suggested that they would enjoy learning more by receiving cooking workshops. Elderly were willing to share their traditional knowledge and also to learn about non-traditional healthy eating habits and dishes if transmitted by radio or TV.

According to the elderly, to have a diet rich in a variety of indigenous foods, financial help was necessary to cultivate traditional foods or to give credit to buy land for farming. The latter would enable the new generation to increase TF availability. Also, by selling the produced TFs, the generated cash could be used to buy other foods not cultivated on their farms. Adults and elderly suggested that a local action for reforestation was necessary for biodiversity conservation.

4.3.2.6 Additional findings

All age groups compared their diets with that of their grandparents in the past. They all perceived that diets some years ago were healthier, more biodiverse and that TF used to be more available than currently. Adults perceived that people who eat healthy traditional diets live longer. Elderly mentioned that current adults are sicker and weaker than when they were younger.

Additionally, adults explained that due to the current low financial access to non-TF, it was difficult to have a varied diet that combines TFs and non-TFs. Elderly were highly aware that bush meat from *guantas (Cuniculus paca)*, *armadillos (Cabassous centralis)*, *sahinos (Tayassu pecari)*, and *guatuzas (Dasyprocta punctata)* were currently less available due to unsustainable hunting practices and the reduction of forest areas.

Foods which were perceived as healthy included lemon (*Citrus limon* (L.) Osbeck), apple (*Malus pumilla* Mill.), cherimoya (*Annona cherimola* Mill.*)*, plantain (*Musa x paradisiaca* L.), cassava (*Manihot esculenta* Crantz.), potato (*Solanum tuberosum* L.), rice (*Oryza sativa* L.), baby banana (*Musa acuminata* Colla), orange (*Citrus maxima* (Burm.) Merr.), mandarin (*Citrus reticulata* Blanco), 'mastrante' (*Lippia alba* (Mill.) N.E. Br. ex Britton & P. Wilson), *naranjilla* (*Solanum quitoense* Lam.), carrots (*Daucus carota* L.), onions (*Allium* spp.), taro (*Colocasia esculenta* (L.) Schott), *llanten* (*Plantago major* L.). Also, some healthy animal foods were 'guatuza' (*Dasyprocta punctata*), paca (*Cuniculus paca*), all local fish species, and animal sub-products such as milk and eggs. Respondents also mentioned that some traditional recipes such as vegetable soup, cooked potatoes, cooked and fried plantain and stews of meat with plantain are healthy.

In addition, each age group mentioned their food preferences. The younger groups preferred traditional fresh fruits, while adults preferred fried TFs such as fried pork ("*fritada"*) and sliced fried plantain ("*patacones"*), and traditional fruit juices. Elderly mentioned they preferred to eat indigenous bush meat and boiled starchy TFs. The most favourite foods were lemon (*Citrus limon* (L.) Osbeck), *papaya* (*Carica Papaya* L.), *araza* (*Eugenia stipitata* Mcvaugh) and *guayaba* (*Psidium guajava* L.). Some of the favourite dishes included fish with cassava, dried meat, and "*estofado* *de guanta*" (stew of *Cuniculus paca*). Furthermore, participants of all ages mentioned they occasionally eat processed foods. The latter were perceived as unhealthy foods and referred to as junk foods or "*comida chatarra*". Adults commented that they were attracted to processed foods because these are convenience and are ready to drink or eat. Children, on the other hand, considered these foods tasty. In this regard, adults and children commented on common parental rules that forbid children to eat processed foods.

4.4 Discussion

The findings of this study indicate that eating TFs is mainly done for health and prevention of non-communicable diseases. The latter shows a very positive perception of the traditional diet. However, there exist many barriers, both intrinsic and environmental, that constrain the consumption of TFs and a varied diet, and these barriers differ between age groups.

The novel finding of this study is that biodiversity loss emerged as a limiting factor for the consumption of indigenous foods (Wahlqvist 2003). Previous studies on eating determinants did not report on biodiversity loss, most likely because they were carried out in industrialised/urban areas (Åstrosm and Rise 2001; Backman *et al.* 2002; Conner *et al.* 2002; Rivis and Sheeran 2003; Rasmussen *et al.* 2006). Urban consumers did not rely on self- produced foods, therefore they were usually less aware of the links between environment and nutrition (Sobal *et al.* 1998). Also, investigations have mainly explored individual psychosocial determinants and therefore overlooked the surrounding environment (Brug and van Lenthe 2005).

The traditional eating behaviour of our studied Latin American community have similar determinants than traditional people in Benin and South Africa (Cloete and Idsardi 2013; Boedecker *et al.* 2014). The latter two studies show that eating TFs is, in this last decade, increasingly done because TFs are considered healthy and nutritious; and not mainly for cultural reasons (Cloete and Idsardi 2013; Boedecker *et al.* 2014). The disappearance of collecting and consuming TFs as cultural habit was also reported in Italy by another study (Pieroni *et al.* 2005). The taste of indigenous foods was an important motivator for its consumption (Cloete and Idsardi 2013; Boedecker *et al.* 2014), however, in the villages of Guasaganda it competed with convenience and taste of commercially processed foods. Food safety is a factor reported to affect the choice of foods in rural adolescents of Ecuador and Benin, mainly by microbiological hazards (Nago *et al.* 2012; Verstraeten *et al.* 2014) whereas in Guasaganda the food safety was linked to chemical hazards of non-locally produced foods which are perceived to be produced using fertilizers and pesticides.

The results suggest that the community is in transition. Hence, diet appears to be shifting from healthy TFs to high-energy dense foods such as non-traditional (i.e. fried starchy foods) and processed foods (i.e. carbonated beverages) (Popkin 1994). The dietary change from traditional to processed and energy-dense foods was reported earlier by nutritionists and anthropologists in indigenous people in Canada (Kuhnlein and Receveur 1996) and urban French (Etievant *et al.* 2010) emerging concerns on the obesity epidemic. Because of this global trend, it is important to prevent further dietary changes in this community. The double burden of malnutrition and the resulting combination of overweight and underweight is an increasing problem in Ecuador as in other Latin American countries that face rapid nutrition transitions (Monteiro *et al.* 2004). Furthermore, changes in the educational environment, from traditional to formal academic pathways, was leading to a reduction of knowledge transfer from elderly to children as it was reported a decade ago to happen on other indigenous peoples in Canada (Ohmagari and Berkes 1997). Traditional knowledge is, nevertheless, recognised as key for both indigenous food security and biodiversity conservation (Altieri 2004).

Due to environmental changes (i.e. deforestation) bush meat was less available and was therefore consumed less (Nasi *et al.* 2011). The consumption of domesticated monogastric small animals such as cavia and chicken would avoid that protein caloric intake is replaced by ruminant meat. The production of the latter is detrimental to the environment, and therefore it is not a sustainable option (Campbell *et al.* 2010). Furthermore, the use of indigenous knowledge of sustainable hunting practices is necessary to avoid overhunting of the threatened species.

This study is the first using a theoretical model to explain eating behaviours of indigenous people. Content analysis results adequate for nutrition education interventions (Kondracki *et al.* 2002). We documented the eating behaviour in the community, by using a humanistic approach which is appropriate when working with vulnerable populations (Buchanan 2004; Lytle 2005). The humanistic approach refers to the investigation of the needs of the people using a theory as stimulus for the dialogue about the role of eating habits to identify the most valuable cues to action (ibid.) Also, it explored different age groups to investigate the perceptions and needs of each age group. Although our results are restricted to the indigenous community of Guasaganda, our methodology is recommended to be used for future investigations in other specifc locations.

4.5 Implications for research and practice

Future interventions in the villages of Guasaganda should disseminate healthy eating messages that are linked to the existing health beliefs, and target barriers according to the age group and use different channels. Integrating the perceptions of indigenous peoples into context-specific interventions against malnutrition is hence important for the sustainable management of natural resources for food.

The findings of this study suggest that nutrition education for children and adolescents should be based on traditional knowledge and the sustainable consumption (FAO 2010c) of TFs in schools (Englberger *et al.* 2010). Additionally, encouraging school meals to contain TFs might be helpful (Cloete and Idsardi 2013). Traditional knowledge of healthy preparation and sustainable consumption of indigenous plants and animals needs to be first gathered from the elderly and then transmitted to younger people using external channels such as teachers or health professionals. Interventions that document and disseminate traditional knowledge are necessary to conserve traditional knowledge. In addition to traditional knowledge, nutrition education also should disseminate messages, such as the different energy content of boiled TFs vs. fried TFs, to prevent overweight. Adults could actively learn about the healthy preparation of TFs by cooking workshops and using innovative food preparation methods. Providing knowledge and motivation to adults to consume locally cultivated and wild fruit and vegetables, and to reduce the consumption of foods high in sugar, fat and salt has already been a good nutrition education cornerstone in indigenous peoples (Pettigrew *et al.* 2015). Traditional practices might need to be adapted to the current needs of having foods ready for consumption such as blanching, refrigeration, deep-freezing or fermentation. Although elderly are not reached by the educational system, they can be educated by mass media messages to support the sustainable consumption of TFs because of their physical limitations (Nur Asyura Adznam *et al.* 2009).

An innovative action to overcome the environmental barriers, i.e. availability and economic constraints, is to promote the cultivation of indigenous plant foods for self-consumption and commercialisation. Some examples of successful actions in Ecuador are “canastas comunitarias” (Paredes and Guerrón-Montero 2014) and FORSANDINO (FAO 2016a) which support small rural farmers to produce indigenous foods and distribute these directly to the urban consumers. Traditional knowledge of the sustainable cultivation of plant foods is implemented resulting in food production and knowledge conservation. Elderly (high valued ole people) are the main source of traditional knowledge, as they transmit this knowledge to adults who are in charge of agricultural activities. Additional outcomes of this intervention include that the dietary diversity of the indigenous farmers is increased, biodiversity is conserved in situ, multi-cropping reduces the outbreaks of pests, indigenous people return to their land, revenues are created by selling the surplus, traditional food systems are strengthened, and ultimately the urban consumers also increase their dietary diversity. These indicators show that this type of intervention brings development to a sustainable food system (Jaramillo *et al.* 2005; Maire and Delpeuch 2005).

Future action should implement the already existing nutrition (Freire *et al.* 2013) and biodiversity conservation (CBD 2001) Ecuadorian policies, giving more attention to indigenous communities. Policies should shift towards the use of sustainability indicators for food and development (Jaramillo *et al.* 2005; Maire and Delpeuch 2005). It is imperative that indigenous communities, who are in transition, adapt to the environmental changes they are facing. Innovative research is needed to measure nutrition indicators for development and indicators for sustainable food systems to evaluate the effectiveness of the interventions.

CHAPTER 5: Traditional foods contribute to dietary diversity and nutrient adequacy of women in Guasaganda, Central Ecuador

Abstract

Background: paradoxically indigenous women in Ecuador are involved in cultivation and collection of fresh food, but they suffer from malnutrition.

Objective: conduct a food intake study in indigenous women living in Guasaganda, central Ecuador evaluating the dietary diversity of the traditional diet and the contribution of traditional foods (locally cultivated and wild) to the nutrient adequacy of the diet.

Sampling: we used a two-step cluster design for sampling. Initially, 18 villages were selected (out of 38) using probability proportional to size from a list retrieved by the Ecuadorian Institute of National Surveys. Then, households were selected at random from a list of houses marked on a map using GPS coordinates.

Outcome indicators and methodology: food intake was recorded applying a 24-hour recall which was repeated to the same respondents after 14 days, and a food frequency questionnaire that was used in a subsample. Quartile 1, median and quartile 3 of energy, protein, total fat, total carbohydrates, available carbohydrates, dietary fibre, calcium, iron, zinc, vitamin A and vitamin C intakes were reported. The intake in g of the 15 most-consumed traditional foods was computed using Multiple Source Method. Nutrient Adequacy Ratios, Mean Adequacy Ratio, Food Variety Score and Minimum Dietary Diversity for Women (MDD-W) were reported.

Analysis: the usual diet was simulated using the food intake data from the two visits and frequency of consumption. Summary statistics using S-Plus reported the nutrient intake of the studied group. We gave a value of 1 point to all individual foods in a day record to determine Food Variety Score. To calculate WDDS, foods were grouped according to the 10 main food groups proposed by FAO. SPSS was used to calculate Spearman correlation and linear regression between TF intake and NAR and MAR.

Results: the studied diet has a median Food Variety Score of 23, mean Minimum Dietary Diversity for women of 7, and Mean Adequacy Ratio of 0.84. Consumption of traditional foods contributes to 38.6 % of total energy intake. Daily requirements for protein, carbohydrates, iron, zinc and vitamin C are reached. Plantain, milk, banana, papaya and orange are the most-consumed traditional foods contributing to considerable intakes of macro- and micronutrients.

Conclusions: traditional foods are contributing to adequate intakes of macro- and micronutrients and dietary diversification in indigenous women in Guasaganda. Future healthy-eating interventions should promote the consumption of traditional foods to increase dietary diversification and therefore the quality of the diet, but also to increase the cultivation and consumption of vegetables.

Key words: diet, nutrients, cultivated and wild foods, Ecuador, women

5.1 Introduction

A common issue for developing countries is malnutrition, despite their high and diverse agricultural production and wild foods from the forest. The most affected are people living in rural areas, who practice agriculture or collect food from the forest. Availability of a diversity of foods is thus a necessary but not a sufficient condition to reach energy and nutrient needs. A limited body of evidence shows that people living in rural and forest areas could consume the required energy and micronutrients by eating foods cultivated in the farms or found in the forest (Penafiel *et al.* 2011). Nutrition interventions in developing countries demand that both the consumption and contribution of local foods (wild and cultivated) is documented prior promoting local food consumption.

According to the pathways proposed by Kennedy *et al*. (2017) a diversity of foods reaches the consumers when they eat self-produced foods, wild plants and animals available in their environment and purchased those foods they cannot cultivate nor hunt or collect (BI 2017). This indicates the association of food biodiversity with food security. For example, in America there exist the *Inuit* Canadian aborigines who obtain up to 36% of their energy intake from TFs (Kuhnlein *et al*. 2004; Kuhnlein *et al*. 2009), whereas the *Awaju'n* indigenous Peruvians obtain 90% of their energy from Amazon foods (Roche *et al.* 2008). Among the most consumed energy-source foods are cassava, banana, plantain, sugar cane, rice, peanuts, sugar cane, taro, maize (ibid.). In the *Mand* of Pohnpei, the Federated States of Micronesia, 27% of calories come from local foods (Englberger *et al.* 2010), whereas in Africa, 52% of the dietary energy of *Evodoula* in Cameroon is provided by local foods (Mennen and Mbanya 2000). For the *Turumbu* in D.R. of Congo, up to 45% of total energy is coming from local roots and tubers (Termote *et al.* 2012).

Other studies show that local food biodiversity, cultivated or wild, significantly contributes to micronutrient intake. Eating a variety of local fish species in poor rural communities of Bangladesh provides them with 31 to 40% of the recommended intake of vitamin A and calcium, respectively (Roos *et al.* 2003). In rural villages in Vietnam, eating wild vegetables contributes to 21% of folate intake (Ogle *et al.* 2001c). The consumption of a high variety of local Arctic foods by local Canadians provides with 87, 23 and 37% of their total daily intake of cholecalciferol, vitamin A and tocopherol, respectively (Kuhnlein *et al.* 2006). High agricultural biodiversity, cultivated and wild food species, has been correlated with high Nutrient Adequacy Ratios for zinc, vitamin B12, B6, C, folate and riboflavin in two rural Kenya Villages (M'Kaibi *et al.* 2015).

Because most of the studies on food biodiversity concentrate on documenting the number of species in the diet, the contribution of local cultivated and wild foods to dietary diversity is implicit. A review of literature on food biodiversity shows *(Chapter 2*) that in rural areas diets are often diversified by foods coming from local agricultural production (crops and animals) (Lykke *et al.* 2002; Frei and Becker 2004; Rais *et al.* 2009; Powell *et al.* 2011; M'Kaibi *et al.* 2015), forests (wild foods) (Begossi and Richerson 1993; Ogle *et al.* 2001b; Osemeobo 2001; Passos *et al.* 2007; Powell *et al.* 2011; M'Kaibi *et al.* 2015) or wild fresh water fish or from aquaculture (Roos *et al.* 2003; Roos *et al.* 2007a; Bogard *et al.* 2015). Analysis of the former studies shows that farms are not only the main source of staple crops, but also supply wild foods such as wild vegetables; whereas forests are always the main source of wild foods, mainly fruits and bush meat.

The diets of rural people living in forest areas are, however, not entirely based on traditional foods. Apart from consuming foods from natural environments, rural people also consume industrialised foods as a result of acculturation (Kuhnlein and Receveur 1996). The latter combined with current environmental changes, which result in biodiversity loss; the scenario for rural people living in forest areas is worrisome as locally and wild foods contribution is expected to decrease. Documentation of current TF (locally cultivated and wild foods) consumption is needed to have a better knowledge of the sustainable management of natural resources for food.

5.2 Methods

5.2.1 Study area and subjects

Guasaganda is a tropical rural parish located in central Ecuador in the Andes region with altitudes that vary between 250 and 1,000 meters above sea level. The population (~3,900 inhabitants) are mainly indigenous. Figures of malnutrition presented in *Chapter 1* illustrate that indigenous women are vulnerable to overweight and micronutrient deficiencies, and therefore selected as study subjects. A previous forest inventory of edible plants in Guasaganda, reported a high number of food species, but the food intake of these foods was not quantified. This study recorded the food intake of indigenous women in Guasaganda during the rainy period of 2011.

5.2.2 Dietary surveys

Recording the intake of foods is a methodology widely used to assess the food intake of people and populations. One of the most commonly used is the 24-hour recall since it is very practical, has a relatively low cost and can be administered by interviewers after receiving simple training. This study used first a 24-hour recall questionnaire (from March to May 2011) which was repeated after 14 days in a second visit to have two non-consecutive days and reduce intra-personal variability, and further compute usual food intakes (Otten *et al.* 2006). The studied individuals were adult indigenous women (older than 18 years) living in Guasaganda, central Ecuador who were neither pregnant nor breastfeeding and who wehre living in Guasaganda for more than a year. Women were interviewed because they are often responsible for food preparation in rural areas.

The questionnaire recalled all food eaten in the previous 24 hours, including the amount of food consumed (using standardised measuring tools), the local name of each food used to prepare a recipe with its food source (i.e. collected/hunted or cultivated, purchased but not processed, purchased/processed food, food aid), brands for commercialised foods, and cooking method (i.e. raw, cooked, fried, oven). The interviews were done in the rainy season assuming there are more food species available (M'Kaibi *et al.* 2015). Also, demographic information documented age, household size, part-time or full-time occupation, and education level. Interviews were administered to participants at their house and in Spanish by trained interviewers supervised by the author of this thesis who is familiar with the study area and has indigenous ethnicity. Interviews conducted by the author served as control performance for the other interviewers. Protocols were developed using literature on dietary surveys (Willett 1998; Gibson 2005) and food biodiversity manuals

(FAOSTAT 2010). Participation was voluntary and with written consent. Interviews received ethical clearance from the ethical committee of Ghent University (B670201213216) and the Ecuadorian Ministry of Public Health (MSP-DIS0056-2012). The latter revised the CV of the author of this thesis and the interviewers to accept the protocols.

The number of households interviewed in the first and second visit was different because the heavy rains destroyed the main bridge that gave us access to the initial set of villages. For the first visit, sample size was calculated by using G*power software (general power analysis, v. 2009) aiming a precision of 0.5 SD and 80 % power on based on the the mean energy from traditinal sources among indigenous Awajun was of 3,478 ± 1,567 kcal/day, correcting for design effect and adding 15 % for drop off generating a sample of 300 individuals (FANTA 1997; Creed-Kanashiro *et al.* 2009). The latter number was confirmed by using the same sample calculation methodology but using TFDS from Roche *et al*. 2008 (9.5 ±3.5) generating 260 individuals. From the two calculations, we selected the higher number (300 individuals). Sampling was done following manuals from Food and Nutrition Technical Assistance (FANTA 1997,2005), and used a 2-step cluster design. In the first step, villages were selected from a list of all villages in the parish of Guasaganda provided by the Ecuadorian Institute of National Surveys (INEC 2010) using the Probability Proportionate to Size method. The second step involved a random selection of households within each village using a map created by us that positioned each house using GPS points. In the first visit, 18 villages were sampled, and a total of 260 households were visited. In each household, one woman in charge of TFs preparation was interviewed. For the second visit, only 10 villages were accessible, and therefore only 167 respondents were re-visited (Figure 5.1).

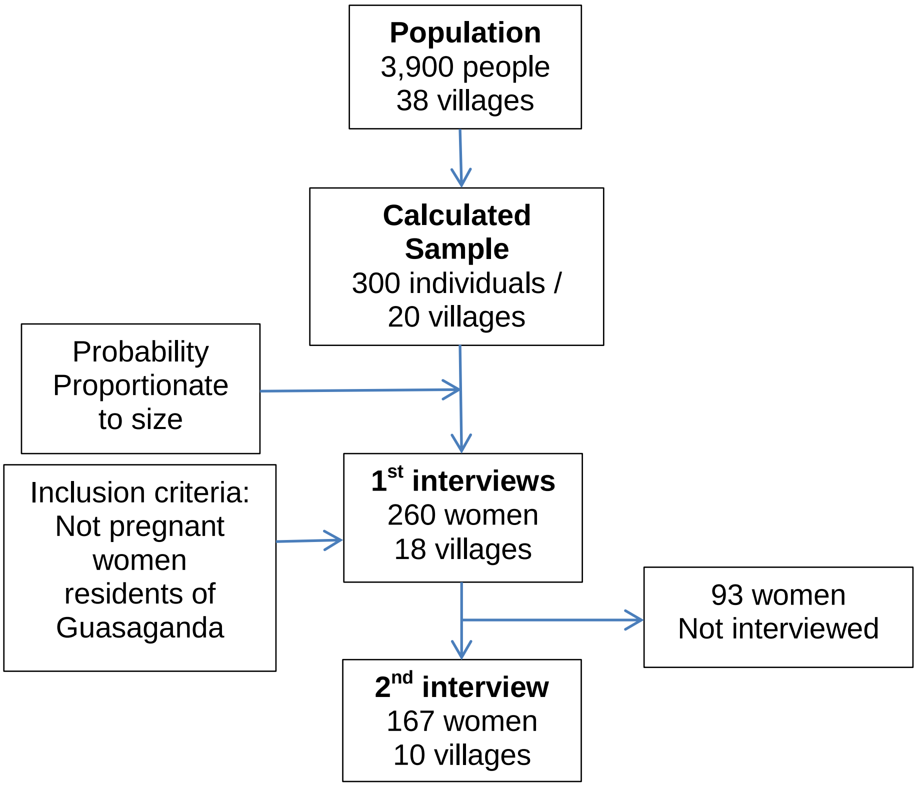

Figure 5.1 Sampling flow process for food intake study in Guasaganda

In each visit, a kit containing a standardised cup, dish and spoon were provided by the interviewer to the participant for more accuracy when describing portion sizes. This kit was given to the respondents as an incentive for participation following the recommendation from the ethical *ad hoc* committee of ESPOL.

A third visit to the villages (June 2012) was done using a Food Frequency Questionnaire (FFQ) to record the frequency of consumption of local foods. The latter is needed to use the Multiple Source Method to calculate usual intakes. In the third visit, 127 women (from the 167 interviewed in the second visit) were interviewed. The FFQ questionnaire had a list of 90 local plants, 26 animal foods, and a frequency of consumption of times per day, week, and per month to evaluate the most consumed TFs.

5.2.3 Traditional food identification

We collected plants in 2012, from June until August, in the *Sacha Wiwua* forest (Central Guasaganda) and surrounding farms areas. The collection of plants was done following literature (Bonham 1989; Elzinga *et al.* 1998) and as described in

Chapter 3 . We collected and identified all plants which were listed in *Chapter 3* as traditional plant foods (Table 3.1 and 3.3). The Ecuadorian Ministry of Environment provided a scientific permit allowing collection of edible plant sample (Permit N° 03-12IC-FAU-FLO-OPAC/MA). Animal samples (Table 3.2) were not collected because this was not allowed by the Ministry of Environment who forbids the capture of local animal species. Scientific names of plants were given following the botanical binomial nomenclature. For the latter, we used the official names as registered in the web page source (www.theplantlist.org, V 1.1). The scientific name for local birds, mammals and fish were retrieved from three web databases of Ecuador (Freile and Bonaccorso 2011; Ramiro 2011; Burneo and Boada 2012).

5.2.4 Recipe preparation

To conduct an adequate dietary assessment, it is necessary to know the nutrient content of all foods. The latter is often provided by a Food Composition Table (FTC) which fundamentally has a list of foods and their nutritional content. However, because this study recorded traditional recipes which were not found in any TFC we needed to construct them. We prepared traditional recipes at least three times to correct for different family cooking recipes, using traditional ingredients and the following the cooking practices of local people. Cooking was done to calculate the amount of each ingredient per total weight of the final dish. Preparation of the latter was done using local ingredients, in local kitchens and using local utensils. Each ingredient was weighed using a digital scale (± 0.01 g) which measured the ingredients in g and two decimal points (Mettler Toledo, EL 2001). The mixed method for recipe calculation recommended by FAO was used to correct nutrients at ingredient level by using nutrient retention factors (USDA 2007) and yield factors (Bergstronm 1998), according to the preparation method reported in the 24 hour-recall. By this method, the percentage of weight change, or the percentage of nutrient retention or loss, due to cooking methods was corrected. For example, when plantain is cooked in a soup it tends to absorb water and increase its weight but also losses vitamin C due to the heat. This way we could correctly calculate for weight and vitamin C content based on the values from the FCT for plantain in raw state.

5.2.5 Analysis

All food intake data from the 24-hour recall questionnaires was entered in Lucille application (Lucille, Version 0.1.6.8) to have the list and the number of foods present in the diet. The latter application exported an excel document with the list of all consumed foods and the quantified intake per person. We used FCTs of Peru (INS 2009) and Central America (INCAP 2012) to extract the nutritional content of each food item assuming that these were similar geographical areas. The FCT of Ecuador was used only for foods that were not found in the other two FCTs because it is a very old publication (INN 1695). The USDA National Nutrient Database for Standard Reference was used for missing values (USDA 2014). Energy, protein, fat, carbohydrates, fibre, calcium, iron, zinc, vitamin A and vitamin C were retrieved from the FCTs. Vitamin D was not studied assuming that in Ecuador this vitamin is mainly cutaneous synthesised under high sun exposure (EFSA-NDA 2016b). Iodine was also not considered because 99 % of the Ecuadorian population consumes iodised salt (MSP 2013). Compilation of the final FCTs was done assigning to each reported food the nutrient content exported from the FCT or the mixed method for recipe calculation following manuals in the literature (Charrondiere and Burlingame 2010). Also, a column that included the FCT source was added for traceability. The original Excel data set from Lucille was double checked to correct for data entry errors comparing outliers with the original recall forms.

To report Food Variety Score, we used a simple count of food items giving a value of 1 point to each food consumed in a day record. To report Minimum Dietary Diversity for Women of reproductive age (MDD-W) foods were grouped into 10 food groups as proposed by FAO (FAO 2014a). MDD-W is a dichotomous indicator that shows micronutrient adequacy of the diet when more than 5 food groups (out of the 10) are consumed and has been validated in developing countries (FAO/FHI360 2016). Individual foods were grouped into all starchy and staple foods, beans and peas, nuts and seeds, dairy, flesh foods, eggs, leafy vegetables, other vitamin A-rich vegetables and fruits, and other fruits. Locally cultivated Vitamin A-rich dark green or other vegetables were not recalled during the interviews and therefore not included in the analysis.

Summary statistics were reported by using SPSS for the demographics of studied women (Table 5.1). The average nutrient intake of the first and second visit (n=260) was calculated and summary statistics were retrieved correcting for clustering of villages using SPSS. Most of the data was not normally distributed, therefore, the quartile 1 (25^{th}), median and quartile 3 (75^{th}) values of intakes were reported (Table 5.2). Reporting quartiles and the median as the central tendency is aimed to facilitate non-scientist readers to know the composition of the diet (Lang and Secic 2006).

Nutrient Adequacy Ratio (NAR) was calculated by dividing the quantified intake of a nutrient by the Estimated Average Requirement (EAR) as proposed in the literature (Otten *et al.* 2006 and Murphy 2008). The EAR is the intake sufficient to meet 50 % of the nutrient requirements (which in a normal distribution is the mean or median), thus a person that consumes the EAR for a specific nutrient has 50% probability to meet the requirement, therefore EAR was used as the cut-off point (Otten *et al.* 2006). Table 5.2 shows the percentage of the population below the EAR except for energy (because the requirement is highly correlated with the intake) and iron (because the distribution of the requirement is normally distributed) (ibid.). Values below the EAR show that interventions are needed as the probability of adequacy is less than 50 % (ibid.). Calculating NAR allows us to easily see if the requirements are met. Values closer to 1 indicate that the intake is closer to the requirements. For energy, the EAR in emergency situations was used (Clugston 1999) because of the heavy rainy season the population was confronting and assuming 55 kg of body weight, and physical activity level for non-mechanized farming and home chores (FAO/WHO 1973). The EAR for protein was at 0.66 g/kg assuming 55 of body weight and quality and digestibility of the protein as for eggs (FAO/WHO 1973; EFSA-NDA 2012). The requirement for fat intake was converted from 20 % of total energy consumption to g of fat using the Atwater factor of 9 kcal/g (FAO/WHO 1994; EFSA-NDA 2010b). The requirement for carbohydrate intake (50% of the total energy intake) and fibre was for not-pregnant and not breastfeeding female adults (EFSA-NDA 2010a; IOM 2010). The calcium requirement covered dermal and urinary losses (FAO/WHO 2004; EFSA-NDA 2015). The iron requirement covered menstruation losses and assumes 55 kg of body weight and 12 % bioavailability as the diet is composed of rice, fruits and animal protein (FAO/WHO 2004; EFSA-NDA 2016a). Zinc recommendations assumed a bioavailability of 30 %

since local diets consist of both animal and plant foods and 55 kg of body weight (FAO/WHO 2004). EAR for vitamin A was at 8.4 µg/kg and assumed 55 kg of body weight (EFSA-NDA 2016b). The EAR for vitamin C assumed an absorption of 80 % and a body weight of 55 kg (EFSA-NDA 2013). Additional to use the EAR cut-off point hypothesis testing (non-parametric) was conducted to test if the intake was significantly higher than the EAR for nutrients that reported a NAR higher than 1.

Using SPSS, correlation (Spearman's rank correlation) was performed to evaluate the correlation between NAR and nutrient contribution of TFs (cultivated and wild merged) since normality of the residuals and constant variances were not present. The latter was tested qualitatively by using QQ and residual plots, respectively. Using pivot tables from the original Lucille Excel-dataset the intake of TFs (cultivated and wild merged) in g was calculated. Linear regression between the intake g of TFs (independent variable) and MAR (dependent variable) was calculated using SPSS. MAR of 0.75 was used as cut-off for adequacy of the diet (Schuette *et al.* 1996; Hatloy *et al.* 1998). MAR of 0.75 was selected because it has shown to identify as many inadequate diets as possible (high sensitivity) with a combined ability to identify nutritional adequate diets (specificity) (ibid).

Summary statistics were used to report the quartile 1, median and quartile 3 of consumption for the 20 most-consumed TFs under the MDD-W food groups (Table 5.4). The 20 most consumed foods were identified using pivot tables from the original Lucille Excel-dataset which allowed us to calculate the average intake of each TF in g/day and then foods were organised according to intake in g/day from 0 up to the higher consumption. The Multiple Source Method (MSM) was used to simulate the usual diet during the sampled season. This method is a relatively novel method that uses at least two-day intake records and a frequency of consumption and applies two regression models, one for the positive daily intake data and one for the event of consumption to simulate usual diet. MSM computes the individual probability of consuming a specific food or nutrient by estimation using a logistic regression model that uses age and interviewer codes as covariates. This methodology allowed us to use the MSM software's option to correct for the interviewer (because of the different interviewers involved in the field work which may affect the documented intake) and age (because the wide age range of the studied women that may also affect the results). Within-person variability was reduced by using the quantified intakes from visit 1 and visit 2, and using the frequency of consumption from the FFQ (visit 3). The MSM uses the residuals of the regression to estimate variances and a Box-Cox transformation to estimate inter- and intra-individual variance (MSM V 1.01 https://msm.dife.de/).

SPSS summary statistic was used to report the mean intake of traditional foods (locally cultivated and wild) and non-traditional (not locally cultivated nor wild but purchased in markets) and foods processed by the industry for fruit, vegetables, staples, animal meal and legumes correcting for clustering of villages. Hypothesis testing (non-parametric) was used to test if the mean intake of TF was significantly different to non-traditional intake for fruit and vegetables, and legumes (because the number of reports for industrialised products was not adequate for an ANOVA test). The mean intake of traditional drinks was compared with the consumption of industrialised foods also in a non-parametric test. Levene test was applied to assess homogeneity of variances for staples and animal flesh, which indicated us to conduct a Kruskal-Wallis test.

The mean intake of total fruit and vegetable consumption was also computed. One sample t-test was conducted (assuming CLT) to test significant difference between the mean total fruit and vegetable consumption, and the 200 g fruit and 200 g vegetables, respectively, recommended for the prevention of chronic diseases (Kromhout *et al.* 2016) correcting for villages using SPSS. The results were confirmed by a second statistician using Stata (using the command svy).

5.3 Results

Table 5.1 shows the demographic characteristics of the respondents. The age of the studied women ranges from 18 to 69 years, with a median age of 38. Visited households have a maximum of 13 inhabitants and a median of 5. Most of the studied women are housewives who practice agriculture at home as a part-time occupation. Most women were agriculturally employed at the moment of the interview, in other words, they were working for others on land that does not belong to them. However, their partners had employments different from agriculture. Most of the studied women received primary education whereas their respective husbands reached secondary school.

Table 5.1 Demographic characteristics of the studied women and their respective partners

Characteristics (260 women)	n (%)
Full-time occupation	
Agricultural employment	28 (10.7)
Non-agricultural employment	14 (5.4)
Housewife	208 (80)
Student	4 (1.5)
Home agricultural activities	6 (2.3)
Part-time occupation	
Agricultural employment	83 (31.9)
Non-agricultural employment	15 (5.8)
Housewife	50 (19.2)
Student	2 (0.8)
Home agricultural activities	106 (40.7)
None	4 (1.5)
Main Home Income	
Agricultural employment	127 (48.8)
Non-agricultural employment	86 (33.1)
Home Agricultural activities	45 (17.3)
None	2 (0.7)
Education	
Primary school	161 (61.9)
Secondary school	68 (26.1)
University	5 (1.9)
Technical Training	2 (0.8)
Other	23 (8.8)
None	1 (0.4)
Conjugal Status	
With Partner	219 (84.2)
Without partner	41 (15.8)
Occupation partner	
Agricultural employment	41 (15.8)
Non-agricultural employment	149 (57.3)
Household	52 (20)
Student	4 (1.5)
Home Agricultural activities	11 (4.2)
Other	3 (1.2)
Education partner	
Primary school	41 (15.8)
Secondary school	153 (58.8)
University	41 (15.8)
Technical Training	8 (3.1)
Other	1 (0.4)
None	16 (6.1)

Table 5.2 Description of the diet of women in Guasaganda-Ecuador during the rainy season of 2011 (n=260), and the percentage of women below the Estimated Average Requirement (EAR) for the listed nutrients, and the nutrient adequacy ratio (NAR)

Nutrient (unit)	Q1	Median	Q3	EAR	%<EAR	NAR	p-value
Energy (kcal)	1114.7	1315.9	1611.2	1990	-	0.67	
Water (g)	1223.2	1457.3	1718.3	-	-	-	-
Protein (g)	33.3	44.5	57.7	36.3	32	1.30	0.001*
Total Fat (g)	25.2	32.5	42.3	29.7	40	1.18	0.001*
Carbohydrates Total (g)	162.6	202.5	261.6	167	28	1.29	0.001*
Carbohydrates Available (g)	157.8	196.7	249.5	-		-	-
Dietary Fibre (g)	5.1	7.5	11.3	25	97	0.35	
Calcium (mg)	220.4	346.8	527.9	750	93	0.52	
Iron (mg)	5.7	7.3	9.4	6.87	-	1.49	0.001*
Zinc (mg)	3.9	5.5	7.3	5.8	54	1.01	0.8204
Vitamin A (RE)	214.1	329.8	465.9	464	75	0.88	0.001
Vitamin C (mg)	50.7	80.5	131.3	75.6	47	1.62	0.0002*
Mean Adequacy Ratio						**0.84**	

*Wilcoxon signed-rank test right-tailed was conducted to test if the mean nutrient intake was significantly higher than the EAR
EAR cut-off method was not used for energy or iron as both do not meet the conditions for this methodology (Otten et al. 2006)

The diet during the rainy season of 2011 was based on 140 different food items. The studied women consumed at least 10 different foods per day (FVS), with a maximum of 31 and a median of 23. In general, the diet is short in kcal with only 6 % of the surveyed women consuming the required caloric intake whereas the rest consumed less than required (89 %) or more (5 %). On the other hand, the mean intake of protein, fat, total carbohydrates, iron, zinc and vitamin C is significantly higher than the EAR, meaning that enough of these nutrients are consumed (NAR > 1) (Table 5.2). The Mean Adequacy Ratio calculated for 10 nutrients (truncated to 1) was 0.84, meaning that the diet is adequate for some of its nutrients.

During the sampled period, 70 TFs (locally cultivated and wild foods) were consumed. These include 50 plants and 13 animal species, and 7 medicinal plants.

The consumption of these TFs contribute to a mean TFDS of 8.9 ± 3.7, and to 38.6 % of the total energy intake. The latter excludes 7 medicinal plants that do not contribute to energy because they are used as infusions. Furthermore, the proportion of TFs intake contributing to total protein, fibre, calcium, iron, zinc, vitamin A and C is higher than 50 % (Table 5.3). Spearman correlation shows that the consumption of locally cultivated and wild foods is positively correlated with higher intakes of micronutrients, whereas correlation with macronutrient is low (Table 5.3). There exists a stronger correlation between the consumption of locally cultivated and wild foods (TFs) and the NAR for iron calcium, zinc and vitamin C. The intake in g of TFs was correlated (correlation coefficient r=0.425) with MAR (0.0005 effect and 0.6661 intercept). Out of the 260 participants, 179 (68.8%) had a MAR higher than 0.75 and an average TF consumption of 656 g.

Table 5.3 Correlation between NAR and contribution of traditional foods (locally cultivated and wild foods merged) to energy and 9 nutrients

Nutrient	**Mean (SD) Nutrient intake From TFs**	**Contribution (%) of TFsintake to total nutrient intake**	**Spearman correlation TFs and NAR**
Energy (kcal)	515.7 (225.2)	38.6	0.48*
Protein (g)	30.0 (19.0)	63.6	0.61*
Total fat (g)	15.5 (9.8)	43.9	0.43*
Carbohydrates Total (g)	56.4 (34.5)	26.1	0.32*
Fibre (g)	4.9 (5.0)	55.1	0.62*
Calcium (mg)	235.8 (198.3)	59.4	0.71*
Iron (mg)	5.5 (8.7)	54.5	0.52*
Zinc (mg)	3.5 (2.3)	59.3	0.67*
Vitamin A (RE)	213.1 (259.0)	52.2	0.59*
Vitamin C (mg)	85.9 (133.9)	70.1	0.64*

*Significant at 0.01 level

The studied women consumed a median MDD-W of 6 out of 10 food groups, which is higher than the cut-off of 5, meaning that the studied diet is adequate in micronutrients (FAO/FHI360 2016) . Table 5.4 presents the consumption in g and the frequency of consumption of the top 20 TFs within each MDD-W food group. The usual intake of the most-consumed TFs (mainly cultivated) that contributed to the MDD-W is presented in Table 5.5.

Plantain (*Musa* x *paradisiaca* L.) is the most-consumed starchy TFs, it is consumed as a staple food, boiled or fried, one or twice a day, and it supplies 6 % of total energy. Bananas (*Musa acuminata* Colla) and oranges (*Citrus maxima* (Burm.) Merr.) are consumed as fruits, riped and raw, once or twice a day. The latter contributes to 45 % of total vitamin C intake. Orange juice consumers drink about one litre per day. Tree tomato (*Solanum betaceum* Cav.) and mandarins (*Citrus reticulata* Blanco) are also highly consumed in a frequency of twice per week and once a day, respectively. The former needed a blanching process to remove the peel, while mandarins are easily peeled and eaten fresh.

Sixty-seven percent of the population consumes more protein than the required 36.3 g/day (p-value<0.001). Milk and egg consumption contributed to 7 and 5 % of total protein intake, respectively. The community consumes milk and eggs, generally as part of breakfast or as an ingredient in traditional dishes. Pork and freshwater fish are eaten in a higher amount than other flesh foods but are eaten once a week (p-value<0.001). The intake of fish contributes 7 % of total energy and 4 % of total calcium intake. Pork and freshwater fish are traditionally prepared in soups, stews, or fried. Most of the interviewed people had eaten beef or chicken on the surveyed days. Beef and chicken intake contributed to 24 % and 15 % of the total protein intake, respectively.

Peanut (*Arachis hypogaea* L.) paste is also used as an ingredient in some traditional dishes which are frequently consumed. Faba beans (*Vicia faba* L.) are consumed weekly, whereas red beans (*Phaseolus vulgaris* L.) are only monthly consumed. Beans are used to prepare “menestras” (beans cooked in water and spices at high temperatures for a long period until these melt) or as an ingredient in soups. Red beans’ consumption contributes to 29 % of total iron intake.

Table 5.4 Intake of locally cultivated foods in grams (g), during rainy season of 2011, contributing to Minimum Dietary Diversity for Women

MDD-W food groups	*Scientific name* author	Repeated 24-hour recall (n=260)				FFQ (n=127)
		n recalls intakes	g / serving			Mean Frequency consumption
			Min	Median	Max	
Starchy staple foods						
Plantain	*Musa x paradisiaca L.*	260	5.8	87.5	451	2.5 times/week
Cassava	*Manihot esculenta* Crantz	41	10	58.4	292	1 time/week
Maize	*Zea mays* L.	38	0.2	33.6	455	1 time/month
Taro/Papa china	*Colocasia esculenta* (L.) Schott	7	10	38.2	251	1 time/month
Dairy						
Milk		173	0.3	183.1	467	3 times/week
Flesh foods						
Beef	*Bos taurus*	193	4	32.3	255	1 time/week
Chicken	*Gallus gallus domesticus*	155	8.5	36.9	330	1 time/week
Freshwater fish	Eight species merged	48	15	41.6	506	1 time/week
Pork	*Sus domesticus*	36	15	51.8	220	1 time/week
Eggs		141	0.5	49.4	83	2 times/week
Other vitamin A-rich vegetables and fruits						
Banana	*Musa acuminata* Colla	34	60	164.4	329	3 times/week
Papaya	*Carica papaya* L.	14	57	182.9	200	1 time/week
Baby Banana	*Musa acuminata* Colla	5	52	52	104	1 time/week
Pumpkin	*Gurania* sp.*	4	24	77.3*	95.2	1 time/month
Other fruits						
Oranges	*Citrus maxima* (Burm.) Merr.	122	1	185.2	1500	4 times/week
Tree tomato	*Solanum betaceum* Cav.	54	25	91.7	183	2 times/week
Mandarines	*Citrus reticulata* Blanco	5	95	120	213	2 times/week
Beans and peas						
Faba beans	*Vicia faba* L.	71	2	17.5	72	1.5 times/week
Red beans	*Phaseolus vulgaris* L.	33	6	60.3	121	1 time/month
Nuts and seeds						
Peanut	*Arachis hypogaea* L.	12	5	10.9	55	2 times/month

*average
MDD-W refers to Minimum Dietary Diversity for Women

Table 5.5 Usual intake * of the most-consumed traditional foods, that contribute to the Minimum Dietary Diversity for Women (MDD-W)

MDD-W food groups	Mean intake (SD)											
	Energy kcal	Water g	Protein g	Fat g	Carbs g	CarbsA g	Fibre g	Ca mg	Fe mg	Zn mg	VitA RE	VitC mg
All starchy staple foods												
Plantain	81 (45)	34 (18)	0.5 (0.3)	0.1 (0.1)	22 (12)	20 (12)	1.2 (0.5)	5.1 (2.5)	0.4 (0.2)	0.1 (0.1)	53 (27)	3.5 (3.0)
Cassava	17 (14)	6.8 (5.5)	0.1 (0)	0 (0)	4.2 (3.3)	4.0 (3.1)	0.2 (0.1)	3.2 (2.2)	0 (0)	0 (0)	0 (0)	2.5 (2.1)
Maize	12 (20)	1.9 (3.6)	0.3 (0.5)	0.2 (0.3)	2.9 (5.6)	2.7 (5.4)	0.2 (0.3)	0.6 (1.3)	0.1 (0.1)	0.1 (0.1)	0(0)	0.2 (0.5)
Dairy												
Milk	48 (48)	71 (68)	2.6 (2.5)	2.6 (2.6)	3.7 (3.5)	3.7 (3.5)	0 (0)	91 (88)	0 (0)	0.3 (0.3)	22 (22)	0 (0)
Flesh foods												
Beef	88 (46)	19 (10)	8.9 (4.7)	5.7 (2.9)	0 (0)	0 (0)	0 (0)	6.4 (3.4)	0.6 (0.4)	1.6 (0.8)	0 (0)	0 (0)
Chicken	37 (34)	13 (12)	5.6 (5)	1.4 (1.4)	0.1 (0.1)	0 (0)	0 (0)	2.9 (2.7)	0.2 (0.2)	0.4 (0.4)	3.1 (2.9)	0 (0)
Freshwater fish	15 (22)	5.9 (8.6)	2.8 (4.2)	0.4 (0.6)	0 (0)	0 (0)	0 (0)	15 (23)	0.2 (0.3)	0.1 (0.1)	0 (0)	0 (0)
Pork	15 (24)	2.6 (4.3)	1.5 (2.3)	1 (1.5)	0 (0)	0 (0)	0 (0)	1.6 (2.5)	0.1 (0.1)	0 (0)	0 (0)	0 (0)
Eggs	19 (18)	10 (9.6)	1.8 (1.6)	1.1 (1.1)	0.3 (0.2)	0.3 (0.2)	0 (0)	4.1 (3.8)	0.1 (0.1)	0.1 (0.1)	14 (13)	0.3(0.3)
Other fruits												
Oranges	32 (34)	81 (97)	0.5 (0.6)	0.2 (0.2)	7.9 (8.9)	7.1 (8.5)	1.5 (1.8)	25 (30)	0.2 (0.2)	0.1 (0.1)	2.5 (8)	55 (70)
Tree tomato	6 (11)	10 (20)	0.3 (0.5)	0.1 (0.2)	1.2 (3.2)	1.2 (2.3)	0 (0)	1.1 (2.1)	0.1 (0.2)	0 (0)	35 (69)	3.4 (6.6)
Beans and peas												
Faba beans	9.4 (10)	2.0 (2.1)	0.7 (0.7)	0.2 (0.2)	1.0 (1.5)	1.4 (1.6)	0.1 (0.1)	1.8 (1.9)	0.2 (0.2)	0.1 (0.1)	0.3 (0.3)	0.7 (0.7)
Red beans	15 (20)	1.3 (1.8)	0.9 (1.3)	0.1 (.1)	2.7 (3.7)	2.0 (2.7)	0.9 (1.3)	4.0 (5.4)	2.7 (3.6)	0.1 (0.2)	0.2 (0.3)	0.1 (0.2)

kcal refers to kcalories, CarbsA refers to available carbohydrates, Ca refers to calcium, Fe refers to iron, Zn refers to zinc, VitA refers to vitamin A and VitC refers to vitamin C

*Usual intake computed using day 1 and day 2 intakes and frequency of consumption simulated by using the MSM method (V1.0.1), only for food groups which were consumed in the 2 recalls of the 260 studied women

5.3 Additional findings

Additional to locally cultivated and wild foods, 46 non-locally produced cultivated foods were part of the diet and the studied women consumed 33 commercialized foods with industrial origin. Table 5.6 shows the consumption of fruit, vegetable, staples and animal meat, legumes and drinks of the studied women whether locally cultivated and wild (TFs), non-traditional (listed in Table 5.7) or industrialised (listed in Table 5.8). The number of plant species locally cultivated and wild fruit and vegetables consumed is 1.5 (± 0.5) and 1.7 (± 0.9), respectively. An ingredient considered a condiment and used daily in almost every dish is coriander (*Coriandrum sativum* L.) which provides with 4 % of the total vitamin A intake but was not counted as vegetable within the MDD-W score.

Table 5.6 Intake in grams (Mean and Standard Deviation corrected for clustering of villages) of traditional (locally cultivated and wild merged), non-traditional (not locally cultivated) and industrialised foods in Guasaganda, Ecuador

Source / Food group	Traditional food		Non-traditional food		Industrialised		p-value
	Intake g Mean (SD)	n	Intake g Mean (SD)	n	Intake g Mean (SD)	n	
Fruit	195.7 (204.8)	223	129.9 (63.8)	58	25	1	0.097
Vegetables	30.39 (14.6)	245	118.7 (51.1)	259	-	0	<0.001
Staples	106.4 (75.1)[a]	212	366.7 (170.4)[b]	259	45.7 (24.6)[c]	161	<0.001
Animal flesh	88.8 (70.1)	220	73.68 (53.4)[a]	50	42.7 (36.9)[b]	39	<0.001
Legumes	34.4 (28.3)	81	32.5 (16.2)	64	-	0	0.963
Drinks	305.4 (128.1)	144	-	0	322.5 (14.2)	58	0.433

In grey: Wilcoxon (non-parametric two-sample test) rank-sum tests (5% level of significance) between traditional and non-traditional food, except for drinks which mean consumption of traditional (aromatic drinks) was compared with carbonated drinks.
White cells: Kruskal-Wallis rank sum test used because LEVENE test (p-value<0.001) indicates that at least one variance is not equal, when p<0.05 Tuckey for multiple comparisons (family wise 5% significance) was performed.
n is the number of respondents consuming each food group
Superscript letters show significant difference between groups

Total fruit and vegetable intake do not meet the 200 g recommended preventing chronic diseases for each food group (WHO 2003a; Kromhout *et al.* 2016), respectively (both p-value<0.001). Analysis of ruminant meat intake shows that the mean intake is higher than the maximum 50 g recommended for sustainable diets (p-value<0.001).

Table 5.7 List of purchased-raw plant foods recorded by the 24-hour recalls as consumed in Guasaganda, Ecuador

English name	***Scientific name author****	***Local name***	**Use**
Apple	*Malus domestica* Borkh.	*Manzana*	Fruit
Babaco	*Vasconcellea × heilbornii* (V.M. Badillo) V.M. Badillo	*Babaco*	Fruit
Barley	*Hordeum vulgare* L.	*Cebada/Machica*	Starch/flour
Beetroot	*Beta vulgaris* L.	*Remolacha*	Vegetable
Blueberry	*Mora* spp.	*Mora*	Fruit
Broccoli	Brassica oleracea L.	Brocoli	Vegetable
Cactus pear	*Opuntia ficus-indica* (L.) Mill.	*Tuna*	Fruit
Carrot	*Daucus carota* L.	*Zanahoria*	Vegetable
Cauliflower	*Brassica oleracea* var. *botrytis* L.	*Coliflor*	Vegetable
Chard	*Beta vulgaris subsp. vulgaris*	*Acelga*	Vegetable
Cinnamon	*Cinnamomum verum* J.Presl	*Canela*	Spice
Cucumber	*Cucumis sativus* L.	*Pepino*	Vegetable
Cumin	*Cuminum cyminum L.*	*Comino*	Spice
Flesh onion	*Allium fistulosum* L.	*Cebolla blanca*	Vegetable
Garlic	*Allium sativum* L.	*Ajo*	Spice
Grape	*Vitis vinifera L.*	*Uva*	Fruit
Green beans	*Phaseolus vulgaris sp.**	*Vainitas*	Vegetable
Green peas	*Pisum sativum* L.	*Alverja*	Legume
Greengages	*Prunus domestica* subsp. *italica var. claudiana*	*Claudia*	Fruit
Honey	*	*Miel de abejas*	Sweetener
Lentils	*Lens culinaris* Medik.	*Lentejas*	Legume
Lettuce	*Lactuca sativa* L.	*Lechuga*	Vegetable
Melon	*Cucumis melo* L.	*Melon*	Fruit
Mote	*Zea mays sp.**	*Mote*	Vegetable
Oats	*Avena sativa L.*	*Avena*	Cereal
Oregan	*Origanum vulgare* L.	*Oregano*	Spice
Peach	*Prunus persica* (L.) Batsch	*Durazno*	Fruit
Pepper	*Capsicum annuum* L.	*Pimiento verde*	Vegetable
Pineapple	*Ananas comosus (*L.) Merr.	*Piña*	Fruit
Pitahaya	*Selenicereus megalanthus* (K. Schum. ex Vaupel) Moran	*Pitahaya*	Fruit
Potatoes	*Solanum tuberosum* L.*	*Papas*	Starch source
Quinoa	*Chenopodium quinoa* Willd.	*Quinua*	Cereal
Radish	*Raphanus sativus* L.	*Rabano*	Vegetable
Red beans	*Phaseolus vulgaris* L.	*Frejol de palo*	Legume
Red onion	*Allium cepa* L.	*Cebolla roja*	Vegetable
Rice	Oryza sativa L.*	*Arroz*	Starch source
Soybean	*Glycine max* (L.) Merr.	*Soya*	Vegetable
Spinach	*Spinacia oleracea* L.	*Espinaca*	Vegetable
Strawberry	*Fragaria × ananassa* (Duchesne ex Weston) Duchesne ex Rozier	*Frutilla*	Fruit
Tararind	*Tamarindus indica* L.	*Tamarindo*	Fruit
Tomato	*Solanum lycopersicum* L.	*Tomate*	Vegetable
Turnip	*Brassica rapa* L.	*Nabo*	Leaves and root as vegetables
Ulluco	*Ullucus tuberosus* Caldas	*Melloco*	Vegetable
Watermelon	*Citrullus lanatus* (Thunb.) Matsum. & Nakai	*Sandia*	Fruit
Wheat	*Triticum* spp.	*Trigo*	Flour
White cabbage	*Brassica oleracea* L.	*Col blanca*	Vegetable

Table 5.8 Industrialised foods of plant and animal origin, consumed in Guasaganda, Ecuador in 2011

Main source	English name	*Local name*	Use
Plant	Bread	*Pan de sal*	For Breakfast
	Sweet bread	*Pan de dulce*	As snack
	Candy	*Caramelos*	As snack
	Chocolate powder	*Chocolate en polvo*	For warm drinks
	Corn starch	*Maicena*	Thickening agent
	Crackers	*Galleta de sal*	As snack or to cover chicken or meat
	Instant coffee	*Café instantáneo*	For warm drinks
	Instant soup	*Sopita china*	Replacement of soup
	Mustard	*Mostaza*	As dressing
	Noodles	*Fideo o Tallarín*	In soup or pasta
	Soy sauce	*Salsa china*	As spice
	Sugar	*Azúcar*	Sweetener
	Sweet cookies	*Galletas de dulce*	As snack
	Vegetable oil (palm and soy)	*Aceite*	In all fried preparations
	Wafers	*Galletas de wafer*	As snack
	Wheat flour	*Harina de trigo*	To prepared bread and cakes
	Marmalade	*Mermelada*	To add to bread or cakes
Animal	Bouillon cubes	*Cubito de pollo/carne*	For soup
	Canned european pilchard	*Sardina enlatada*	In soup or with rice
	Canned tuna	*Atún*	In salad, or with rice
	Gelatine	*Gelatina*	As dessert
	Margarine	*Margarina*	In some fried preparations, with bread
	Mayonnaise	*Mayonesa*	As dressing for salad or meat
	Milk powder	*Leche en polvo*	For dessert or coffee
	Mortadella	*Mortadela*	As snack or with rice
	Sausage	*Chorizo*	As snack or with rice
	Yogurt	*Yogur*	Dessert or for breakfast
Other	Soft drinks	*Jugos*	As cold drink
	Baking powder	*Polvo de hornear*	To prepared bread and cakes
	Salt	*Sal*	For flavour
	Carbonated soft drinks	*Cola*	As cold drink
	Iced tea	*Té helado*	As cold drink
	MonoSodiumGlutamate	*Ajino moto*	Flavour-enhancer

5.4 Discussion

In this study, we demonstrated that TFs (cultivated and wild) were providing to indigenous women in Guasaganda with substantial amounts of nutrients, mainly micronutrients, during the rainy season of 2011. Results show that the studied diet is adequate in some nutrients (MAR = 0.84), although mean energy intake is lower than the daily required. Dietary diversity is based on the 140 different food items, of which

70 are locally cultivated and wild. About 9 food species (TFDS) are consumed per day from local and wild sources. MDD-W of 6 shows adequacy of micronutrient intake (FAO/FHI360 2016). The most consumed TFs, cultivated and wild, are identified and quantified, which serves for future interventions that aim to promote TF consumption in the area. Also, commercialised foods are identified showing that the indigenous diet is in transition and requires an increase consumption of locally cultivated and wild foods.

TF consumption contributed to Mean Adequacy Ratio. Almost 69% of the studied group had a MAR higher than 0.75 which infers adequacy for 9 of the studied nutrients. Using the computed regression model, we can assume that when no TFs are consumed, the MAR is 0.66, indicating that indigenous women consumed foods that are not locally cultivated (listed in Table 5.7) and need to be purchased resulting in essential contributors of food security. However, the limited economic access to buy foods is a common issue.

The most-consumed starchy TF is plantain (*Musa x Paradisiaca* L.) and therefore an important source of energy. The high consumption of plantain by indigenous people in South America has been reported by another study in the field of nutrition and forest conservation (Roche *et al.* 2008). An exploratory study done in Guasaganda reported that plantain was the most abundant species in the area (Aguilar *et al.* 2010), which is probably the reason for its high consumption. From the same family, banana (*Musa acuminata* Colla) is the most-consumed fruit. The high consumption of banana by South American forest communities has also been reported by other studies (Passos *et al.* 2007; Roche *et al.* 2008). Consuming 100 g of *Musa* spp. fruit with high pro-vitamin A content has been reported to contribute to 95 % and 47 % of the EAR for children and adults, respectively (Davey *et al.* 2009). Our study also shows that cassava (*Manihot esculenta* (L.) Schott) is the second most-consumed starchy food. Indigenous Awajun in Peru eat cassava tubers as a staple food, but they also consume cassava leaves which is not consumed in Guasaganda (Roche *et al.* 2008; Creed-Kanashiro *et al.* 2009). Another difference in eating habits is that the Awajun eat cassava every day whereas in Guasaganda it is eaten once per week. Surprisingly, the intake of calcium is significantly lower ($p<0.001$) than the recommendation considering that milk is intensively produced in the area. The limited consumption of foods, such as milk, which are locally produced and inexpensive, is a behaviour that deserves to be further studied in this population.

Our study supports findings of similar studies done in indigenous communities in South America (Roche *et al.* 2008), Canada (Kuhnlein *et al.* 2006), Africa (Termote *et al.* 2012), Oceania (Englberger *et al.* 2006) and South East Asia (Ogle *et al.* 2001b) in that TFs (whether cultivated or wild) contribute to a share of micronutrient intake. Because we merged cultivated and wild foods the reported contribution is, however, probably higher than the referred studies. The study of Roche *et al.* (2008) reported an energy intake of 3,478 ± 1,567 kcal/day for the indigenous Peruvian Awajun similarly to a recent study on adult Sagaruros who are an ethnic group of Southern Ecuador characterized for their strongly preserved traditional eating and dressing who are consuming an average of 2,349 ± 419 kcal/day in 2016 (Loyola and Pauta 2017).

A strength of this study is that to evaluate the quality of the diet we used two approaches. Initially, to evaluate the nutrient adequacy of the total diet, we compared energy and nutrient intakes with EAR and not with RDA (Murphy 2008). Originally (in 1972) NAR was calculated using the RDA in the denominator, but this method appears inappropriate because overestimates the true prevalence of inadequacy as DRA is 2SD higher than the EAR (Otten *et al.* 2006). Secondly, we used food-based dietary recommendations of fruit and vegetable recommendation to evaluate if the diet meets the recommended amount that would help for the prevention of chronic diseases according to Kromhout *et al.* 2016. Food-based dietary guidelines are often used to guide food and nutrition policies, health promotion interventions and diseases prevention (FAO/WHO 2004). Because the recommendations of Kromhout and collegues are more recent (2016) than the WHO (2003), we used the 200 g recommendation separately for fruit and vegetables, than the 400 g merged (WHO 2003a). Our results show that by consuming at least three of locally cultivated fruits (listed in Table 3.1) per day (i.e. banana, papaya, baby banana, oranges, tree tomato, mandarins) the recommended 200 g/day intake would be reached to prevent coronary heart disease and stroke as reported in cohort and randomized control trial studies (Kromhout *et al.* 2016). A relative increase in consumption of locally cultivated and wild fruits is recommended for adequate nutrient intake and the prevention of chronic diseases.

We also suggest that the studied indigenous women need to consume a higher amount and the diversity of vegetables. Only one locally cultivated and one wild plant species used as condiment were reported, yet providing vitamin A. It is recommended to increase the cultivation of leafy vegetables or consume wild leafy vegetables to increase the total consumption to 200 g recommendation. Eating leafy vegetables has been reported to contribute to vitamin A, C and calcium when 50 g/day are consumed (Ogle *et al.* 2001b). This highlights the importance of consuming green leafy vegetables for micronutrient intake. Providing seedlings to promote fruit and vegetable cultivation in home gardens is recommended.

Ruminant meat consumption was reported as an additional finding to be alert about the sustainability of the diet. Results show that the second local-food source of energy is beef. The population consumes more than 50 gr of ruminant meat per day which is the maximum recommended to mitigate Greenhouse Gas Emissions (GHGE) (McMichael *et al.* 2007). Reducing the consumption of red meat to meet energy needs has shown to decrease diet-associated GHGE in up to 10.7 % (Vieux *et al.* 2012; Auestad and Fulgoni 2015). Reducing the consumption of animal protein, from 60 to 20 g, also reduces calcium requirements in the diet (Otten *et al.* 2006). Providing seedlings of fruit and timber trees is a recommendation for reforestation (that may involve the reduction of pastures) which benefits should be evaluated as recommended in *Chapter 3.*

Based on the latter evidence, we suggest that the traditional diet of Guasaganda could be adapted to more sustainable and healthy choices. People eating more than 50 g of ruminant meat per day could choose to replace that caloric intake by plant protein foods (i.e legumes such as beans, lentils) or monogastric animal meat. The current consumption of legumes (mainly beans) 1 time per week meets the general recommendation of Kromhout *et al.* 2016, nevertheless increased legume consumption to more than 3 servings per week has shown to have an effect in the reduction of low-density lipoprotein (LDL) compared with control groups and with diets having 1 serving per week (Bazzano *et al.* 2011; Padhi and Ramdath

2017). The latter evidence indicates that increased consumption of beans (130 g/serving) is beneficial to the diet. However, we should consider that legumes provide with non-haem iron which is less bioavailable. It is recommended to promote the consumption of freshwater fish, to reach an increase from once per week to three times per week, especially if aquaculture is practiced in the area.

Additional to TFs, we also identified 33 food items that are processed by the industry which need to be purchased. Most of them are characterised by containing high amounts of fat and refined sugar that are not beneficial for the diet., such as *mortadella* and soft drinks. The latter shows that acculturation is present as the studied women are adopting eating patterns from urban areas. Change from traditional to western diet has also been observed in other ethnic groups in South America (Creed-Kanashiro *et al.* 2009; MHB 2014). Therefore, we highlight the importance of promoting the conservation of traditional diets for health.

The main limitation, but also an unintentional asset, of this study, is that because the 24-hour intake records were collected during a torrential rainfall, the food intake was highly restricted to locally cultivated and wild foods that resisted the floods. Based on this circumstance we infer that in periods of food shortage, TFs appear to be a steady source of macro and micronutrients. However, this positive relation shows a high vulnerability. When TF availability increases the nutrient contribution could potentially increase, but when TF are not available, people could become food insecure (i.e. hungry season). Unexpectedly, mean energy requirement was only accomplished by only 6% of the women. Because of using 24-hour recalls during a heavy-rainfall under-reporting is probably one of the reasons for the marginal energy intake. To have a more accurate calculation of the NAR, the computed energy intake was divided by 1990 kcal/ day which is used for emergency situations. Underreporting of energy intake often occurs when using 24-hour recall (Johansson *et al.* 2001) particularly in portion sizes of socially undesirable foods, so that three recalls are recommended when possible (Ma *et al.* 2009).

A second limitation related to the heavy rainy season, is that we were not able to contact the 260 households in the second visit because the breakdown of a bridge which interrupted our access to all villages (Mejia 2016). Adding 15 % of households for contingency to the calculated sample size helped us in the latter situation. Also, the use of the MSM method allowed correcting these missing values reducing thereby within-personal variation. An additional limitation is that most of the statistical tests performed were non-parametric because data pre-conditions (normality and equal variances) were not present. These non-parametric tests made our conclusions a bit weaker, however statistically correct.

Future studies on TFs in Ecuador need to have access to more accurate and updated FCT. High-quality FCTs should be representative of national foods including the consumption habits and portions (INFOODS 2007). Nutrient content analysis of TFs needs to be conducted by certified laboratories to report accurate and reliable FCTs. This will allow nutritionist to identify micronutrient-rich foods that need to be promoted during healthy-eating interventions. Prior nutrient analysis species should be adequately identified, the cooking method and geographical area (INFOODS 2007). For example, using standardised sampling and analytical protocols on *Musa* spp. fruits (171 genotypes from different geographical areas), different contents of pro-vitamin A, iron and zinc have been reported (Davey *et al.* 2009). Although the use of a combination of FCTs in this PhD study included most of the foods studied, an updated FCT for Ecuadorian foods including the different species and varieties of foods is urgently needed. The latter should be constructed taking as reference the FCT of INCAP which used scientific names to identify food adequately. Having a reliable FCT is of fundamental importance in the field of nutrition, however, to create a FCT with adequate plant and animal identification, multidisciplinary work is needed with nutritionist, botanist and zoologist (INFOODS 2007).

5.5 Conclusion

Traditional foods (TFs), cultivated and wild, provide with a small share of energy which is essential for food security. Peasants require purchasing foods that they do not produce to reach nutrient requirements. However, the evidence shows a positive correlation between TF consumption and nutrient adequacy. Intake of adequate amounts of TFs is necessary to meet nutrient requirements. However, current fruit and vegetable consumption does not meet the (200 g/day each) recommendation for the prevention of chronic diseases. Thus, it is suggested to increase the cultivation and consumption of fruit and particularly vegetables in home gardens. The traditional diet of Guasaganda is based on a combination of plant and animal products which need to be balanced towards sustainable diets. By replacing a share of red meat with plant foods, the traditional diet is to be associated with environmental sustainability and healthy eating progressing towards SDG2. Further research requires a more accurate food composition table for Ecuadorian foods that will allow accurate calculation of nutrient intake.

CHAPTER 6: Conclusions and recommendations for future research and practice

This chapter summarizes the main findings of this thesis. It also provides recommendations for future research, policy and interventions.

6.1 Recapitulation

The primary purpose of this thesis is to provide evidence of the contribution of cultivated and wild foods to traditional human diets. To reach this goal terms and definitions used in the field of nutrition and biodiversity are defined in *Chapter 1*. The author of this thesis used the concept of conservation of natural resources for food as the research cornerstone. The studied area is Ecuador which is a developing country that requires to reach SDG2 aiming to eradicate hunger and poverty, and ensure that food is produced within a sustainable system (UN 2015a).

Conducting a literature review of the contribution of food biodiversity to human diet was a novel starting point of the research (*Chapter 2*), leading to several reviews updating the research state of the art (Masset *et al.* 2011; Masset *et al.* 2012; Powell *et al.* 2015; Pandey *et al.* 2016; Bvenura and Sivakumar 2017; Jones 2017). Consequently, we studied three elements of the integrated conceptual model of food and nutrition system proposed by Sobal *et al.* (1998). By this method i) food biodiversity; ii) eating behaviour of native people; and iii) nutrient adequacy of the traditional diet were investigated in *Chapter 3, 4 and 5*, respectively. The study of the aforementioned three elements required the use of a methodology constructed by a multidisciplinary team. Each chapter responds to a research question as presented in Table 6.1. Finally, this last chapter merges all conclusions, by following the pathway proposed by Gillespie *et al.* (2012), Kennedy *et al.* (2017) and presents the links between biodiversity, TF consumption and its contribution to nutrition.

Table 6.1 Research questions used for investigations conducted in C*hapter 3, 4 and 5.*

Chapter	**Study element**	***Research Question***
3	Biophysical Environment: Food biodiversity	*Is the farm or the forest the bigger source of edible species in Guasaganda, Central Ecuador?*
4	Socio-cultural environment: Eating behaviour of native people	*What are the factors that influence native people to eat a variety of traditional foods?*
5	Nutrition: Nutrient adequacy of the traditional diet	*Is the traditional diet diverse and nutritionally adequate?*

6.2 General results

The results of this study show that there is a link between i) the availability of TFs in the studied food system; ii) the benefits of TF consumption; and iii) the nutritional adequacy of the indigenous diet.

In the studied traditional food system, we found 90 plants and 22 animal species, along with 14 medicinal plants that are available from local cultivation and collection/hunting for human consumption (Figure 6.1). Our findings also show that the diet of women is composed of what is available in the biophysical environment which is not only locally cultivated and wild foods, but also non-locally cultivated foods that also are biodiverse (46 foods), and industrialised foods (33 foods). According to the pathway proposed by Kennedy *et al.* (2017) a person who consumes their own locally cultivated and wild food biodiversity is likely to have dietary diversity, nutrition security and good health outcomes. Kennedy *et al.* (2017) also distinguish that purchased food biodiversity is also part of the nutrition pathway.

Likewise, this study assumed that in a high biodiversity area people are relying on forest foods but also that farms are rich in food biodiversity. However, the limited number of cultivated species at the farms (3 ± 1.45) for food, suggests that farmers in Guasaganda are not practising nutritional-sensitive agriculture which also happens in the food system in India (Gillespie *et al.* 2012). In the Guasaganda food system, 13 plant species are available to be cultivated in the farms and other 21 species are present in the forest. Animal husbandry in the farms have 8 domesticated animal species whereas the forest supplies 12 wild animal species. In home gardens, domestication of 28 plant and 1 animal species could be practised. Additional, findings show that 14 medicinal plant species are present in the biophysical environment. Medicinal plants require further ethnobotanical and biocomponent research because they are frequently consumed particularly for their health perceptions. Medicinal plants are reported to have a positive effect on health such as free-radical sequestration (Restrepo *et al.* 2012), treatment of diarrhoea (Longanga Otshudi *et al.* 2000), and have a low cost compared with prescription drugs (Hoareau and DaSilva 1999).

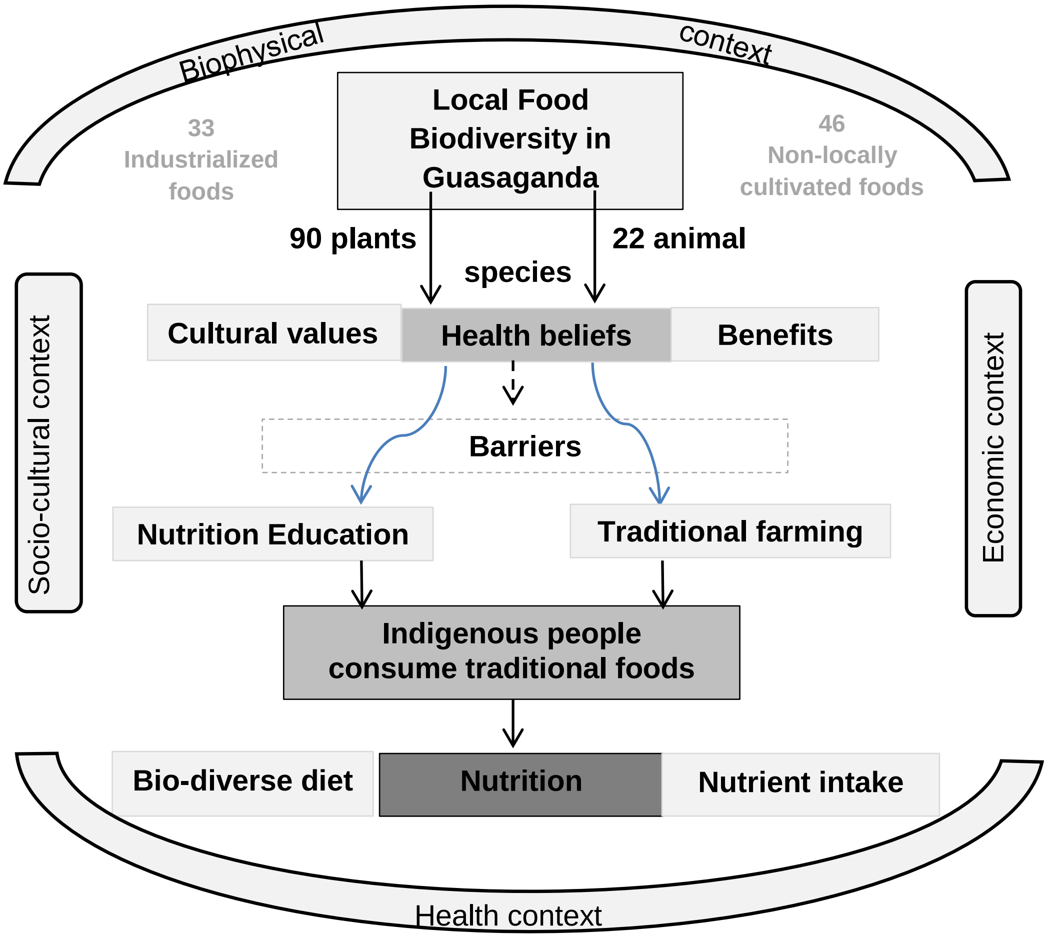

Figure 6.1 The links between biodiversity, locally cultivated and wild foods, consumption and nutrition

Despite the limited number of reported food species cultivated at the farms, and the limited consumption of wild foods reported in the eating recalls local people of all ages have positive perceptions linked to TFs consumption mainly related to health and economic benefits. By the analysis of the eating behaviour the perceived health and economic benefits are the two robust reasons to still consume TFs. Eating preferences towards TFs shows that FTs are important for food sovereignty.

Results from the dietary intake study show that the traditional diet is still present as TFs are frequently consumed by women in Guasaganda, however, non-traditional foods are consumed in significantly higher amounts and therefore crucial for food security. Non-traditional foods require, however, to be purchased likewise food processed by the industry. Foods processed by the industry are consumed in less frequency and amounts than TFs, showing that there is acculturation which intensification can be prevented by nutrition education that promotes the consumption of local foods enhancing the aforementioned health and economic benefits.

Our results generated a high concern on the balance of the studied food production system as the amount of cultivated foods is limited therefore we infer that indigenous people of Guasaganda have two options: whether i) to rely on the plant foods they collect from the forest and hunt animal species for food, or ii) to purchase foods in nearby markets (Kennedy *et al.* 2017). Our qualitative study shows that indigenous people share our concerns as they fear of the negative consequence of biodiversity loss on food security because they are already struggling with financial access to foods and food shortages. Figure 6.2 ilustrates the contribution of different food sources by pathways which according to our results suggest that the main problem of food security is not the availability of a diversity of foods but the financial access to foods.

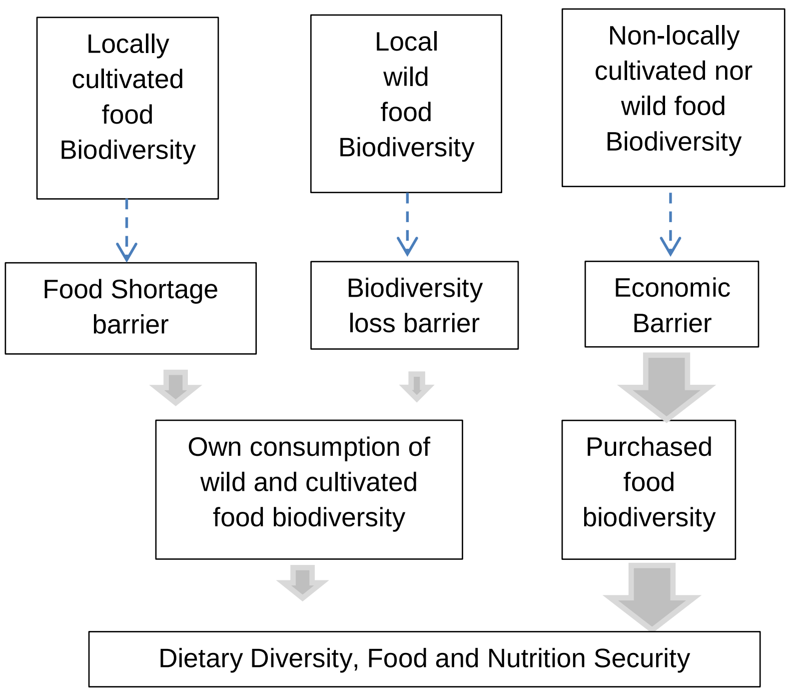

Figure 6.2 Pathways which are leading to dietary diversity, food and nutrition security based on food biodiversity. Bigger arrows show higher contributions than thinner arrows

As mentioned above, indigenous people of different age groups and gender prefer to eat locally cultivated and wild plants and animals (TFs) mainly because of the associated health beliefs, it is culturally accepted, and their cultivation has economic benefits. Despite the positive perceptions, individual and environmental barriers exist that do not allow indigenous people to eat TFs. We found no differences between the perceptions from males and females. To overcome these barriers, the community requested nutrition education for all age groups and all genders towards the increase of benefits awareness of TF consumption, and highlighted that economic incentives or credit was necessary to mainstream the cultivation of TFs and reforestation.

By analysing the diet, we found that is the combination of all food sources that results in a highly diverse diet (Figure 6.2). From the total 140 food items reported, which includes 70 locally cultivated and wild species, a median of 23 food items (FVS) were consumed of which at least 9 are locally cultivated or/and wild (TFDS). The studied women eat 6 out of the 10 food groups indicating that dietary diversification (measured as MDD-W) meets micronutrient requirements according to the dichotomous indicator used (FAO 2014a). Further analysis allowed us to identify the species whiting the 6 food groups that are major contributors of energy and the 9 studied nutrients. The correlation of TF consumption and nutrient adequacy is positive and significant for protein, fibre, calcium, iron, zinc, vitamin A and C. Undoubtedly, local biodiversity is contributing to dietary diversification and micronutrient intake in Guasaganda, but the amount of the species consumed remains as *the* necessary condition to support this statement. The amount locally cultivated and wild foods consumed only provides with 38.6 % of the total energy intake, whereas fruit and vegetable intake is significantly lower than the recommended 200 g/day for each group.

In summary, biodiversity and human health is linked by eating and cultivating practices which require being balanced to reach both human and environmental health. Humans require protecting nature hence ecosystems services such as foods and medicine are necessary for survival.

6.3 Conclusions on the benefits of diets based on locally cultivated and wild foods, and recommendations for future interventions.

By comparing the benefits of cultivating TFs reported by several scientists (*Chapter* 1, Table 1.1) and the documented benefits of cultivating and consuming TFs perceived by the studied community in our different Chapters (Table 6.2), our finding suggest that the state of the art of the investigated literature is highly comparable with what is occurring to the studied indigenous peasants. Knowledge sharing between scientist and peasants to identify the barriers that inhibit cultivation and consumption of TFs to further propose potential solutions is imperative (BI 2012). The systematic analysis of indigenous people's perceptions is key to translate native knowledge into empirical results is the strength of this PhD thesis. The innovation of this study is the combination of scientific and humanistic approach which was used to translate the needs of the neglected population into specific recommendations for future interventions (Lytle 2005).

Table 6.2 List of documented benefits of traditional food cultivation and consumption in Guasaganda, Ecuador

Level	Benefits	Results
Environmental	Plant foods supply	-Forest supplies 21 plant wild foods -Farms supply 13 cultivated plants. -Home gardens are a niche for domestication of about 28 plant species
	Animal foods supply	-At the farms, 8 domesticated animals serve as food whereas forest supplies with 12 wild animals, but these are rarely hunted
	Medicinal plants	-Medicinal plants are used for preparation of traditional drinks which are consumed daily to preserve health
Psychosocial	Positive perception Health beliefs Wellbeing Food safety Cultural Shelter	-Positive perceptions towards health -Perception that traditional foods are important source of nutrients -Traditional foods help for physical strength -Traditional foods to prevent diseases -Traditional foods are free of chemical hazards -Older people consume traditional foods as a cultural practice -Traditional foods are perceived as a safe source in emergency situations when other crops are less available
Economical	Income generation	-Cultivation and selling traditional foods generate economic profit and poverty alleviation
Nutritional	Dietary diversity Micronutrient contribution Nutrient adequacy Dietary Quality	-The traditional diet can contain up to 140 different foods, of which 70 are traditional foods -Traditional diets have a median of 23 foods (Food Variety Score) -Minimum Dietary Diversity for women is 6 (higher than 5) -Traditional diets supply with enough quantity of macronutrients, iron, zinc and vitamin C -There is a strong correlation between the consumption of locally cultivated and wild foods and the nutrient adequacy ratio (NAR) for iron and vitamin A -Mean Adequacy Ratio of 0.84 indicating that the diet is adequate for some of the nutrients

GHGEs refers to greenhouse gas emissions

Recommendations are based on the sustainable use of natural resources for food. Current traditional farming needs to focus on producing enough food to cover energy needs and recommendations for the prevention of chronic diseases. Therefore, local cultivation of vegetables, fruits and staples for consumption is recommended to meet macro and micronutrient requirements, preventing malnutrition and associated chronic diseases. Along with cultivation, commercialisation is recommended as income generating activity that would serve to increase the capacity to buy food species that are not produced locally. Action plans should follow the example of “canastas comunitarias” and “FORSANDINO” which are interventions that resulted to increase food security and income of traditional farmers (Paredes and Guerrón-Montero 2014; FAO 2016b).

Additionally, nutrition education is necessary to disseminate healthy food-preparation methods, reinforce health beliefs, and preserve indigenous knowledge of healthy eating. The best starting point for nutrition interventions is to work with the foods which are preferred for taste and familiarity, which are reported in the additional findings of *Chapter 4*. Education should transfer the traditional knowledge from elderly to the younger generations to prevent its total loss. Also, it is important to generate awareness of the sustainability of traditional diets which is of paramount relevance for our future-generations’ environmental and human health. It is recommended that the concept of sustainable diets is applied through all the education process. A common request among age groups, is to maintain traditional diets and native agricultural practices as it is imperative for the sustainability of the food system. Recent publications recommend supplying seeds or seedlings to promote local cultivation of indigenous species (Bvenura and Sivakumar 2017). Maintaining traditional agriculture and eating practices is expected to help indigenous community to better adapt to environmental changes (such as biodiversity loss and acculturation) and prevent increased consumption of industrialized foods. Although food safety was a concern of few respondents, it is recommended that nutrition education also disseminate food safety messages most likely to prevent foodborne illness that is prevalent in rural areas (Medeiros *et al.* 2001). The use of theatre is recommended for educational interventions by a study carried out in Guasaganda that found that this technique is efficient for children's learning process (Guanotuña 2011).

6.4 Limitations to consider for future studies

This study started assuming that with adequate nutrition, based on the consumption of locally cultivated and wild foods, the population of Guasaganda would be able to develop physically and eventually economically (Chivian 2002). However, affirming that the consumption of TFs is a driver for development needs stronger evidence. The results of this study show that having many TFs in the biophysical environment is not a sufficient condition to fulfil macro and micronutrient requirements because it is the amount consumed a co-necessary element. The health beliefs attached to TFs certainly increase the tendency to eat more TFs. Despite the strong health beliefs associated with TF consumption, cultivating few species at the farm limits the availability of TF. Therefore, the combination of diversity and quantity of TFs by application of traditional farming practices is an essential condition towards increasing nutrient consumption and thus physical development. Nevertheless, knowing that peasants cannot entirely rely on subsistence farming, improved market access to peasants to buy and sell a diversity of products is a strategy towards dietary quality and nutrition that is currently debated (Sibhatu *et al.* 2015b).

Our results show that financial access to non-locally cultivated and purchased foods is limited, probably associated with the high poverty in the area. Future research requires quantifying the consequence of poverty on the financial access to a nutritious and diversified food basket. This analysis requires assessing the cost of self-cultivated foods and non-locally cultivated foods separately. Also, it is required to quantify the income of the population, more specifically the income from traditional farming (i.e. fruit, vegetables and staples), commercial farming (i.e. cash crops) and dairy production. Before promoting local cultivation of TFs, the intention of peasants to increase fruit, vegetable and staple cultivation for self-consumption and commercialisation needs to be studied using psychosocial, behavioural models such as the Theory of Planned Behaviour. The help of economists is needed to understand better the positive benefits from cultivating fruit, vegetables and staples for human consumption and comparing the production of a crop for animal feed.

Although the availability of TF is generally identified as a big barrier for consumption, interviewed people were not aware of preventive actions for emergency situations or food shortages. It is also recommended that nutrition education would train all the community to use basic food preparation techniques (such as boiling, cooking, deep-freezing, drying) in order to store foods adequately for the consumption during emergency situations, and the preparation of emergency kits with water, non- perishable foods, seeds and medicine. This would help indigenous people to adapt and be prepared for periods of food shortage.

6.5 Recommendations for future literature review on food biodiversity

The first chapter of this thesis highlighted that the importance of the diversity of plant and animal foods is limited to specific regions and diets. Future review of literature should concentrate on reporting the contribution of food biodiversity to specific regions. Current reviews such as Masset *et al.* 2011; Masset *et al.* 2012; Powell *et al.* 2015; Pandey *et al.* 2016; Bvenura and Sivakumar 2017; Jones 2017 have updated our state of the art. According to our results in *Chapter 2*, the investigations should be conducted using the Vavilob centres of origin (geographical regions described in Table 2.4) as search scheme. Thereafter, better comparisons can be made because similar food biodiversity is involved together with the cultivation and consumption practices. For example, the cultivation of cassava, its cooking methods and consumption is not the same for African ethnicities than for South American ethnic groups.

Future systematic research of literature would require extended search terms according to the subject of interest because of the different definitions and concepts used in the study of food biodiversity. For example, some specific search terms that should be included are: (cultivated OR wild OR traditional OR indigenous) AND food AND Amazon" if Amazon foods are studied; "AND/OR Andes" if Andean foods are also the area of interest. When the interest is only cultivated foods in the farms the terms "(farm AND cultivation AND domesticated AND agriculture) AND foods OR crops OR plant* OR livestock" can be used; whereas for wild foods the terms "wild

AND undomesticated AND bush AND native" are recommended. Furthermore, if the interest is to study the loss of traditional eating culture and its effect on nutritional status the combination of terms "industrialised OR processed OR purchased" is recommended using as a filter "overweight OR obesity OR acculturation".

6.6 Recommendations for future research on food biodiversity

The results of the food intake study are presented in *Chapter 5*, which describes the diet, its diversification and the correlation between the intake of locally cultivated and wild foods and nutrient adequacy. Recommendations for future research are directed to a standard methodology on food biodiversity research.

To reduce intrapersonal variation, it is necessary to document more than one dietary intake. Therefore, at least two and even three dietary recalls are recommended (Ma *et al.* 2009). However, documenting three dietary recalls has its limitations. A common limitation of rural field surveys it that revisiting the respondents is difficult because of their irregular schedules or loss of interest. Also, more visits require an increase of fieldwork budget which is often restricted. In this study, we faced the two above limitations. Therefore, we did not collect 260 dietary recalls in the second visit because some villages were not accessible due to torrential rainfall. This resulted in missing data that was not generated at random and therefore difficult to correct.

A strategy used to correct this missing data was to simulate the diet using the MSM method. This method requires the use of quantified dietary intake of at least two days and quantified data from food frequency questionnaire to simulate a usual diet and uses linear trend interpolation to replace missing values (Fau *et al.* 2011). Thereafter, we evaluated the dietary intake beyond the two studied days using the MSM method. However, there exist other methods to replace missing values such as using the series mean or the median of nearby point with SPSS for random missing data (IBM 2012). We recommend using the mean intake per village to do not affect central tendency values. However, when working with biological data, such as dietary intake that differs within people and between people, there is not a standard method that to our knowledge can be used. Specific approaches should be developed. For example, a four-step imputation methodology has been used to model children's intake, assuming that missing values occur at random and considering weekdays and weekends as different (Stevens *et al.* 2015). Future research should consider the biological nature of the data and use a statistical tool to create a model that serves to replace missing values considering the biological data is not always normally distributed, that outliers are always present, and that missing data can be at random and not at random (Cevallos Valdiviezo and Van Aelst 2015).

Another limitation of this study is that may affect the interpretation of the results is that the mean energy intake of the population was significantly lower than the EAR. In epidemiologic studies, adjustment for total energy intake is often used to adequately evaluate the effect of a specific nutrient on an outcome (Willett *et al.* 1997). However, the variation in energy intake can be the result of a measurement error, resulting in total energy intake less than the other nutrients, probably because of the food composition table used, serving sizes or underreporting (Johansson *et al.* 2001; Rhee *et al.* 2014). Because of the latter, the descriptive nature of this study and type of the foods investigated we did not correct for energy intake. Undoubtedly, FCT affected our results because locally cultivated and wild foods in Guasaganda have different nutrient composition than foods from other countries, also there could exist underreporting because TFs are reported differently than non-socially accepted foods. Therefore, future studies in food biodiversity urgently require using correct nutrient content before suggesting high contributions. For better assessment of adequacy for energy (instead of the EAR) the BMI is a better indicator that would reflect the balance between energy intake and energy balance (Otten *et al*. 2006)

In *Chapter 5*, we also reported the energy and nutrient contribution of locally cultivated and wild foods, and the intake in grams from different food sources. This analysis required coding all foods whether locally cultivated and wild, non-locally cultivated or industrialised which was only possible after the inventory of food species (*Chapter 3*). Coding foods based on their source allows further research to analyse wild food and locally cultivated intake separately.

To report dietary diversity, we used FVS, TFDS and MDD-W, being the latter the only indicator which cut-off is validated for women, and adequate for rural settings such as our studied group. We recommend the use of DDS and FVS only to describe the diet but not for food biodiversity research because of the limitations we faced. First, the counting of all food items (FVS) merges locally cultivated and wild, non-locally cultivated and industrialised foods. FVS does not consider the count of species (for example, chicken is only one species but 3 food items are derived from it), and does not consider the unhealthy nature of industrialized foods (for example, carbonated drinks and chips would raise in two points the score instead of eating 2 healthy foods such as tomato and lettuce) (Drescher *et al.* 2007). To avoid overreporting of unhealthy foods, a study (not related to food biodiversity) used a scoring system that add 1 point to desired food and 0 to unhealthy foods. This approach has been used to count TFs. In the food biodiversity research, the TFDS has been proposed by Roche *et al.* 2008 giving a count of 1 only to locally cultivated and wild foods (obtained by cultivating, hunting, gathering, fishing and raising animals).

To study food biodiversity DDS is not the most appropriate indicator. The use of DDS to report the diet diversity highly depends on how many and which food groups are used. DDS does not represent the diversity of the species consumed because food species are merged into food groups. DDS was used to measure the correlation between diversity of species at the farm with the diversity of the diet (Sibhatu *et al.* 2015a). DDS was selected because it was a common indicator in 4 counties datasets (ibid.). However, it is not recommended to use this methodology because the results highly depend on how the dietary diversity is counted (Berti 2015). A recommendation for the methodology of Sibhatu *et al.* 2015 is to use count of species cultivated or/and wild at the farm and the count of consumed species at the household (as proposed by Roche *et al.* 2008) so the correlation is more representative. An example of this would be a woman who cultivates cassava, plantain and maize from her farm and who consumes traditionally these cultivated foods. Her production diversity score is 3 and her TFDS is also 3, which correlation would be 100%, whereas by using DDS the diversity score would be only 1 after grouping the three species within staple foods group.

However, the use of TFDS does not consider the amount of food consumed. For example, the same woman who consumes cassava, plantain and maize likes to use plantain every day as *bolon* for breakfast, in soups for lunch and chips for dinner whereas just a few maize grains are used as an ingredient in soup once a week. This latter carries an additional limitation which is the contribution of the food to the nutrient intake. The referred woman would have a higher nutrient intake from the plantain than from maize when consumption is considered. In response to all the limitations mentioned above, a combination of diversity, amount and nutrient content of the food is an adequate approach (Drescher *et al.* 2007). This approach can be adapted to the study of different food species in the diet, consumed in irregular amounts and with different nutrient contents (i.e. different maturation, source and preparation). This indicator would be more helpful when identifying the importance of a diet based on diversity of locally cultivated and wild foods. Furthermore, it can be used when studying the contribution of cultivated foods apart from wild. This type of studies would be helpful before recommending the increase of dietary diversity based on locally cultivated or wild foods.

Alternatively, a more novel approach is the use of Shannon index (originally proposed by Shannon 1948) which is a commonly used diversity metric of species richness that has been by Remans *et al*. (2014) combined with Food Balance Sheets to measure the nutritional diversity of national food supplies (Remans *et al.* 2014).

6.7 Recommendations for future policies

Because natural resources are situated in specific geographic regions, nations have policies that govern these resources. According to the report of the Centre of Health and Global Environment (Chivian 2002), the role of international Institutions devoted to the conservation of natural resources is to identify priority issues. Some of these organization are the World Health Organization, (WHO), the United Nations Environment Programme (UNEP), the U.N. Convention on Biological Diversity (CBD), the U.N. Development Programme (UNDP), the U.N. Food and Agricultural Organization (FAO) and the World Bank.

At National level, Ecuadorian policies that guide the adequate use of natural resources for food urgently needs to create an institutional framework that involves the Ministry of Agriculture, Environment, Education and Health. This framework needs to assess the nutritional problems associated with the low farm diversity, biodiversity loss, absence of nutrition education, and high prevalence of nutrition-related diseases. Strengthening highly diverse food systems for human and environmental health is needed. To accomplish this, all ministries require creating multidisciplinary strategies that use the existing health, environmental and education policies as cornerstones. One recommended strategy is to provide incentives, such as TFs' seedlings, to local farmers for local food production aiming the creation of local markets (FAO 2015a). The main objective of such multidisciplinary participation is to improve institutional understanding of the links and synergies between human health and conservation of natural resources, which will generate public awareness (Chivian 2002). For example, the integrated framework can observe that extracting fossil fuels from forest areas generates economic growth for the nation but those communities subsisting from forest become food insecure. Furthermore, they can quantify the cost of environmental degradation as health programs need to be created to assist the underfed and intoxicated populations. Also, a strategy is needed to conserve, and sustainably manage the use of medicinal species as these are essencial for the existence of indigenous people.

Nevertheless, the institutional framework needs to emphasize the use of adequate indicators to adequately measure the effects of multidisciplinary interventions as suggested by policy guidelines for voluntary use of biodiversity and nutrition (FAO 2015a). Implementation of biodiversity conservation policies requires continuous monitoring because of the constant environmental change. An action plan needs to be developed attending the population needs and cultural practices towards effective cultivation and marketing of TFs and nutrition education. It is recommended that the Ecuadorian Food Sovereignty legislation (EC 2011) is used as starting point to develop the action plan because food, production, consumption and eating culture are integrated in the latter.

Food availability in the study area is fragile despite the highly biodiverse ecosystem. Action is needed to ensure a healthy future of this community which requires change towards improved food intake and healthy eating behaviour based on local cultivation and consumption of fruit, vegetables and staples. If alternative recommendations are not proposed, without an action the community of Guasaganda will follow a tendency that is occurring in most of developing countries which is characterised by high rates of malnutrition and hampers SDG2.

6.8 Conclusions on the sustainability of the diet

To make a multi-dimensional discussion about diet sustainability, we examined socio-cultural, economic and environmental factors, which are considered the three pillars of sustainability. To achieve this, we used relevant indicators (in italics below) which have been proposed by other studies on dietary sustainability. In C*hapter 3* and *4*, we describe how the eating patterns of the studied population are linked to the three (above mentioned) pillars of sustainability, and in *Chapter 5* quantitative indicators (of food intake) were used to reflect the quality and sustainability of the diet.

It is imperative to analyse the consumption of local foods to conduct a dietary sustainability assessment. Local foods are known to be culturally accepted, economically accessible and sustainable for the environment (Nugent 2011, Fanzo *et al.* 2012). A review of indicators for sustainable diets summarises the following basic guidelines (Auestad and Fulgoni 2015). *Consuming locally produced foods* (food consumed/purchased close to the production area) involves a lower use of energy and reduced transportation cost (Gussonw 1986). The consumption of locally cultivated foods (g/day) has thus not only low impact on the environment (GHGEs measured as CO_2e/100 g of edible food), but also has lower cost, thus, in this way two pillars of sustainability are covered (i.e. environmental and economic). In *Chapter 4*, results show that indigenous people perceive that consuming locally cultivated and wild foods is beneficial, not only for health but also for the environment, and that cultivating and consuming local/traditional food is cheaper than buying food from external markets. Several studies carried out in Europe have found that sustainable diets, which imply a lower production of GHGEs, also have lower production costs (Berners-Lee *et al.* 2012; Masset *et al.* 2014b). It is important to consider when organising nutrition education programs that people understand that sustainable diets are not necessarily more expensive**.** In this line, it is a priority to communicate to those who have the land and skills to produce their food have higher possibilities to eat sustainably at a low cost.

Another indicator related to the potential sustainability of the diet is the *selection of plant foods instead of animal foods*. This is not only good for health (i.e.

low Body Mass Index, lower mortality rates, low plasma cholesterol) (Key *et al.* 2006) but also better for the environment because of the lower GHGEs plant food production has compared with meat production (Kling and Hough 2010; Masset *et al.* 2014a). Our results from *Chapter 3* show that indigenous people of Guasaganda do not consume adequate amounts of fruits and vegetables (about 200 g/day of each food group), whereas they consumed more than the adequate amount of animal protein. Fruit and vegetables are needed in the diet because it is known that the consumption of 200 g/day (each group) contributes to lower the risk of chronic diseases (Kromhout *et al.* 2016). The author of this thesis recommends increasing the consumption of fruit and vegetables considering that chronic diseases are the top causes of death in Ecuador (INEC 2005,2012).

The consumption of meat is generally recognised as unhealthy because its association with colorectal cancer (Millward and Garnett 2010), whereas vegetarian diets have been identified to achieve relatively low BMIs and low plasma cholesterol levels (Key *et al.* 2006), and are also associated with low GHGEs (Vieux *et al.* 2012). Nonetheless, we do not recommend full replacement of animal protein by plant protein. Whether to stop eating red meat or not is controversial because animal meat consumption provides with haem iron and vitamin B12, and the reduction of both could cause nutrient deficiencies and be detrimental to health (Millward and Garnett 2010; Temme *et al.* 2013). Also, the livestock sector contributes to 40 % of agricultural gross domestic product, generates income for more than 1.3 billion people and supplies protein for at least 800 million food insecure people (Herrero *et al.* 2013).

Livestock production allows native people to consume enough animal protein and generates economic benefits; however, the mean consumption of particularly ruminant meat is above 50 g/day which is the recommended for the mitigation of GHGE. Consequently, we discussed that nutrition education should disseminate the concept of sustainable diets and communicate that replacing a share of animal protein by plant protein such as beans, lentils and soya is a healthy alternative that implies low detrimental effects on the environment. A study in France found that when replacing caloric intake from meat by plant foods, GHGEs were reduced clearly because ruminant meat production implies a higher contribution to GHGE than plant production does (Vieux *et al.* 2012). Also, the substitution of meat-protein by plant-protein intake has been recommended by other authors who suggest that by giving up animal husbandry the land use could be changed from pastures to other vegetation that sequestrates carbon better (Risku-Norja *et al.* 2009; Stehfest *et al.* 2009). Reducing the intake of meat to encourage environmental protection and a better human health is also recommended by other studies. Two studies (Aston *et al.* 2012; Farchi *et al.* 2015) have associated diets containing low processed meat with a reduced risk of coronary heart diseases, diabetes, colorectal cancer and stroke. However, vegetarian/vegan diets are lacking in vitamin B12 and calcium (Key *et al.* 2006). Therefore, it is recommended to restrict the consumption of meat to a maximum of 50 g/day and replacing the rest of the caloric needs by fruit and vegetables to reduce 12 % of the diet-related GHGEs (Vieux *et al*. 2012), and not necessarily adopt an entirely vegan diet.

Another important indicator of sustainable diets is *the consumption of refined sugar*. It has been estimated that by halving the consumption of refined sugar and alcohol, GHGEs could be reduced as much as by eliminating meat from the human diet (Saxe *et al.* 2013). In *Chapter 3*, we found that the diet of the studied indigenous group is composed of some industrialised foods which contained refined sugars. The mean consumption of refined sugar was 16.3 ± 9.6 g/day and was significantly higher than the use of traditional sweeteners such as the *panela* from sugar cane. Nutrition education should communicate the differences between refined sugar and sugar from the phloem sap of sugar cane as well as the effects of sugar refinement on health and the environment.

Energy intake (kcal/day) is a necessary indicator to identify if the diet is adequate or if extra calories are consumed (Vieux *et al.* 2013). This indicator can also manifest sustainability as the unnecessary consumption of extra calories reflects that the diet is not appropriate but also linked to extra GHGEs and therefore unsustainable. Sustainable diets have been associated with low energy intakes, when correlated by simple linear regression with GHGEs (Vieux *et al.* 2013). Caloric intake is, however, merely a functional unit used by nutritionist but not widely used for sustainable eating recommendations. The latter does not limit energy intake *per se* probably because people can control the amount of food they consume, in g, better than counting calories. In the same context, people can quickly know the source of a certain food by visiting local markets or reading labels than calculating calories. Our results in *Chapter 5* show that the mean indigenous energy intake is relatively low. Similar results were found when studying local diets in D.R. of Congo (Termote *et al.* 2012) and Kenya (M'Kaibi *et al.* 2015). However, it is striking, to observe that traditional women did not consume the adequate amount of energy although they consumed the required amount of micronutrients. Further research requires testing if the consumption of locally cultivated and wild foods (assuming associated low carbon footprint and associated sustainability) is correlated with low energy intake but adequate micronutrient requirements.

Another important finding of this study related to low energy intake is that a number of traditionally used edible plants are consumed with medicinal purposes but do not provide energy because these are not eaten. Fourteen medicinal plants were consumed as infusion preparations at an average of one litre/day. The most consumed leaves with medicinal purposes were orange (*Citrus maxima* (Burm.)), lemon (*Citrus limon* (L.) Osbeck), guanabana (*Annona muricata* L.), *mastrante* (*Lippia alba* (Mill.) N.E.Br ex Britton & Wilson), and lemon grass (*Cymbopogon citratus* (DC.) Stapf). The consumption of medicinal plants suggests that indigenous knowledge of traditional eating for health is still present and practised and that indigenous people continue to cling to their traditional beliefs. The consumption of plant infusions is by us considered as a sustainable practice, and therefore it is recommended to be promoted. Forest loss could have implications in health care in Ecuador as reported elsewhere (Shanley and Luz 2003).

Mean adequacy ratio (MAR) is an indicator that reflects the nutrient adequacy of a specific diet for a number of nutrients. MAR has also been used to assess the sustainability of a diet combined with data from the life-cycle assessment of the food. A study done in France found that diets with low environmental impact were deficient in some nutrients (Vieux *et al.* 2013). According to the latter study, the sustainability of a diet is more related to the type of food system which produces the food in question, whether contemporary or traditional food system. As mentioned before, further research is needed to clarify whether nutrient adequate diets could have low GHGE using adequate quantitative data from carbon footprint.

Finally, we foresee that if the *proportion of women dedicated to traditional farming activities* increases together with the *number of schools that receive nutrition education and have school gardens programs*, the sustainability of the traditional food system in Guasaganda would increase as proposed by Jaramillo *et al.* (2005). Furthermore, we suggest that future interventions should control that *daily per capita intake of fruit and vegetables* of the population remains adequate, that *percentage of food insecure households* remain low, that the *percentage of farm workers employed through labor contractors* remains as current, the *number of young people involved in traditional farming* increases, and that the *number of people cultivating traditional foods for cash* increases to increase the sustainability of the studied food system (ibid.)

Future interventions are needed that would increase i) the number of women dedicated to farming TFs; ii) their income by selling TFs; iii) and the number of schools with nutrition education that involve the use of small gardens in schools based on the concept of sustainable diets, to escalate the sustainability of the traditional food system in Guasaganda.

6.9 A handbook for nutrition education for Guasaganda, Ecuador

As repeatedly mentioned in this thesis, nutrition education is a necessary tool to prevent both under- and over-nutrition and related chronic diseases which are a big public health burden in Ecuador (Torres 2016), and to increase the sustainability of the food system (Jaramillo *et al.* 2005). A study of health, food, and education policy documents of Ecuador highlights that educational messages should focus on the individuals' behaviour and that schools are the primary intervention institution (ibid.). Furthermore, it indicates that parental and community participation is crucial for the education process. One of the aims of the Educational law in Ecuador is to ensure a holistic promotion of health and sustainability (Torres 2016). The latter is consequent with the Health policies about food and nutrition, which states that bad eating habits should be eliminated, whereas respecting and promoting traditional knowledge and practices.

Our findings in *Chapter 4* confirm the results of Torres (2016) in that nutrition education need to be transmitted in schools and a strategy not only for improve health and prevent chronic diseases, but we also recommended it for the promotion of sustainable food consumption mainly to mitigate the effects of global warming. Our results call for action to apply the existing policies that enhance food sovereignty (National Constitution of 2008 Art. 281(EC 2008) and the use traditional knowledge as the mainstream for sustainability (National Policy for food sovereignty Art, 2,3,4 and particularly 7 which focuses on biodiversity conservation (EC 2011) and the right of Ecuadorians to protect their nature and promote local and global sustainability (National Plan for Goof living objective 7 (EC 2013). Our suggestions are based on our results and revised national policies. It is therefore recommended that educational messages should be based on elders' (highly valued old people) traditional knowledge, to be transmitted to the younger generations.

Any effective educational process, including nutrition education, should be based on educational objectives and have a learning structure to transfer information towards the significance acquisition of knowledge by the student (Contento 2016). Therefore, this thesis presents a table of content for sustainable nutrition education for the Guasaganda community (Table 6.3). The proposed table of content was created based on the content of three handbooks used for similar purposes in Brazil, Malawi and New Zealand (MHB 2014; Judy 2016; Nordin 2016). The aforementioned manuals also use the sustainable utilisation of natural resources for food as an educational objective.

Table 6.3 Prospective content for a nutrition education handbook for Guasaganda, Ecuador

Chapters	**Title**	**Instructional objective** (The student will be able to:)	**Content**
1 Introduction	Nutrition problems in Guasaganda	To know the definition of malnutrition by understanding the importance of healthy eating towards the prevention of weight loss or overweight for a healthy life	-Definition of malnutrition -The difference between undernutrition and over nutrition -Definition of nutrients: carbohydrates, proteins, fats, vitamins and micronutrients -Health consequences of malnutrition -Indicators of under- and over-nutrition (stunting, underweight, wasting, overweight and obesity)
	Malnutrition as development problem	To understand that by having a healthy diet based on locally cultivated and wild foods the community can improve the quality of life and develop physically and environmentally	-Definition of Sustainable Development Goal 2
2 Justification	Nutrition education for better health and sustainable diets	To differentiate between a diet based on locally cultivated and wild foods and foods cultivated away or purchased in markets that are processed by the industry by receiving nutrition education guided by the knowledge of elders	-Definition of sustainable diets -Introducing nutrition education
3 Instruction	Traditional food systems as key for sustainable development	To analyse the elements necessary to produce foods by describing the cultivation/hunt / collection practices done in the community and indicating what is best for human and environmental health	-Definition of a food system and how it is related to sustainability
4 Cooperative learning	Benefits of sustainable diets	To classify the perceived benefits and disadvantages of eating locally cultivated and wild foods	-Explain that sustainable diets are more: Nutritious Cheaper Environmental friendly -Ask their opinions about these statements

Table 6.3 con't

5 Instruction	Basic guidelines for achieving sustainable diets	To learn 5 most guidelines for sustainable eating by comparing their actual diets and eating practices towards a better health	-Explain in detail the 5 major guidelines for sustainable diets: 1) Consume naturally or minimally processed foods 2) Limited consumption of fats, sugars 3) Reduce at minimum processed or packaged foods 4) Avoid alcohol consumption 5) Recommendations on animal protein consumption: Reduce consumption of animal products and replace it by eating legumes. Consume maximum 50 g/day of red meat Eat fish at least once a week
6 Active learning	Identifying traditional foods	To localise the place where it is possible to cultivate and collect fruits, vegetables and staples	-Identification of traditional foods that can be or are currently cultivated in the area -Identification of dishes that contain traditional foods. Cooking and preparation of traditional dishes that are healthy and sustainable
7 Inquiry-based learning	Identifying sustainable meals	To propose meals that are healthy and sustainable following the concepts learned in the previous lessons	-Self-evaluating the meals prepared at home and identify if these are sustainable -Application of the guidelines introduced in lesson 5
8 Promotion	Self-cultivating traditional foods for sustainable diets	To cultivate vegetables in their gardens and fruit trees following traditional cultivation practices for future harvest, preparation and healthy eating.	-Promotion of sustainable production of traditional foods for health and potentiality for commercialisation

The handbook follows a learning structure which starts with introducing to the student essential concepts such malnutrition, development goals and food system using the concepts included in Chapter 1 of this thesis. Furthermore, it continues with 7 chapters that increase the educational process with an evolution of objectives aiming behavioural change towards the cultivation of home gardens and consumption of self-cultivated fruit, vegetables and staples based on the results of Chapter 3 and 4 of this thesis.

In addition, the concept of sustainable diet is introduced as well as guidelines for its application using didactic activities such as theatre. During cooperative learning 5 basic principles are to be introduced based on the guidelines of Brazil (MHB 2014), i.e i) diet is more than the intake of nutrients, ii) dietary recommendations should respond to changes in food supplies and in patterns of population health and well-being, iii) healthy diets derive from socially and environmentally sustainable food systems, iv) different sources of knowledge inform sound dietary advice and that v) dietary guidelines increase autonomy in food choices. The aforementioned guidelines were selected because they are consistent with our research results.

In the future, interventions should evaluate if the person falls into old patterns of behaviour by the use of the Stages of Change Model (Prochaska and Diclemente 1986) to evaluate the effectiveness of the intervention.

To conclude the author of this thesis highlights that every individual in the society plays a decisive multi-dimensional role because eating choices we make have a great impact not only on our health but the health of others and on the world we live (Perez-Cueto 2015).

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Annex

Curriculum Vitae	**PERSONAL INFORMATION**
First name(s) / Surname(s)	**Dolores Daniela PENAFIEL ANCHUNDIA**
Address(es)	Puerto Azul, GYE - Ecuador
Telephone(s)	Offic +593 269 269 Mob +593 096 8069704
E-mail	doloresdaniela.penafielanchundia@ugent.be ddpenafi@espol.edu.ec
Nationality / Ethnicity	Ecuadorian-Belgian : Indigenous / Mestizo
Date of birth	01/ Sept / 1982
Gender	Female
Mother	Lieve Amankay GOETEYN
Present occupation	**Lecturer and Researcher**
Institution	**Escuela Superior Politecnica del Litoral**
Field	**Biodiversity and Human Nutrition, Nutrition Education**
Work experience	
Dates	05/2017 to 12/2017
Position	Full time lecturer with research activities
Main activitities	Teaching nutrition education, qualitative and quantitative analysis of data. Research proposals and publications. Academic training.
Name of employer and	Dr. Ramon Espinel
Institution	Escuela Superior Politecnica del Litoral
Sector	Academic
Dates	02/2007 to 08/2007
Occupation or position held	Extension agent for nutrition education
Main activities and responsibilities	Transferring knowledge and skills about feeding practices, hygiene and nutritious food preparation to mothers and caregivers of children in rural areas of Babahoyo
Name and address of employer	Nilo Anchundia, Babahoyo Cathedral, 10 de Agosto y Bolivar, Babahoyo, Ecuador
Type of business or sector	Religious organization
Dates	10/2004 to 08/2005
Occupation or position held	Dietitian
Main activities and responsibilities	Assessing nutritional status of children, adolescents, and pregnant women on consultation
Name and address of employer	Dr. Arturo Mata, "Quevedo Clinic", 7 de Octubre y calle 11^{ava} , Quevedo, Ecuador
Type of business or sector	Health sector
Education and training	
Dates	01/2010 - present
Training level	PhD research and Doctoral School
University	Gent University - Belgium
Dates	09/2007 to 09/2009
Title of qualification awarded	Diploma: Master in science on Nutrition and Rural Development: Human Nutrition
Principal subjects/occupational skills covered	Epidemiology; Nutrition and food policies, Nutrition interventions; Planning and project design; Nutrition disorders; Food production

Name and type of organisation providing education and training	Gent University -Belgium
Dates	09/2005 to 06/2006
Title of qualification awarded	Credit transcript: Tropical agriculture
Principal subjects/occupational skills covered	Biological production systems in the tropics; Tropical crop production; Post harvest and food preservation engineering in the tropics
Name and type of organisation providing education and training	KU Leuven - Belgium
Dates	09/2003 to 08/2004
Title of qualification awarded	Credit transcript: Dietetic technician
Principal subjects/occupational skills covered	English as a Second Language; Human nutrition; Life cycle nutrition; Sociology; Community health
Name and type of organisation providing education and training	LaGuardia Community College -USA
Dates	05/1999 to 02/2002
Title of qualification awarded	Diploma: Food Technology
Principal subjects/occupational skills covered	Food processing; Food quality control; Nutrition; Food chemistry
Name and type of organisation providing education and training	Escuela Superior Politécnica del Litoral - Ecuador
Seminars and Symposiums	
2017	Ecuadorian Conference of Nutrition in the Andes. SEMPE. Oral poster
2016	TROPENTAG. University of Natural Resources and Life Sciences. Oral poster
2014	Green Week Conference 2014. European Commission
2013	20th Congress of Nutrition. E-Poster. IUSN
2012	I Congress on Biotechnology and Biodiversity. Poster. CIBE-ESPOL
2011	VIII International Symposium of Genetic resources in Latin America and the Caribbean; IUCN
2011	World Food Day – Univesiteit Gent. Poster presentation
2010	Green Week Conference 2010, European Commission
2009	2nd European Organic Congress 2009, IFOAM EU group
2009	5th International BTC Seminar "Agriculture as a motor for pro-poor growth"
2009	15th PhD Symposium on Applied Biological Science, KU Leuven
2009	Wageningen Nutritional Sciences Forum 2009, Wageningen RU
Additional training	
Area	Biodiversity and Nutrition
Institution and duration	Bioversity International, Biodiversity for Livelihoods, 11 Oct 2010 – 15 Nov 2010
Supervisor	Jessica Fanzo
Area	Rural sociology
Institution; and duration	Rural Sociology Group, Wageningen University; 1 Feb 2010 – 15 Feb 2010
Supervisor	Han Wiskerke
Area	Proteomics
Institution; and duration	Laboratory of Tropical Plant Improvement, KULeuven, 01 Sept 2005 – 31 Jun 2006
Supervisor	Ronny Swennen
Mother tongue(s)	**Spanish**

Other Languages

European level (*)	Understanding				Speaking				Writing	
	Listening		Reading		Spoken interaction		Spoken production			
English	C1	Proficient user	C2	Proficient user	C1	Proficient user	B2	Independent user	C 1	Proficient user
Dutch	A1	Basic user	A1	Basic user	A1	Basic user	A1	Basic user	A 1	Basic user
French	A1	Basic user	A1	Basic user	A1	Basic user	A1	Basic user	A 1	Basic user

(*) Common European Framework of Reference for Languages

Social skills and competences
Team work: Enthusiastic and open to work in multidisciplinary groups. Intercultural skills: Highly familiar with multicultural environments. International student in New York, Belgium, Holland and Italy. Good net-working skills with international organizations.

Organisational skills and competences
Management: Experience on management of inter-institutional projects. Familiar with organizing conferences. Highly familiar with international research-funding.

Technical skills and competences
Laboratory: Good laboratory skills in proteomics and bromatology. Field work: Highly skilled in survey data collection both rural and urban areas. Highly trained in anthropometric measurements and focus groups interviews.

Computer skills and competences
Competent with Microsoft Office, Illustrator, NVivo, and SPSS.

Publications

Penafiel, D., C. Lachat, R. Espinel, P. Van Damme and P. Kolsteren (2011). "A Systematic Review on the Contributions of Edible Plant and Animal Biodiversity to Human Diets." EcoHealth: 8; 381–399

Penafiel D, Lachat C, R. Espinel, P. Van Damme and P. Kolsteren (2012). “Everybody loves Musa spp.! an explorative study on local food biodiversity of Ecuador." I Congreso Internacional de Biotecnología y Biodiversidad. CIBE-ESPOL. Poster Presentation

Penafiel D, Lachat C, R. Espinel, P. Van Damme and P. Kolsteren (2012). "Food Biodiversity research requires a methodology". World Food Day 2011-FBI. Poster Presentation

Penafiel, D., C. Termote, C. Lachat, R. Espinel and P. Van Damme (2016). "Barriers to Eating Traditional Foods Vary by Age Group in Ecuador With Biodiversity Loss as a Key Issue." Journal of Nutrition Education and Behavior 48(4): 258-268.

Penafiel, D, Lachat C, R. Espinel and P. Van Damme (2016). “Traditional foods contribute to the Minimum Dietary Diversity for Women in Guasaganda, Central Ecuador” TROPENTAG. BOKU. p. 542

Penafiel, D, C. Termote, R. Espinel and P. Van Damme (2016). “Traditional food consumption by indigenous women in Guasaganda, Central Ecuador” Poster presentation. European EcoHealth Workshop. Brussels