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Topic:

Agrobiodiversity and commercialization of food plant species in mountainous farming systems in northern Laos

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Declaration

I hereby declare that I have done this thesis entitled "Agrobiodiversity and commercialization of food plant species in mountainous farming systems in northern Laos" independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to citation rules of the FTA.

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Acknowledgement

Abstract

Numerous studies were carried out so far on homegarden systems reflecting particularly documenting taxonomy of plant species and ethnobotanical knowledge, understanding of gender aspects or analysing impact on food and nutrition security. However, very little studied have been done on mutual linkages between agrobiodiversity and commercialization tendencies and potential impact of turning these systems from subsistence towards market-oriented ones. Different authors representing various scientific disciplines highlight the necessity to analyse whether generally documented positive impact of species richness on wide range of ecosystem services would also positively influence the livelihoods. Such research is particularly needed in fragile environments, such as mountainous areas. Thus, the aim of the thesis was to analyse the mutual connection between agrobiodiversity and economic performance of homegardens. Total number of 100 homegardens was included in the survey, while 60 were run by Lao Loum ethnic group and 40 by Hmong minority. The most dominant density of food plant species were *Brassica juncea and Capsicum*. Lao Loum homegardens further planted *Coriandrum sativum*, *Allium cepa and Brassica oleracea var. Capitata*, while Hmong homegardenss prefer *Zea mays*, *Ipomoea batatas* Lam. And *Cucummis sativus*. Furthermore, Hmong gardens and household size were larger compare to Lao Loum. Gardens of Lao Loum were more diversed in term of food plant species. Negative correlation was documented between homegarden size and agrobiodiversity.

In summary, homegardens were played crucial role to agrobiodiversity and household cash security in this study area. Therefore, we were recommended homegardens as a key of sustainable development in rural areas.

Key words: ethnic groups, Shannon-wiener, linear regression, cluster analysis, correlation analysis, household survey

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1. Introduction

Global agricultural sector, despite its important in feeding the world with the total could reach 9.15 billion in 2050. This growing will impact world agriculture by lowering its rate of growth compared to the past (Alexandratos & Bruinsma 2012). The agrobiodiversity is fundamental to agricultural production and food security, as well as a valuable ingredient of environment conservation. However, farming practices or changes in agricultural policies and institution, which lead to agrobiodiversity degradation in terms of plants genetic resources, livestock, insects and soil organism. This problem has caused economic loss, threatening productivity and food security, and leading to broader social cost (Trupp 2000). In the previous two decades, the strategies for biodiversity conservation and promotion was applied worldwide and was accepted by scientist and various agencies including the World Resources Institute, International Plant Genetic Resource Institute, Asian Development Bank, Deutsche Gesellschaft fur Technische Zusammenambeit (GTZ), Global Environment Facility, Food and Agriculture Organization (FAO) and many others (Long et al. 2003).

According to the global issue on biodiversity, Laos became a membership of the world biodiversity conservation to eradicate the poverty and ensure food security in 1996. The biodiversity of Lao is globally significant and being the mega-diverse and a primary centre of origin and diversity for cultivation rice (*Oryza sativa* L.) and other crops, such as maize (*Zea May*), chili (*Capsicum annuum L.*). etc. The economy and people's livelihood are highly dependent on utilizing the biodiversity of natural resources. Therefore, Lao government created the strategic vision in agricultural sector for the period 2000-2020. One of the issues was to include biodiversity conservation and promoting of agricultural and forestry research to understanding of plant-associated biodiversity, soil flora and fauna, pollinator and organism providing other ecological function (Saphangthong 2004). Laos was identified as one of ten centres of highest biodiversity in the world and already make extensive use of this diversity in agriculture sector, in contrast there are many people still suffered from hunger and micronutrient deficiency (40% of children were suffered from chronic and 13% adults

were chronically undernourished (Leena et al. 2004). One of the possible solutions for improvement, the Lao government was advised to pay more attention on homegardens as agrobiodiversity hotspot to providing the food for household consumption and also household income.

In global study, homegardens play the important roles in economy both income and subsistence, social and cultural, food security, ornamental, medicine, environment, biodiversity and innovation (Abdoellah et al. 2006; Kumar & Nair 2004; Levasseur & Oliver 2000; Trinh et al. 2003; Vogl et al. 2004). Furthermore, homegardens are still important for firewood and building material (Kumar & Nair 2006). This is typical also for Laos, where homegardens are important to biodiversity conservation and domestication of plant genetic resource as well. Biodiversity in homegardens was considered as a large diversity of plant genetic resources and important sources of providing food for household consumption and nutrition. In addition, homegardens provide cash income to their owners as well (Dyg & Phithayaphon 2004).

However, rapid economic growth of Laos so far does not bring much positive changes to agriculture. Farm productivity remains low, income per capita in agriculture sector is less than haft of the national average and the high yields are mainly from large farms and agribusiness that take advantage from innovations. Moreover, young people in rural areas look for off-farm employment in cities. This situation put a pressure on government to improve extension services in agriculture, such as providing credit, new technologies, seed, fertilizer, irrigation, market information, or promote market access, e.g. through contract farming (The United Nations in Lao PDR 2015). Therefore, farmers have changed their homegarden structure, activities and production. This could have negative impact on household income and agrobiodiversity. Nevertheless, there is still limited knowledge and not much research done on homegardens in Laos. Thus, following thesis is focused on examination of the role of homegardens in agrobiodiversity conservation and to document current commercialization tendencies of food plant species among Lao Loum and Hmong ethnic groups in mountainous areas of northern Laos.

2. Historical development and state of arts on homegardens

Homegardens represent a multistory (multistrata) system, which it typically constructed as combinations of various food and non-food trees, supplementary food, medicinal, ornamental or cultural plant species, very often these plants are combined with domestic animals or aquatics. They have strong cultural and economic importance as they are supposed to contribute to food, nutrition and cash security of their owners' households. They could be described as traditional systems with complex structure and multifunction's that are ecologically and socially sustainable, very often located close to homesteads (Thaman 2006; Tapasi & Kumar 2005; Torquebiau & Penot 2006; Wiersum 1982). Furthermore, homegardens are most popular in the tropics as they predominantly appear between 40° N and 30° S latitudes, e.g. South and Southeast Asia, the Pacific islands, Sub-Saharan Africa, and central part of Latin America (Fernandes 1986). Moreover, homegardening is believed to be the oldest from of agriculture, spontaneously developed even in pre-Neolithic hunters and gatherers. Then, the dissemination become more intentional with valuable species being planted to support their purpose of use. At the beginning such cultivation probably involved the new technology for vegetative propagation and then seeding was introduced. The previous evidence of garden cultivation period at least started since 3,000 B.C. For instance, pre-historic and probably scattered origins, homegardens probably started as a spontaneous growth of plants from leftovers of products brought to camps of the hunter and gatherers (Kumar 2006; Kumar & Nair 2006; Miller et al. 2006; Sauer 1969; Soemarwoto 1987).

2.1. Homegardens as a multipurpose farming system

As stated above, homegardens play a crucial role in biodiversity conservation and household livelihood as it contributed to diversity of nutritionally rich foods, income generation, improved livelihood and household economic welfare in the poorest areas of developing countries as well as promoting food security, small enterprises and rural development, materials, environment service and social cultural enrichment (Eibl et al. 2000; Galhena et

al. 2013; Galluzzi et al. 2010; Kehlenbeck et al. 2007; Mitchell & Hanstad 2004; Montagnini 2006; Trinh et al. 2003; Thomas & Van Damme 2010; Vasey 1985). Furthermore, the benefits from homegardens were not come from only crops but also for domestic animals such as poultry, pigs and aquatic (Okigbo 1990). It was reported that livestock produced in homegardens still provided cash income and assets to households (Devendra & Thomas 2002). Based on all of the above benefits, there are still not clear issues on homegarden development, especially a potential synergy between "tangible" and "intangible" benefits, in other words between generating food or cash and supporting of ecosystem services (Kumar & Nair 2006). Opportunity, we understand that increasing agroforestry practices in homegardens, should be considered as the development policy in rural areas to increase the capacity of local people for their basic needs, e.g. 56-61% for food), environmental sustainability, via providing a variety of ecosystem services, and household income via contributing between 22 and 62% (Edward et al. 2016; Lavasseur & Oliver 2000; Syed et al. 2013). As a published study show that higher income from homegarden leads to lower agrobiodiversity. This consequently leads to higher level of ecological and financial risk for the homegarden owners as well as higher requirement of external inputs, such as fertilizers and pesticides, and increased instability (Oekan et al, 2005). According to the high income from homegarden that mean the return per unit of land for homegarden was higher than the return per unit for other agriculture land. However, homegardens were under condition of the requirement of external inputs for example land, seed, fertilizer, insecticide, labour and other, to produce cash (Andrew et al. 2014; Games et al. 2010; Marsh 1998; Niñez 1984; Stoler 1978). Besides contributing to household livelihood and environmental services, homegardens are increasingly important for keeping farmers in experimentation, innovation or serve as a nursery with commercial crops, food crops and other crops such as hybrid plant species and modern cultivation techniques. These points are need adaptability of researches and suitability of government extensions (Miller et al. 2006; Yamada & Osaqui 2006).

2.2. What affects homegarden characteristics and structure?

Homegardens could be classified into many types based on their size, diversity of plant species, frequency of growth, ethnobotanical screening of useful plants, location and topography or management (Abdoellah et al. 2006; Abebe et al. 2006; Lamanda et al. 2006; Peyre et al. 2006; Thamires et al. 2013). Generally, homegarden classification being closely correlated/affected by household characteristic such as the household size, age of household members, number of labour force, gender, natural resources and socio-economic of homegarden owners. All these characteristics were effected to homegarden size and number of plant species in homegardens (Gbedomon et al. 2015; Howard 2006; Litt et al. 2011; Thaman et al. 2006; Vasey 1990). The modern homegardens were leading to decreased of the tree/shrub species, limited number of cash crop species, increased ornamental plant species, a gradual homogenization of homegarden structure and an increased use of external inputs (Pryre 2006).

One of the positive aspects of homegardens is that they conserve plant genetic resources while contributing to household income, food security and livelihoods of their owners. However, knowledge, age and gender of local people was shaped their homegarden structure which effected to plant diversity among homegardens for example old people did not require hard work for their gardening activities, but they were focused on more plants species which useful for daily use, but young people were interested more on commercialization crops. This is critical to ensure effective mainstreaming of homegarden into future biodiversity conservation (Gbedomon et al. 2015). Therefore, homegardens should be have many plants species and making them important for botanical agrobiodiversity, particularly for food crops and cash crops to fulfilled specific economic of individual owners. This could be a consequence of local culture and conditions of homegarden location which lead them to produce not only generated for utilize crops, but also for biodiversity conservation as they want to their homegardens with similarities to natural forest ecosystems (Kamonnate et al. 2012; Kumar & Nair 2004).

2.3. Future prospect on homegarden

Homegardens provide perspectives for conservation of plant genetic resources while contributing to improving household income, food security and livelihoods of local people. However, knowledge of local people was shaped their homegarden structure which effected to plant diversity. This is critical to ensure effective mainstreaming of homegarden into future biodiversity conservation (Rodrigue et al., 2015). A study from Thailand of compared between Hmong and Mien homegardens showed that homegardens were very rich in species, making them important repositories for botanical agrobiodiversity, particularly for food crops. These was been a consequence of their culture and condition of location which lead them to produce not only generated for utilize crops but also for biodiversity conservation (Kamonnate et al.2012). Other study, found that homegardens were fulfilled specific economic, social, and cultural needs of the individual owners and provided biological conservation as they want to their homegardens with similarities to natural forest ecosystems (Kumar & Nair 2004).

2.4. The future challenge and opportunity on homegardens

With the rapid growth of population and economy, the global agricultural sectors are expected to increase the amount of production for both domestic consumption and even export. This is leading to change agricultural sectors especially in homegarden structure and plant diversity (Anderson 1993; Galluzzi et al. 2010). Commercialization causes a decline in the variety of plants species, an increases risk of losses caused pests and diseases, soil degradation and erosion, high chemical fertilizer use lead to reduce the need for organic manures, high-yielding but high-input and high-risk, market-price-fluctuation and high seasonality. All those factors were affected to sustainability of homegarden structure and biodiversity (Soemarwoto 1987). One of the main features of commercialization of agriculture is that younger farmers prefer new high-yielding crop varieties rather than traditional ones. This might result in decrease of traditional plant species occurrence in homegardens or even loss. Therefore, the local self-saved seeds and local seeds supply are

very important for the future development of homegardens (Negri et al. 2003; Sunwar et al. 2006). Furthermore, to improve homegarden, we should consider in cropping integrating with animal husbandry to conserve the traditional activities and biodiversity. Because of the traditions in management seem to be stronger than innovation management (Abdoellah et al. 2006; Vogl & Vogl-Lukasser 2003).

2.5. Commercialization tendencies and homegardens

Current studies on commercialization show that farmers used 30 % fruits for personal consumption and gifts and 70 % have been intended to be sold on local markets. There were many previous studies presented that most farmers sold their products at farm gate prices to local traders, who take the assembled products to bigger towns, because of there was no market organization. In contrast, the small producers with small volume of products were not attracted to the large traders with high price (Blanckaert et al. 2004; Syed et al 2013; Tilahun & Malugeta 2015).

2.6. Homegardens and ethnicity

Homegardens and ethnic group are very important to promote the food security, livelihood and biodiversity conservation in rural areas. Most of ethnic groups are living in rural areas and depended on agricultural activities and forest products collection. Based on the different cultures and different methods of natural resource using for their living, they were affected to plant species diversity (Blanckaert et al. 2004). Therefore, homegarden and ethnic groups are the available methodology to assessment the biodiversity impact according to the different cultural, because of the different cultural background, different socioeconomic condition and geographical location were influenced to diversity and floristic composition in homegardens (Galluzzi et al. 2010). Homestead and ecosystem service of the ethnic groups were influenced to plants diversity on their farming systems and household income (Rahman 2018). However, the various cultural groups and living in the same area were positively correlated to the diversity of plant species (De la Torre et al. 2012), as a study in Thailand,

Hmong and Mien was found that the number of plant species in Hmong homegardens was higher than Mien homegardens and concluded that diversity in homegardens were strongly related to homegarden geographical location, personal preference, and cultural background of the owners (Kamonnate et al. 2012). Hmong refugee homegarden exotic plants cultivation in Sacramento, California was important role to the basic diet for household consumption and also important to pregnancy and post-partum diets of women (Corlett et al. 2002). In Ethiopia, the knowledge of Meinit ethnic group is very important on medicine plants using to treat or cure disease of humans and domestic animal (Giday et al. 2009).

The Laotian government was classified all indigenous ethnic groups into three general categories, named based on altitude of their usual dwellings and cultural origins. These three groups are the lowland (Lao Loum), midland (Lao Theung), and highland (Lao Soung or Hmong). Lao government was applied the policy toward minorities in mountain highland areas with focused on resettlement to lowland, the official objectives of relocation policy were to enhance the living conditions such as permanent agriculture farming, road access, school, market and hospital. Therefore, the Lao government tried to develop in several ways to become a good ethnicity interaction in development process. However, midland and upland minorities were needed time consume to become similar to lowland Lao culture as working in paddy rice, cash crops cultivating, Lao-speaking citizens (Ireson &Ireson 1991; Michaud 2009).

The Hmong, sometime called "Lao Soung" are originated in south of China and migrated to other parts of southeast Asia (Laos, Vietnam and Thailand) in nineteenth century to look for regular new settlements for their villages, searching for agriculture land. The season of migration was forced out due to political conflicts. The Hmong, they spoken their own language as native language in communication within their community (Lee 2007; Siriphone 2006). The Hmong in Laos, mostly living in the northern of mountainous areas major is Xiengkhoung province and some are living in other provinces from middle (e.g. Vientiane province, Vientiane capital and Borlikhamxay province) and all provinces of northern part and only few families are living in southern part. Nowadays, there are about 10% of total

population of Laos (6.8 million people, 2014), 66% were Lao Loum and 30% were Lao Theung (Lao Statistics Bureau 2014).

2.7. Current stage of research on homegardens and agrobiodiversity in Laos

The Lao PDR National Agro-Biodiversit Programme and Action Plan II (NABP II) was developed in 2004 by FAO, UNDP and NAFRI as a framework and long-term strategy for better implementation of agricultural development. Programme includes also homegardens as an important issue for assessment of the impact of household-based homegardens on food security, increase the amount and variety of nutritious food crops planted, e.g. fruits, vegetables, small animals, fish and other aquatic resources, and assessment of household awareness of nutritional need according to homegarden products (Dyg & Phithayaphone 2004; Sodalak et al. 2005). A programme assessment report of promotion of homegarden for improved nutritional well-being showed that homegardening programmes was positive effected to food production, diversity of food plants species, food nutrition intake and income of rural poor households through integrated homegarden production. This report defined that before the programme, there was no any surplus garden produce for sale but at the end of the programme all households can produce vegetables not only for household consumption but also for sell and can provided within year-round supply of vegetables. In summary, homegarden programme has improved rural livelihoods, increased dietary diversity and improved the nutritional status of the Lao population (Bhattacharjee et al. 2006).

Generally, homegardens in Laos seem to exist in many areas around the entire country and all kinds of environment, from mountain tops to close to rivers in lowland areas. But, there was lacked scientific published available and thus, limited knowledge of their impact especially income generation and agro-biodiversity. Nevertheless, there was a study on assessment of the biodiversity conservation project in homegardens from two areas in northern provinces in Laos, Oudomxay and Loungprabang, indicated that there were different kinds of homegardens. This study found that the size of homegardens ranged between 0.25-

1 ha. A homegarden has highest number of plants species which about 50 different of plants species were grown mainly fruits, vegetables, root crops and various medicinal plantse.g. papaya, banana, citruses, jackfruit, eggplants, chili, cabbage, beans, pineapple, ginger, taro, bitter bamboo, peanut. etc. However, there were no results on homegarden cluster analysis and types of homegarden management (Dyg & Phithayaphone 2004; Sodalak et al. 2005). Based on the above information, we believed that homegarden farming systems in Laos were important to food security, nutrition intake, biodiversity conservation and household income. Therefore, it is necessary to have more research on homegardens in Laos to find out the various information for the future development and studying on homegardens.

3.   Aim of the thesis

Homegardens in Laos should be considered as sources to a large diversity of plant species and they play an important role in the conservation and domestication of plant genetic resources. Agrobiodiversity found in these homegardens provides households with access to a large variety of nutritious foods, thus providing opportunities for better nutrition and food security, but are a promising generator of additional cash income (Dyg & Phithayaphone 2004). Moreover, the Lao Government had developed several policies and strategies to support economic, social and cultural value of biodiversity and importance of its conservation to higher sustainability of farming systems in the period of 2000-2020. Those policies included the following targets: achieving food self-sufficiency, increasing export of agricultural products through crop diversification, commercialization and processing of production, particularly cash crops, livestock, forest products, stabilising and reduction of slash-and-burn agriculture, increasing rural income by the construction of irrigation systems, human resource development on agricultural skills and promoting agriculture and forestry researches (Saphangthong 2004). Therefore, all the above policies are need various researches on agriculture and forestry sector especially in agrobiodiversity to support the food security, household livelihood and sustainable development.

From the last few decades, the Lao government was played important role to homegarden production in rural areas promoting the poverty reduction, food security, sustainable agriculture, increase diversity and poverty reduction which link to household cash security in rural areas. Thus, the aim of this research was to understand and document current status of agrobiodiversity and commercialization of food plants species among Lao Loum and Hmong homegardens in mountainous areas of northern Laos. Specific goals were to document household resources capacity and use, to classify homegarden according to their characteristics, and to quantify agrobiodiversity level, to define the type of homegardens based on purpose of use and the species richness, to identify the most important food plant species and their market orientation.

4.   Methodology

4.1.   Study site characteristics

The research was conducted in Khoun district, located in the Xiengkhoung Plateau in north-east of the Lao PDR and far from Vientiane Capital around 400 km. Xiengkhoung province covers an area of 15,880 km^2 and has largely a mountainous topography. Characterized with surrounding mountain and grassland, the municipality of the province is Phonesavan. The total population of the province is 244,648 people. The altitude in averages 1,300 m, the average of temperature is range between 22.2 -27.4 C$^°$, the average of humidity is 73 %, the total annual rainfall is 1,232.2 mm and the total annual sun shine is 2,565.5 hours. Most people are depended on agriculture production both crop production with the total area 59,460 ha. Main crops are included rice, maize, vegetables, cassava, fruit trees and others, and animal raising, e.g. cattle 174,000 units, pig 107,000 units, poultry 1,388,000 units. Etc (Lao Statistics Bureau 2016).

Khoun district, the study site is located about 32 km southeast of Phonesavan Municipality (19°18´40´´N, 103°22´03´´E). The total rainfall is ranges between 1,500 - 1,900 mm per year, average air humidity is about 73%, the annual temperature in average is around 24˚C and the annual sunshine duration in average is 1,658.7 hours. Two seasons are distinguished: a dry season from April to October and a rainy season from May to September (Ministry of Agriculture and Forestry 2014). The total population is 35,332 people out of which 17,292 were females the authority with 77 villages and 5,856 households. There were four main ethnic groups, particularly Hmongand Lao Loum with 58.81 % and 36.37 % share on total population people) respectively, and two minor ethnicities Khamu and Erdu (Khoun District Statistic Office 2016). The diversity of geography zones instructs a range of agriculture production systems including rainfed rice-based farming systems in lowland of the plateau and following by shifting cultivation in upland areas, cash crops and livestock production. Khoun district is one of the areas which fulfil with natural resources, the most important

agriculture production areas are located along the Namngiew river which can supply water for agriculture at during the whole year. There are 37 permanent weirs, one semi-permanent weir and 135 traditional weirs. All of them were covered around 2,400 ha in rainy season and 484 ha in dry season. According to the good condition of natural resources and environment, most of families in Khoun district are depended on agriculture activities as the main source of household income.
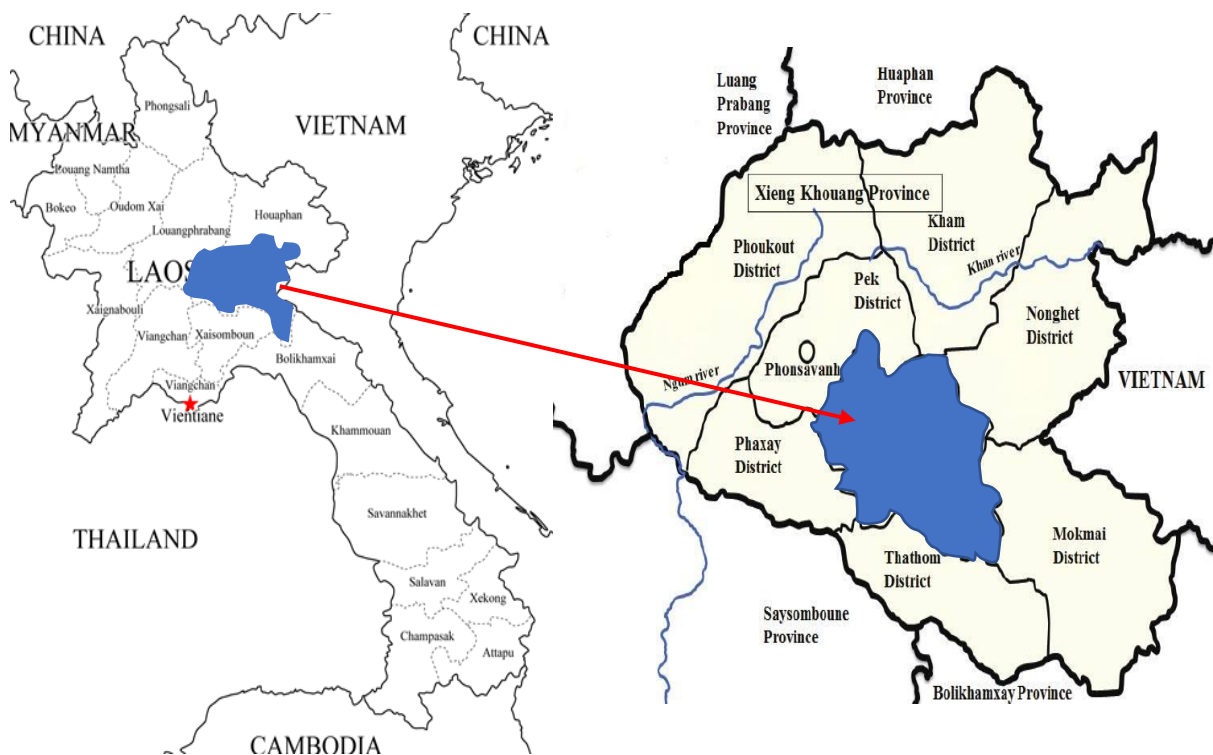
Figure 1. Location of Xiengkhoung province and Khoun district
Source: Author illustration based on Laos maps http://mapsof.net/laos

The total annual harvested areas in rainy season were 4,142.2 ha in 2016. There were many crops produced in rainy season such as paddy rice 2,400 ha, upland rice 420 ha, maize 128 ha, coffee 356.7 ha, fruit trees 126 ha, vegetables 199 ha, root crops 280 ha, pineapple 35 ha, banana 28 ha, and others crops 169.5 ha. In dry season, the total cultivated areas were 288 ha, mainly vegetables, leaf = 125 ha, rhizome = 80 ha or fruit crops = 14 ha, cabbage 35 ha, garlic 48 ha, sweet corn 17 ha, and beans 17 ha. For animals rising were included cattle 19,549 units, buffalo 4,289 units, horse 652 units, pig 19,147 units, goat 1,535 units, and

poultry 76,528 units. Pasture areas is 1,011.9 ha in total, and fish pond 470.3 ha (1,318 fish pond units) (Khoun District Agricultural and Forestry Office 2016). Most of farmers were able to sell the surplus of products to the domestic market and other cities especially Vientiane capital. However, some of families were produced for commercialization both crops cultivation and animals rising. From the point of views, homegardens are played important role to household income and subsistence but still lack of the evidence on its. Hence, we selected Khoun district as a representative study area which have possible for household cash security examination and the effect of homegarden to plants diversity.

4.2. Sampling procedure and data collection

We decided to document 100 homegardens. In order to consider potential difference between different ethnic groups, 60 homegardens were run by Lao Loum households and 40 by Hmong ones. Data were collected in six villages with different topography situation and access road (Table 1).

Table 1. graphical and ethnic distribution of respondents

Name of village	Total household	Lao Loum households	Hmong households	Distance from city market (Km)
Nator	27	8	1	23
Gnounsixaysana	246	11	33	20
Tham-hoy	78	19	0	19
Koa	48	11	5	24
Sang	95	4	0	28
Phiavat	218	7	1	30
Total	712	60	40	-

We used non-random sampling by using convenience and snowball methods. The research was applied multiple approaches for data collection, involving quantitative and qualitative to

obtain the data which are useful and necessary to discuss and answer of the objectives and research questions. We interviewed the farmers by using a structure questionnaire with farmer who has homegarden and Lao language was used during of interview.

Following information was obtained from targeted households. Firstly, household demography, such as age, gender, school attendance and main occupation, overview of household assets and capital, main activities and income diversification were documented. Then were collected the characteristic of homegardens including age, size, ownership of land, elevation from sea level, constraints and owner perception. For vegetable survey, we recorded the following data: species names by local names, number of species, number of individual of each species per homegarden, main purposes of use, part of use, frequency of cultivation in during the year and annual production estimation (annual production can sell), and labour participant on homegarden. After that, we recorded for the important food plant species for commercialization: number of cash crop species, market-oriented of each cash crop species, price of each species, inputs using, number of participant member and time use (Questionnaire in Appendix 1).

4.3. Data processing

Data were summarised for each homegarden and entered into MS Office Excel for cleaning and coding. All statistical analyses were done in the SPSS (IBM SPSS Statistics for Windows, Version 24.0). Differences between surveyed homegardens were analysed via t-test simple descriptive statistics such as frequencies, percentage, mean, minimum, and maximum to explore the differentiation of household characteristics, homegarden characteristics, diversity of plants species and household income diversification. Furthermore, we applied correlation analysis and linear regression to define relationship between homegarden size, homegarden age, number of species, number of individuals of each species and number of species sold.

Household resources analysis included household size, household head age, living in the village, year of school (+15 years), labour force (15-60-year-old), male labour, female labour, dependent member (0-14 year- old, 60+ year old).

Household assets were included as the percentage of each variable such as vehicle, motor bike, bicycle, drying place/dryer, milling drill, fridge, mobile phone, mobile phone plus internet, television and radio. These assets were explained the facility to the market. And then we compared the different of household owned animals which included cow, buffalo, goat, pig, duck/goose and poultry.

Homegarden structural characteristics were classified the homegardens size into five categories and eight categories based on the types of use (e.g. fresh vegetable, food plants for cook, fruits, spices, ornamental, medicine, materials and others). On this part, we were compared the proportion of the number individuals of each species from each homegarden size category and then compared between two ethnics. The relative density of plants species as the following formula:

Relative density of a plant species =

$$\frac{Total\ no.\ of\ individuals\ of\ each\ species\ in\ all\ homegardens}{Total\ number\ of\ homegardens} x100$$

Homegarden income analysis, we compared the income from homegardens and income from other household activities to understanding about how much the share of homegarden income was contributed to household income. We also calculated the homegarden income per labour force, income per working day and income per working hour.

Agrobiodiversity analysis for the species richness were included the homegarden size, homegarden age, total number species, total number individuals. We were calculated the Shannon diversity index to explain that how much diversity as the below calculation method.

$$H = \sum_{i=1}^{S} -(P_i * lnP_i)$$

where:

H = the Shannon diversity index

P_i = fraction of the entire population made up of species i

S = numbers of species encountered

$\sum$ = sum from species 1 to species S

We were defined the correlation between homegarden characteristics and agro-biodiversity based on the homegarden size, number of plants species, homegarden age, household head age and number of cash crops species by using

The classification of 100 homegardens, a hierarchical cluster analysis was applied using number of plants species, Shannon-Wiener index and homegarden age as the main variables. Ward's method was used to identified homegarden types with Euclidean distances as a measure of dissimilarity. The results were divided into five clusters of homegarden types and the data on homegardens' characteristics were analysed using the statistical package MS office Excel based on following variables: 1) number of plants species, 2) Shannon-Wiener index, 3) homegarden age, 4) homegarden size and 5) homegarden income.

Linear regression was used to define the relationship between homegarden, household characteristics and commercialization and agro-biodiversity. The data for analysis was used the statistical package MS office Excel based on following variables: 1) homegarden age, 2) household size, 3) household head age, 4) number of labour force, 5) Shannon-Wiener index, 6) number of plants species sold and 7) homegarden income. Shannon-Wiener was used as dependent variable and the rest was used as independent variables.

Finally, we calculated the ratio of the market-oriented with comparing between market places such as farm gate, middle man, local market and city market.

5. Results

5.1. Household resource characteristics

Significant different between Lao Loum and Hmong were documented in five out of eight chosen variables, e.g. household size, household head age, living in the village, year of schooling of household members reaching at least 15 years of age, total household labour force, male labour, female labour and dependent members (table 2).

Table 2. Comparison of human resources capacity and use among two ethnic groups

Variable	Unit	Lao Loum (n=60)	Hmong (n=40)	P-value
		Mean	Mean	
Household size	members	5.25 (±1.56)	6.95 (±6.28)	0.047**
Household head age	years	46.68 (±10.33)	43.15 (±1.56)	0.109
Living in the village	years	43.25 (±14.80)	37.90 (±16.58)	0.095*
Year of school (+15)	years	8.47 (±2.50)	6.60 (±2.42)	0.000***
Labour force (15 - 60)	members	3.33 (±1.22)	4.30 (±2.81)	0.004***
Male labour	members	1.75 (±0.75)	1.90 (±0.98)	0.390
Female labour	members	1.58 (±0.85)	2.40 (±1.26)	0.001***
Dependent members	members	1.92 (±1.42)	2.20 (±1.59)	0.353

Note (s):   Statistical significance at 10 % (*), 5 % (**) and 1 % (***).

Hmong households were larger compare to Lao Loum (significant at 5%, p=0.047). In contrast, the household head age of Lao Loum was higher than Hmong, however, there was no statistic significant different between among them. For living in the village, Lao Loum were lived longer than Hmong and significant different at 10% (p-value <0.095). Regarding to education Lao Loum were more educated and strong statistically significant at 1 % (p-value <0.000). Nevertheless, labour force and female labour were highest in Hmong and strongly significant at 1 % (p-value <0.004 and p-value <0.001). Finally, with the different labour force but there were similar in male labour and independence members mong two groups of study sites.

Table 3. Household assets analysis for marketing access assets in two ethnic groups

Variable	Lao Loum (n=60)	Hmong (n=40)	P-value
	Average (%)	Average (%)	
Vehicle	55.0	30.0	0.014**
Motor bike	95.0	97.5	0.529
Bicycle	31.7	20.0	0.197
Drying place/dryer	11.7	0.0	0.025**
Milling drill	6.7	2.5	0.347
Fridge	100.0	52.5	0.000***
Phone	100.0	100.0	1.000
Phone + internet	73.3	67.5	0.529
TV	96.7	72.5	0.000***
Radio	40.0	42.5	0.806

Note (s): Statistical significance at 10 % (*), 5 % (**) and 1 % (***).

Table 3 shows the different between Lao Loum and Hmong on household assets. We were recoded that there was statistically significant difference in five variable such as vehicle (p-value<0.014), drying place/dryer (p-value <0.025), fridge (p-value <0.000) and television (p-value <0.000). For the others, such as motor bike, bicycle, milling drill, phone, phone + internet and radio, were very similarly. These assets were important to farmers with market access capacity major are vehicle, motor bike and mobile phone as they able delivering homegarden products to the market and market information.

Table 4. Livestock household assets comparison among two ethnic groups

Variable	Lao Loum (n=60)	Hmong (n=40)	P-value
	Average	Average	
Cow (number of head)	5.27	4.50	0.601
Buffalo (number of head)	0.83	1.03	0.661
Goat (number of head)	0.27	0.00	0.159
Pig (number of head)	0.48	0.45	0.869
Duck/Goose (number of head)	25.47	14.28	0.000***
Poultry (number of head)	39.67	22.30	0.001**

Note(s): Statistical significance at 10 % (*), 5 % (**) and 1 % (***).

Table 4 we found that the average of each animal was closed to each other except duck/goose and poultry. The average number of duck and poultry in Lao Loum households were higher than the average number in Hmong household and there was very statistic significant different between on this two types animal at 1 % (p-value <0.000 of duck and p-value <0.001 of poultry).

5.2. Homegarden structure characteristics and factors influencing of plant species diversity

The mean of the homegarden size in Lao Loum was declared as 1,650.68 m^2 ($\pm$1,407.60 m^2; range: 130-5,388 m^2) and the mean of Hmong homegarden size was declared as 2,195 m^2 ($\pm$1,644.55 m^2; range: 210-7,500 m^2). We recorded that Hmong homegarden sizes were larger than the Lao Loum homegarden size and differ significant at 1 % level (p–value < 0.001) (Table 5). Nevertheless, the mean of Lao Loum homegarden age was higher than the mean of Hmong homegarden age as the mean showed that 20 years ($\pm$ 13.32 years) in Lao Loum homegardens and 12 ($\pm$9.66) years in Hmong homegardens and were also significant different between them at 1 % level (p–value <0.004).

Table 5. Homegarden characteristics in two study sites

Variable	Unit	Lao Loum (n=60) Mean	Hmong (n=40) Mean	P-value
Homegarden size	m^2	1,287 ($\pm$1,096.37) 130 - 5,388	2,195 ($\pm$1,644.55) 210 – 7,500	0.001***
Homegarden age	years	20.20 ($\pm$13.32) 2 - 50	12.88 ($\pm$9.66) 2 - 50	0.004***
Elevation from sea level	m	1,154.97 ($\pm$85.72) 1,073 - 1,271	1,231.85 ($\pm$165.63) 1,092 - 1,559	0.003***
Number of species	number	21.15 ($\pm$8.72) 7 - 47	13.88 ($\pm$7.98) 4 - 39	0.000***
Shannon diversity index	number	1.49 ($\pm$0.41) 0.33 - 2.23	1.33 ($\pm$0.46) 0.10 - 2.12	0.061*

Number of species regularly sold	number	7.42 (±3.48) 1 - 18	4.95 (±2.65) 1 - 14	0.000***

Note (s): Statistical significance at 10 % (*), 5 % (**) and 1 % (***).

However, the range of homegarden age was the same from both study sites as range from 2 – 50 years. According to the location of homegardens are different, there were strongly significant different between Lao Loum and Hmong homegardens at 1 % level (p – value < 0.003) as our results showed that the mean of the elevation from the sea level of Lao Loum homegardens was 1,154.97 m (± 85.72; range: 1,073 - 1,271 m) and the mean of the elevation from the sea level of Hmong homegarden was 1,231.85 m (±165.63 m; range: 1,092 - 1,559 m).

The different number of plants species between Lao Loum and Hmong homegardens were presented that an average of 21 species (± 8.72 species; range: 7 – 47 species) in 60 homegardens of Lao Loum and an average of 13 species (± 7.98 species; range: 4 – 39 species) in 40 homegardens of Hmong. We were recorded that Lao Loum homegardens were more species than Hmong homegardens and strongly differ significant. The maximum number different of plants species were found in Lao Loum homegardens with a total number of 47 different species and minimum number different of plants species were found in Hmong homegardens with a total number of 4 different species. Furthermore, the number different of plant species with market oriented, in Lao Loum homegardens were higher than Hmong homegardens and were recoded that the average number is 7.42 species (range: 1-18 species) in Lao Loum homegardens and 4.95 species (range: 1 – 14 species) in Hmong homegardens and significant difference plant species in Lao Loum and Hmong homegardens on market oriented. Based on the average number of Shannon - Wiener diversity index from both study sites showed at higher than one as we found that the average of Shannon – Wiener diversity index in Lao Loum homegardens was 1.49 (± 0.41; range: 0.33 – 2.23) and in Hmong homegardens was 1.33 (± 0.46; range: 0.10 – 2.12). We were recommended that homegardens in mountainous northern of Laos were more diversity in both Lao Loum and Hmong homegardens, but Lao Loum homegardens were more diversity of plants species and differ statistic significant at 1 % level compared.

Figure 2. and figure 3. Were defined the relationship between household characteristics and homegarden characteristics linking with the diversity of plants species. Assemble to number of plant species was negatively correlated with the homegarden size (Pearson Correlation: -0.164; Fig. 2a), the number of species were decreased based on the size of homegardens which mean that many of small homegardens were have more number of plant species than of large homegardens for both Lao Loum and Hmong, nonetheless there was not significant for both study sites (total p - value >0.102).
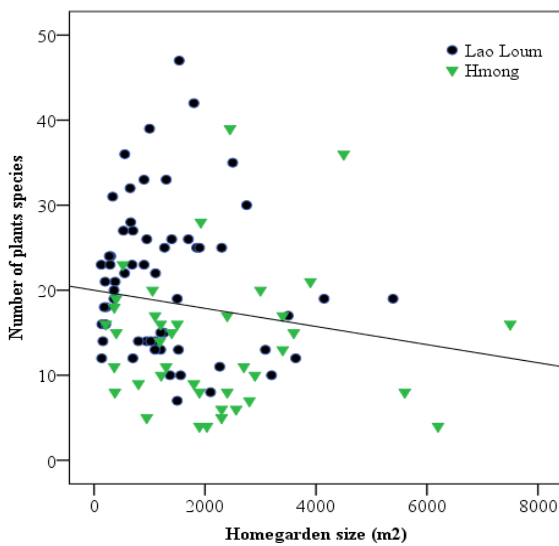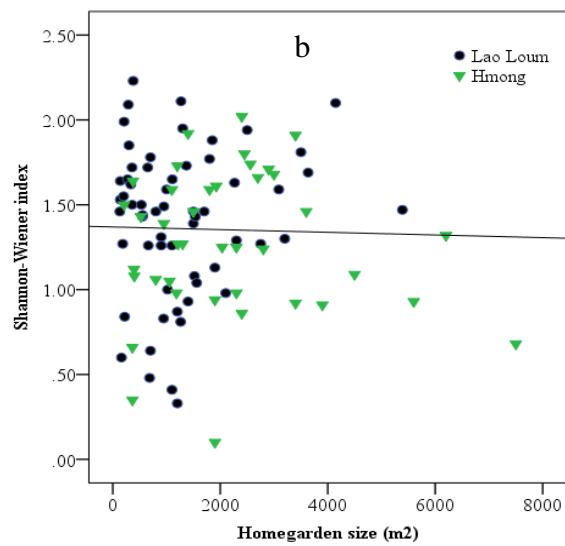
Number of plants species and homegarden size   Agrobiodiversity and homegarden size
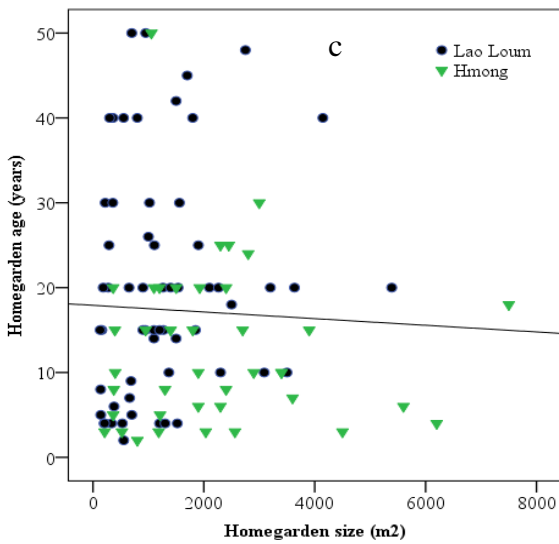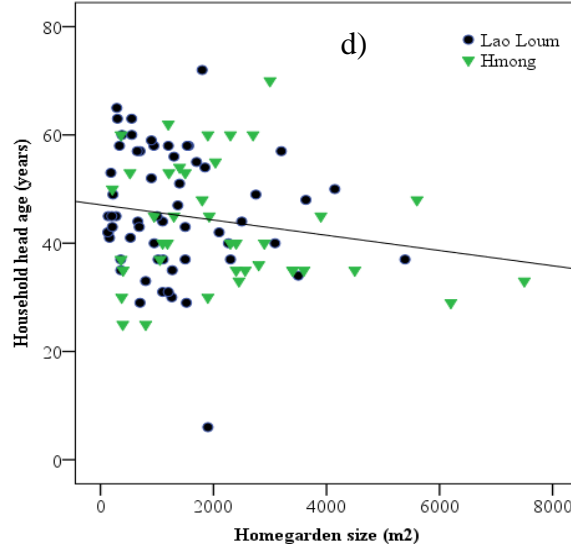
Household head age and homegarden size   Household head age and homegarden size

Figure 2. Various relationship between homegarden characteristics and agrobiodiversity

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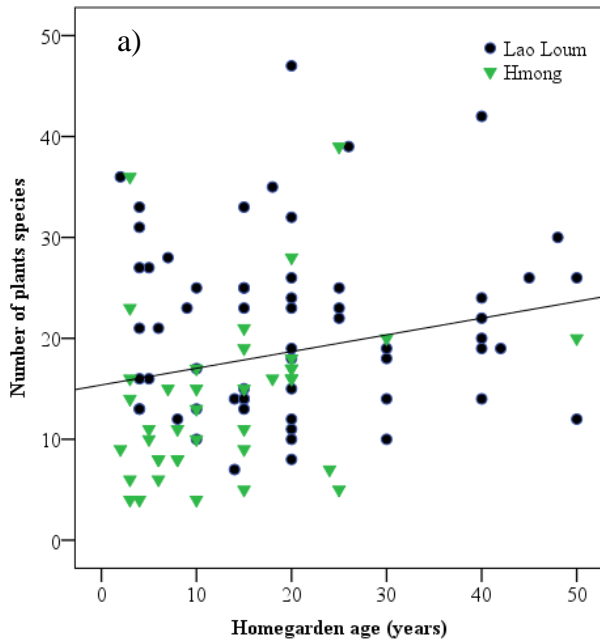
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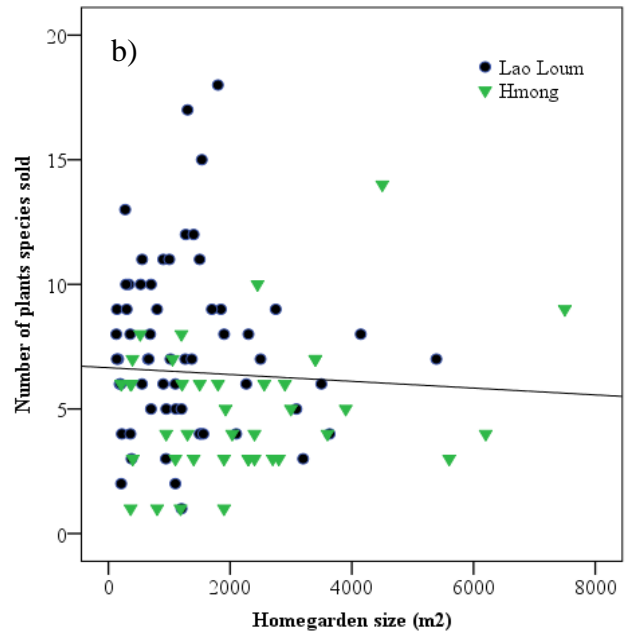
Number of plants species sold and homegarden size
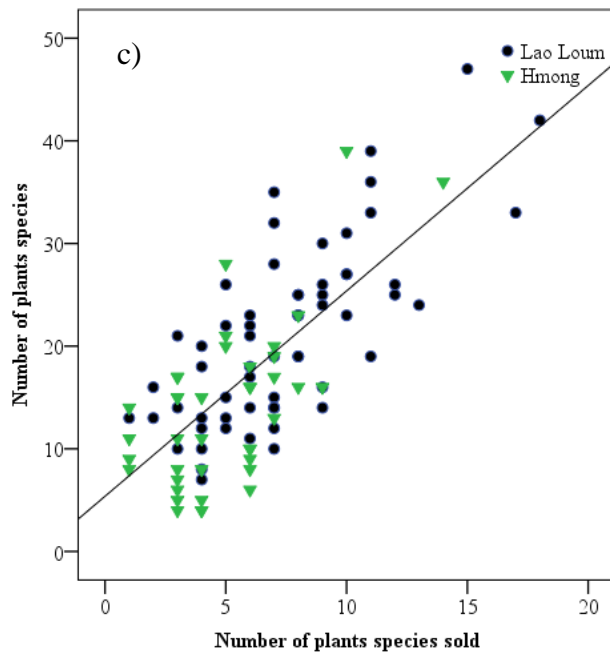
Number of plants species and homegarden age

Figure 3. Various relationship between homegarden characteristics and agrobiodiversity

However, the number of individual of each plant species was positively correlated with the size of homegardens and significant in both Lao Loum and Hmong (0.175; p–value < 0.082; there was no figure in our results). Regard to Shannon - Wiener diversity index and homegarden size were also negative correlated and not significant (Pearson Correlation: -0.053; p - value >0.597; Fig. 2b). However, we found that there was slightly significant in Hmong homegardens with p-value <0.082. Furthermore, we examined the interaction between homegarden age and homegarden size, household head age and homegarden size, we found that both study sites were negative interacted (Pearson Correlation: - 0.044; p - value > 0.662; Fig. 2c; Pearson Correlation: - 0.173; p - value > 0.85; Fig. 2d), there was only significant correlated between household head age and homegarden size.

We continued examined the correlation between homegarden age and number of plants species we found that there was positive correlated and statistically significant (Pearson Correlation: 0.194; p-value < 0.054; Fig. 3a), we were recorded that old homegardens were have more plants species than young homegardens.

Moreover, we also defined correlated between homegarden size and number of plants species particularly sold to the market and found that there was negative correlated between them and no significant (Pearson Correlation: - 0.057; p - value > 0.576; Fig. 3b). In contrast, there was positive correlation between number of plants species and number of plants species particularly sold and statistically significant (Pearson Correlation: 0.742; p - value < 0.001). We concluded that number of plant species is depended on the homegarden age and number of species for commercialization might depended on the total numbers of pants species in homegardens.
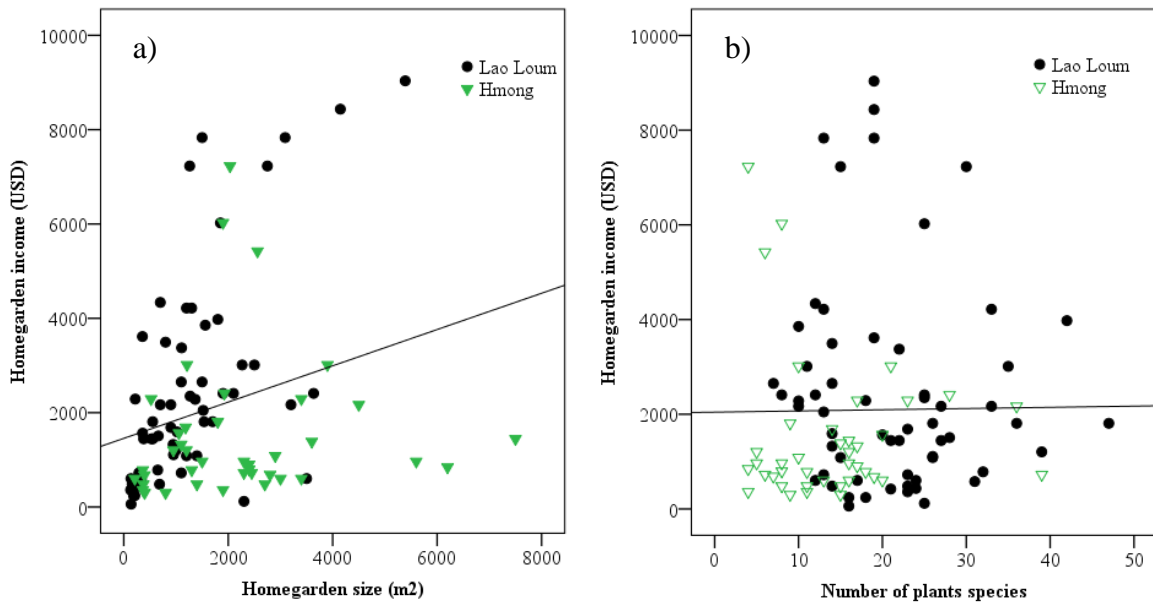
Figure 4. Relationship homegarden structure characteristics and household cash security:
a) homegarden size and homegarden income and b) number of plants species and homegaden
income.

Figure 4a, there was positive correlated impact between homegarden income and the
homegarden size, Pearson correlation = 0.007 and significant at 1% level (p-value <0.007).
This mean that homegarden size was strongly influenced to the homegarden income both Lao
Loum and Hmong. At the same time our results showed that homegarden income was very
low positive correlation to number of plants species and not significant (Pearson correlation:
0.011 and p-value >0.910). On this point, we are not sure because of we just tested the for all
homegardens but not for only commercialization homegadens. Therefore, we need to analysis
more on multiple linear regression as the following table:

Table 6. Multi-linear regression between household resources, commercialization of homegardens homegardens and agrobiodiversity

Variables	Estimate	Std. Error	z-value	Pr(>|z|)
(Constant)	0.717	0.210	0.430	0.001
Homegarden age	0.013	0.003	0.082	0.895
Household size	0.008	0.010	-0.025	0.931
Number of Labour force	0.047	0.029	0.081	0.647
Household head age	0.194	0.004	0.266	0.058
Number of species sold	0.306	0.013	0.340	0.003
Homegarden income	- 0.018	0.000	0.009	0.781

Note (s) Dependent Variable: Shannon-Wiener index

Regardless of the correlation of multiple factors influencing to plant species diversity as indicated by Shannon – Wiener index (Table 6), we found that there was only homegarden income with the negative effected to plant species diversity in homegardens as showed in estimate value equal (-0.018, R^2=0.16), this mean that if increased income by 1 % will lead to decreased of plants species diversity by 0.018 unit. Thus, imply that increased commercialization on homegardens is leading to decrease plant species diversity in homegarden, there is not significant. Unlike to other factors especially are number of species sold and household head age, the results showed that if these factors increased will be increased plants species diversity and statistically significant (p-value < 0.03 and p-value < 0.058). For the homegarden age, homegarden size and number of labour force factors evenness had positive effected to diversity but were not statistic significant.

5.3. Classification of homegarden types

Based on the cluster analysis using a dissimilarity index of 9.0 as a cut – off point, the 100 targeted homegardens were classified into five types (Fig. 5 and Table 7). We found that the highest number of homegarden was homegarden type 3 with included 47 homegardens and then followed by type 1, 2, 5 and 4 were created by 25, 15, 9 and 4 homegardens. Hmong homegardens were found in type 3 (28 homegardens), type 2 (9 homegardens), type 1 (2 homegardens) and type 5 (1 homegardens). In type 1, was considered as smallest homegarden with average size 974 m^2, but highest number of plants species by 24 species in average. Type 2 and 3 were considered as medium homegardens with the average size 1,732 m^2 and 1,636 m^2. The last, type 4 and 5 were classified as largest homegardens with the average size 2,725 m^2 and 2,122 m^2. Type 4 showed the oldest homegardens (33 years), followed by type 5, 1,3 and 2 with the average age 26, 19, 16 and 14 years. Type 2 was showed the highest Shannon – Wiener index with 1.45, type 1 and 2 were showed the same number of Shannon – Wiener index with 1.34 and the same in type 4 and 5 with 1.24. The large homegardens were found as the highest in come such as type 4 and type 5. The lowest income homegardens were found in type 3 with contained many Hmong homegardens.
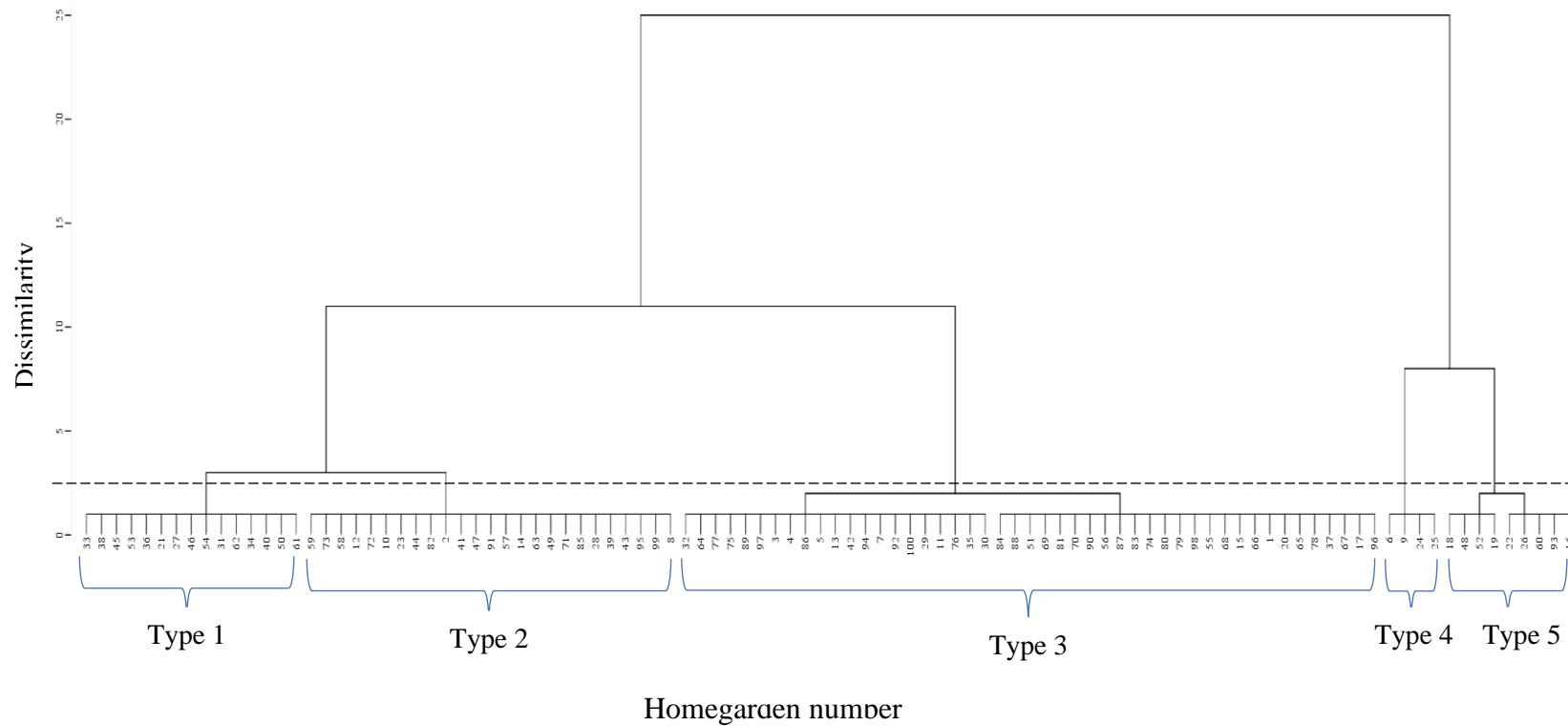
Figure 5. Cluster dendrogram of Khoun district based on Ward's method with Euclidean distances as measure of dissimilarity

Table 7. Structural characteristics of homegarden types

Variables	Homegarden types				
	1 (n=15)	2 (n=25)	3 (n=47)	4 (n=4)	5 (n=9)
Number of species	24	19	16	21	21
Homegarden age	19	14	16	33	26
Homegarden size (m^2)	974	1,732	1,636	2,725	2,122
Shannon-Wiener index	1.34	1.45	1.34	1.24	1.24
HG income (US$)	2,269	2,087	1,224	7,831	3,681

5.4. The patterns of agrobiodiversity based on homegarden size and purpose of use

Table 8. shows the proportion of individual in each plant category based on the size of the homegarden and in terms of the main use of each plant species. We determined into eight plant categories in both study site as the following: fresh vegetable, plant for cook, fruit, spice, ornamental, medicine, material, and others. And then identified the homegarden size into five categories: < 500 m^2, 501-1,000 m^2, 1001-1,500 m^2, 1,501-2,000 m^2 and $>2,000$ m^2. From the Lao Loum homegardens. Based on the results we found that the proportion of fresh vegetables was highest for all the size of the homegarden of Lao Loum homegardens except the size of the above 2001 m^2 (range from 19 % to 61.9 % of the total number individuals) and secondly was plants for cook. In contrast, the proportion of plant for cook was highest in Hmong homegardens (52.8 % to 81.7 %) and followed by fresh vegetables (5.6 % to 35.4 %). For the other purposes of use were very small proportion of number individuals of each plant species on both study sites.

Table 8. Proportion of the plants in each of plant categories based on size of the homegarden in study sites

Ethnics and HG area classes	n	Proportion of the number of individuals in each plant category (%)							
		Fresh vegetable	Vegetable for cooking	Fruit	Spice	Ornamentals	Medicine	Material	Others
Lao Loum									
<500 m^2	15	61.3 (12,021)	27.5 (5,400)	0.4 (74)	9.9 (1,940)	0.1 (11)	0.1 (18)	0.0 (1)	0.7 (135)
501-1000 m^2	11	53.8 (13,639)	36.6 (9,292)	2.8 (717)	6.5 (1,648)	0.0 (11)	0.0 (10)	0.0 (2)	0.2 (42)
1001-1500 m^2	13	61.9 (19,905)	26.3 (8,451)	2.0 (654)	8.2 (2,636)	0.0 (0)	0.0 (7)	0.0 (3)	1.6 (526)
1501-2000 m^2	7	54.0 (16,950)	34.2 (10,737)	2.6 (823)	8.2 (2,582)	0.0 (9)	0.0 (10)	0.0 (4)	0.9 (277)
>2001 m^2	14	19.0 (19,168)	23.5 (6,938)	1.5 (438)	9.6 (2,826)	0.0 (4)	0.0 (7)	0.0 (1)	0.4 (106)
Hmong									
<500 m^2	6	35.4 (1,510)	48.9 (2,083)	8.3 (352)	4.6 (197)	0.0 (0)	0.2 (9)	0.0 (2)	2.6 (111)
501-1000 m^2	4	20.7 (2,123)	63.1 (6,470)	7.4 (756)	1.8 (189)	0.0 (1)	0.0 (0)	0.0 (0)	7.0 (717)
1001-1500 m^2	8	14.6 (1,004)	67.0 (4,620)	8.3 (572)	5.6 (387)	0.0 (2)	0.0 (1)	0.0 (2)	4.5 (310)
1501-2000 m^2	3	37.4 (5,764)	52.8 (8,132)	3.5 (545)	0.9 (135)	0.0 (5)	0.0 (1)	0.0 (10	5.3 (818)
>2001 m^2	19	5.6 (837)	81.7 (12,191)	6.3 (934)	3.1 (468)	0.0 (3)	0.2 (34)	0.0 (1)	3.1 (459)

Table 9. Dominance ratio of the main categories of plans in homegardens of two study sites

Plant category	Summed dominance ratio	
	Lao Loum	Hmong
Fresh vegetable	59.19 %	22.74 %
Vegetable for cooking	29.64 %	62.68 %
fruit	1.87 %	6.74 %
spice	8.48 %	3.22 %
ornamental	0.03 %	0.02 %
medicine	0.04 %	0.09 %
material	0.01 %	0.02 %
other	0.75 %	4.50 %
total	100.00 %	100.00 %

Continue with table 8. The reason of Lao Loum homegardens are more proportion density on fresh vegetable than Hmong homegardens were caused from the different behaviour of household consumption between Lao Loum and Hmong. Lao Loum people were preferred consumed fresh vegetable while Hmong people were preferred consumed vegetables after cooked. According to Hmong homegardens located in high land, therefore most of them were likely to grown fruit crops such as maize, cucumber, banana and others more than Lao Loum as the showed at 6.74 % (Table 9). In contrast, Lao Loum people were grown of the spice crops more than Hmong people at 8.48 %. However, the relative proportion of the number of individuals in each plants category did not show the correlated with homegarden size for both study sites.

In summarized both study sites, the proportion of the number of individuals of each plant species categories was recorded that the highest proportion based on the purpose of use was found fresh vegetables and plants for cook, these purposes of use in Lao Loum homegardens were proportion density about 59.19 % and 29.64% and highest proportion of plants for cook and fresh vegetables in Hmong homegardens were found about 62.68 % and 22.74 %. There were very small proportion of ornamental, medicine, materials and others, the reason because

of most farmers were concentrated in producing for household consumption and household cash income commercialization.

5.5. The most food plant species in homegardens

According to the use for commercialization of each plant species, we defined the five most dominant species from two sites were vegetable (Table 10) and we found that the five most species in Lao Loum homegardens were included: Coriander (*Coriandrum sativum)* had far the highest relative density 37.89 % per homegarden with 3.86 of relative frequency and 20.88 % of summed dominance ratio, the rest four dominance species were followed by Green onion (*Allium cepa)* with 12.83 % relative density*,* Mustard green *(Brassica juncea)* with 7.45 % relative density*,* Cabbage *(Brassica oleracea* var. *capitata* with 6.38 % relative density*),* and Chili (*Capsicum annuum)* with 2.41 % relative density.

For Hmong homegardens, the five most dominance species were comprised: Mustard green (*Brassica juncea)* as the highest dominant with 31.14 % of relative density per homegarden, 3.60 of relative frequency and 17.37 % of summed dominance ratio and then followed by Maize (*Zea mays),* Sweet potato *(Ipomoea batatas* Lam.*),* Cucumber (*Cucumis staivus*), and Chili *(Capsicum annuum)* and their relative density were included 6.60, 3.28, 2.84 and 1.66. All plants species names and frequency in homegardens (Appendix 2).

Table 10. The five most-dominant of food plant species (based on the summed dominance ratio) in Lao Loum and Hmong homegardens

Type of homegardens and species rank order	Dominant species	Relative density	Relative frequency	Summed dominance ratio
Lao Loum				
1	*Coriandrum sativum*	37.89	3.86	20.88
2	*Allium cepa*	12.83	4.10	8.47
3	*Brassica juncea*	7.45	3.07	5.26
4	*Brassica oleracea* var. *capitata*	6.38	2.60	4.49
5	*Capsicum annuum*	2.41	3.94	3.18
Hmong				
1	*Brassica juncea*	31.14	3.60	17.37
2	*Zea mays*	6.60	5.59	6.10
3	*Ipomoea batatas* Lam.	3.28	3.96	3.62
4	*Cucumis sativus.*	2.84	4.32	3.58
5	*Capsicum annuum*	1.66	4.86	3.26

5.6. The impact of commercialization homegardens to family income

The homegardens were important roles for contributed to the household income in both study sites, as the data (Table 12 and figure 6) showed that, both were contributed to family income at a high share for example 31 % (2,468 US$) of average income per family in Lao Loum homegardens and 37 % (1,523 US$) in average income per family in Hmong homegardens. There was statistically significant different between Lao Loum and Hmong (p < 0.022; Table 12). The homegarden income for Lao Loum was the second source of income beyond the salary/wage by 2,706 US$ (34 % of total family income). In contrast, Hmong homegardens were the first source of family income (40 %) and second source was being salary/wage by 1,442 US$ (37.8 % of family income). The other sources of household income for Lao Loum were come from annual crops production, livestock and others (handicraft, fishing, forest

products and relative or friends) and Hmong household income sources were come from others mainly forest products collection, and then annual crops production and livestock.
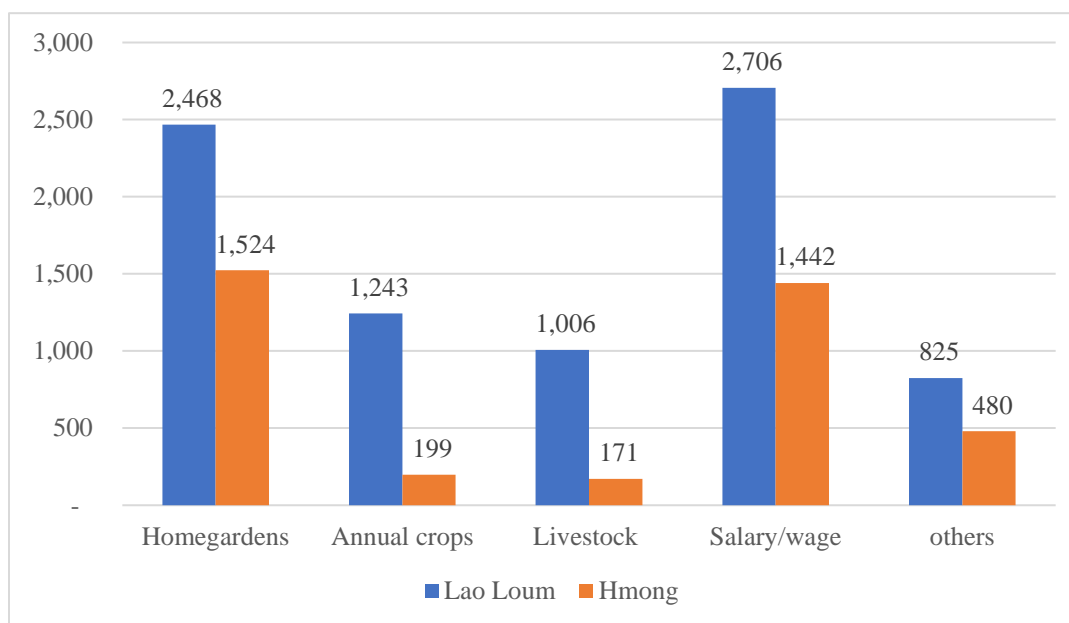
Figure 6. Household income diversification among two ethnic groups

In term of homegarden income, we calculated the average income based on the labour used, it showed that the average income per labour force was highest in Lao Loum (864.53 US$; Table 11), while in income per labour force in Hmong was only 512.42 US$, and there was significant different by p-value <0.052.

Table 11. Comparison homegarden income based on labour used between two ethnic groups

Variable	Lao Loum (n=60)		Hmong (n=40)		P-vale
	Average	Range	Average	Range	
Income from HG (US$)	2,468.37	60.24-9,036.14	1,523.80	301.20-7,228.92	0.022**
Labour force	3.3	1.0-6.0	4.3	2.0 - 8.0	0.004***
Working hours (hour)	1,535	260 - 3,700	1,391	450 - 3,600	0.372
Working days (day)	192	32.5 - 462.5	190	67.5 - 775	0.372
Income per labour force	864.53	15.06 - 3,975.90	512.42	51.64 - 3,614.46	0.052*
Income per hour	1.54	0.10 - 4.82	1.04	0.22 - 2.51	0.010**
Income per day	12.35	0.72 - 39.16	8.35	1.69 - 20.00	0.010**

Income per hour and per day were also highest in Lao Loum homegardens (1.54 US\$ and 12.35 US\$) and significant different between two study sites (p-value <0.010). Based on the results of our study we considered that both study sites were significant in average of cash income per person per day. Average homegarden income per land unit (m^2) was 2 US\$ in Lao Loum homegardens and 0.7 US\$ in Hmong homegardens.

5.7. Perception of homegarden owner to homegarden

Regardless to the homegarden owner perception to homegardens, most of Lao Loum (Fig. 7a) and Hmong (Fig.7b). Lao Loum homegarden owners showed that more than 90 % of 60 homegarden owners were awareness that homegardens played very important roles for provide food, reduce food expense and easily of food access, 78 % were said that homegardens are important for household income. In contrast, there were less than 50 % Hmong homegarden owners were understood that homegardens are very important for those homegarden roles.

The others were less important for both study sites such as beautiful place and relax place, hobby job, keeping traditional activities, exchange the product and consider more species. Moreover, most of Hmong homegarden owner were strongly disagreed with these homegarden roles as showed more than 60 % out of 40 homegarden owners were said that homegarden are not important those roles. According to Hmong homegarden owners' opinion, we assumed that because of Hmong homegardens are not close to their house and located at the high areas as in the mountainous areas.
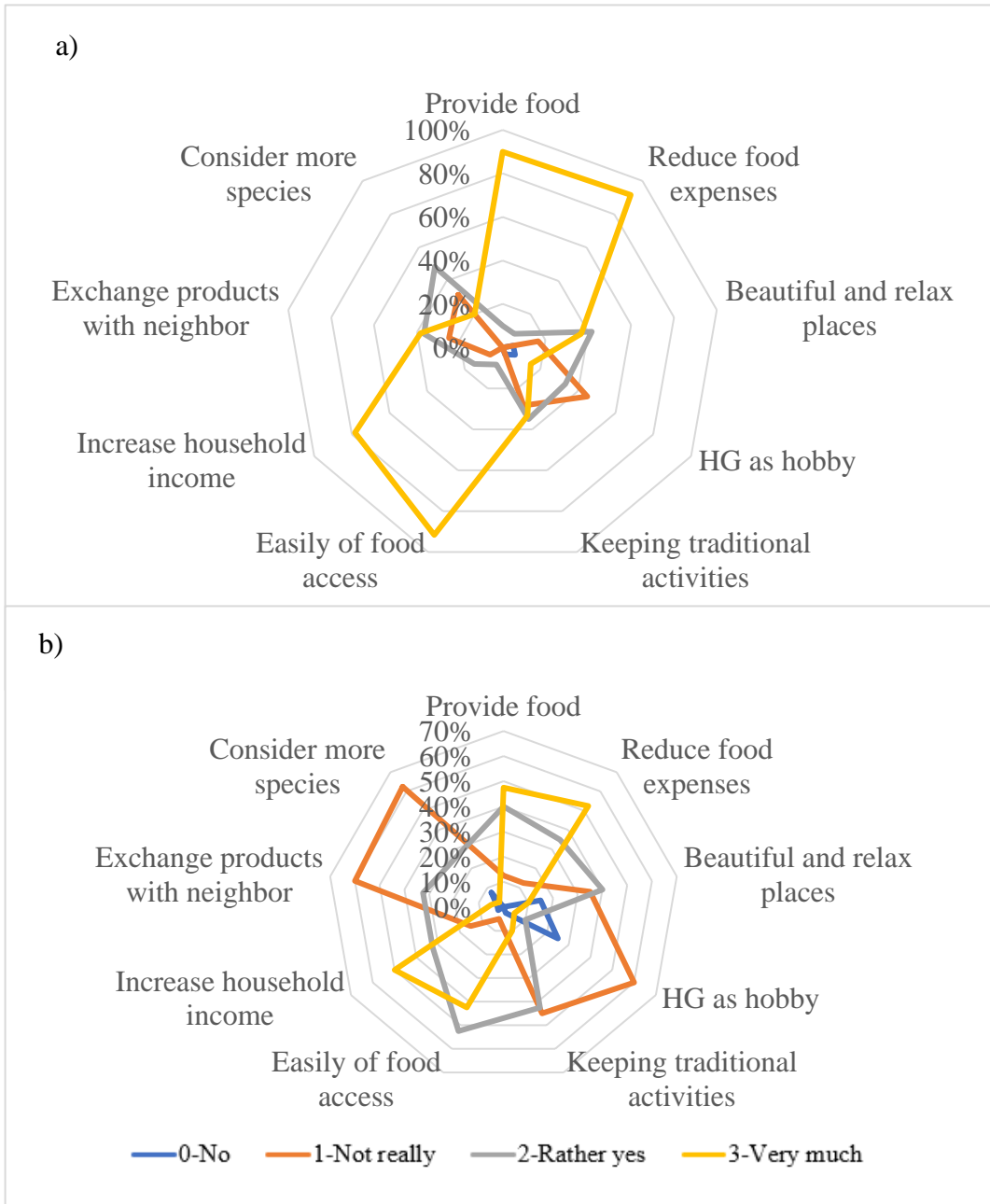
Figure 7. Perception of homegarden owners to homegardens, a) Lao Loum homegarden owners, b) Hmong homegarden owners.

5.8. Market orientation of studied homegarden

Regardless to market oriented of homegarden products in both study sites of Khoun district (Table 12). We found that Lao Loum homegarden owners were sold majority of the production particularly at farm gate about 56.3 % of total homegarden production with 290 of the number frequency of plants species and an average price 0.97 US$/kg and then sold to local market about 35 % at an average price 0.99 US$/kg with 193 of the number frequency of plants species, there was only little amounts sold at city market as about 8.5 % with an average price 1.08 US$/kg and 38 of the number species frequency. Lao Loum homegardens owners were not sold their homegarden products to the middlemen.

Table 12. Market orientation on homegarden products

Ethnic group	Variables	farm gate	middle man	local market	city market
Lao Loum	frequency of species	290	0	193	38
	percentage sales (%)	56.3	0.0	35.1	8.5
	average price (US$/kg)	0.97	-	0.99	1.08
Hmong	frequency of species	46	5	134	36
	percentage sale (%)	22.5	2.1	61.1	14.2
	average price (US$/kg)	0.58	0.47	0.68	0.71

On the contrary, Hmong homegarden owners were targeted to sold their homegarden products at local markets showed more than 61 % of total homegarden products with an average price 0.68 US$/kg and 134 of the frequency of species, the rest of the products were sold at the farm gate in about 22 % (46 of frequency species) with an average price 0.58 US$/kg and city market was 14 % (36 of frequency species) with an average price 0.71 US$/kg. There was minor number percentage sold to the middlemen (2 % and 5 of frequency species) at lower price as an average price 0.47 US$/kg. However, based on our survey we

found that the smaller and medium homegardens with grown many kinds of plants species were preferred to sold products to local markets more than other types of markets. Additionally, all plants species were found in all types of market (except middle man), but different in volume of selling as already showed in Table 12. Consistent with the price of homegarden products, we found that the highest price was chilli (*Capsicum annuum*) with price range from 0.8 to 2.5 US$ per kg; and following by coriander (*Coriandrum sativum*), price range from 0.7 to 2.3 US$ per kg; green onion (*Allium cepa*), price range from 0.6 to 2.2 US$ per kg; and garlic (*Allium sativum*), price range from 0.6 to 2.1 US$ per kg. For the other plants species, the price was range between 0.3 to 1.8 US$ per kg (Appendix. 2).

In term of marketing situation, all plants species, the price was fluctuation depended on the seasonal and other factors both socio-economic and environment factors for example: too many growers in the same species, bad weather (too much rainfall and too cold), insects and plants diseases and soil fertility degradation. On the other hand, it was affected from the increasing/decreasing market demand from others big cities namely Vientiane capital, Loungprabang province and included Thailand (import Chili when concerned with flooding).

6.   Discussion

Study revealed that household size, household head age and the household labour force had positive effect on the structure of homegardens. The homegarden size, larger household size, younger homegarden owner and labour force were possibility increased the homegarden size to ensure their food consumption and cash income in households. From our results showed that Hmong were higher than Lao Loum with average number of household size, homegarden size and number of labour force, and significant different. The age and labour force were indicated that there are many people involved in homegarden activities in both study sites. Instance of the homegarden sizes were caused from the significant different of education levels of the household head with Lao Loum were higher than Hmong, in this case we assumed that higher education levels had more opportunity to get the off-farm jobs which able to earn more income than agriculture activities and may perhaps Lao Loum household head have less time to work in homegardens, which similar to studies published (Amede &Taye 2015; Gbedomon et al. 2015; Méndez et al. 2001; Waliczek et al. 2006). However, the finding showed that the household head age and living in the village were highest in Lao Loum households which present that old people did not put enough physical efforts to working hard but based on their experience they were focused on plants species diversity and keeping the traditional activities in their homegardens more than younger people and new comers. While younger people and new comers were focused on plants species for commercialization. This supporting to Lao Loum homegardens had more plant species diversity than Hmong homegardens (Table 2 and 5; Figure 2a and 2b). Moreover, our finding showed that homegardens age and homegarden owner age were negative correlated with homegarden size, which implied that older homegardens are smaller than younger homegardens but have more plants species, and these finding are like previous studies (Gbedomon et al. 2015; Howard 2006; Rodrigue et al. 2015; Thaman 1995; Vasey 1990). On the other hand, men and women labour force may influenced to homegarden structures especially women, as our finding showed that the average number of women labour force was strongly significant highest in Hmong. Thus, may possibly made Hmong homegarden

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size larger than Lao Loum homegarden size. In contrast, in relation to education, we found that Lao Loum women have more educated than Hmong women (this information not mention on the results). Therefore, we would like to evaluate that women knowledge was positively affected to plant species diversity in homegardens as our results presented that Lao Loum homegardens had more diversity than Hmong homegardens. In term of women and diversity of plants species in homegardens, this finding was similar to previous studies such as in Latin America, Howard (2006) and in Benin, Rodrigue et al. (2015). Then again, we may not able to ignore for child labour because they also participated in all homegardening activities. In our survey, we found that in Hmong homegardens were highest numbers of child labours as 31 child labours in 19 homegardens out of 40 homegardens. For Lao Loum homegardens were found only 13 child labours in 11 homegardens (this information was included in dependent members on Table 2. Child labours might be a key factor affected to homegarden structure characteristics especially in minority ethnic and should include for the future study.

According to the average of homegarden size and the location of homegardens were differ statistically significant between the study sites (Table 5), we were record that the location of homegardens were directly influenced to the homegarden size as our finding found that most of Lao Loum homegardens were located close to homestead of lowland which mean that they were faced with the limited land to increase the homegarden size. In contrast, Hmong homegardens were mostly located far away from homestead (range from 1 km to 6 km) and in the mountain tops with high elevation (Table 5) that give a good opportunity to increase their homegarden size. However, the consequence of the difference of location, the higher elevation may provide the different ecological conditions, and combine with Hmong culture, household economic and social factors were negative affected to plants species diversity and also commercialization of homegardens (Blanckaet et al. 2004; Kamonnate et al. 2012; Kehlenbeck et al. 2007). We agreed that location and cultural of minority ethnic are negative influenced to plants species but not the homegarden size. Therefore, we would like to present that the number of plants species were not depended on the homegarden size as our finding showed that number of species and homegarden size were negative correlated and no significant between Lao Loum and Hmong homegardens. (Figure 2a). In fact, we found that

many small homegardens but have a lot of plants species in Lao Loum homegardens and only two small homegardens in Hmong with located close to home street (they were learned from Lao Loum homegarden owners culture). This finding was similarly to many previous studies (Abdellah et al. 2006; Lamanda et al. 2006; Peyre et al. 2006; Thamires et al. 2013; Trinh et al. 2003). However, the number of individuals of each plant species was positive correlated with the homegarden size and significant in both Lao Loum and Hmong (data was not showed in ours results). The number individual of each plant species is increased with increasing the size of homegardens (Abdellah et al. 2006). The average number of Shannon – Wiener index was higher than one in both Lao Loum and Hmong homegardens (average: 1.49 in Lao Loum and 1.33 in Hmong, Table 5) which mean that there was more diversity of plants species in both study sites but Lao Loum homegardens were more diversity than Hmong homegardens and significant different between to Hmong homegardens. However, there was low negative correlated between homegarden size and Shannon – Wiener index (Figure 2b), small homegardens were higher index than big homegardens as the same as with number of plants species we are already mentioned on the above. This finding is similar to many studies for example: in Indonesia (Abdellah et al. 2006), in India (Peyre et al. 2006), In Melanesia (Lamanda et al. 2006), and in Amazonia (Cardozo et al. 2015). But different from a study from Nepal, Sunwar et al (2006) with concluded that the homegarden size and species richness were positively correlated. However, our study showed that the homegarden age and species richness were positive correlated and differ significant between Lao Loum and Hmong homegardens (Figure 3a). The number of plants species tented to increase with increasing the age of homegardens (Gbedomon et al. 2015; Wezel et al. 2005).

The cluster analysis was divided homegardens into five homegardens types based on many factors such as number of species, homegarden age, homegarden size, Shannon – Wiener index and homegarden income. The highest number of homegardens was found in type 3 and type 2 (Figure 5 and Table 7). However, we found that all homegarden types were more diversity but diffident between their factors for example the large-size homegardens were less diversity than small-size homegardens, in contrast the large-size homegardens were higher income than small-size homegardens. This finding is similar with a study from Vietnam (Vlkova et al. 2011). Based on homegarden income, our finding is not cleared

answer about the different income between homegarden type 1, 2 and 3. Why type 1 is highest then type 2 and 3? Even type 1 has smaller size than type 2 and 3 but higher income, we assumed that may cause from homegarden owners of type 1 are produced many cash crops species with high price and able to produce many times in during the year as intensive farming. Therefore, we would like to suggest that we should analysis more on this for the future study.

Once again, in term of species richness, Cardozo et al (2015) was studied on species richness increase income in agroforestry systems of eastern Amazonia was discussed that agroforestry species richness and diversity were positive correlated with non-monetary income and net income. This study was similarly to our finding as there was strongly positive correlation between number of plant species and number of plant species sold to the market and significant (Figure 3c), and also was statistically significant different between Lao Loum and Hmong homegardens, Lao Loum owners were sold higher number of different plant species than Hmong homegarden owners. We were recommended that commercialization homegardens can maintain plant species diversity (Major et al. 2005). The small homegardens were produced high number of cash crops species with a little volume of each species. In contrast, the large homegardens were produced low number of cash crops species with a big volume of each species. Based on our results, the average homegarden income in Lao Loum was range between 60.24 US$ to 9,036 US$ and the average homegarden income in Hmong was range between 301.20 US$ to 7,228.92 US$ (Figure 3). We were recorded that homegardens were played important to family income for both study sites as they contributed about 31 % of total family income in Lao Loum and 37 % of total family income in Hmong (Edward et al. 2016; Lavasseur & Oliver 2000; Syed et al. 2013). According to the homegardens had a high share in family income (Figure 6) on both study sites and high income per area unit especially in Lao Loum homegardens. In this point there was similar to a study in India, Mohan et al (2006), they were discussed that the income per unit area was highest for the small gardens and was lowest in the large gardens. Furthermore, the average homegarden income per labour force and per time unit (hour and day) were highest in Lao Loum and differ significant to Hmong (Table 11). This finding was affected from the different of knowledge, homegardening experience and cultural between ethnic groups that

lead to different on their technology using for gardening activities. Furthermore, in income of homegardens were increased the homegarden size (Rahman et al. 2013). We were reported that Lao Loum homegarden owners are more skills and knowledge than Hmong homegarden owners as their opinion to homegardens (Figure 7). Moreover, Lao Loum women were have more empowerment than Hmong women which influenced to decision making on homegarden producing (Gbedomon et al. 2015; Howard 2006; Kamonnate et al. 2012; Mohan et al. 2006; Thaman 1995). Our study results, we did not quantify the volume of production of each plant species and we just quantified the percentage of products to analyse the market orientation and found that most of Lao Loum homegarden owners were sold their products at farm gate and followed by local market and city market. In contrast to Hmong homegarden owners were preferred to sell their products to local market and then farm gate, city market and a very little middle man. There was no Lao Loum homegarden owners sold their products to middle man. The large homegardens with big volume of products were favour to sold at farm gate and the rest to city market in both Lao Loum and Hmong. For the small and medium size of homegardens were likely to sold at farm gate and local market, there was no market organization in our study areas (Tilahun & Malugeta 2015). However, fortunately in the late of this year, the local authority was organized a plan to open the organic vegetable market within the district market. The price of each plant species was depended on the seasonal, number of producers, economic condition and environment factors.

Finally, according to our finding, household resources capacity and use were significant different between Lao Loum and Hmong. We found that average of household size, labour force, male and female labour were highest in Hmong. Thus, mean Hmong ethnic was more capacity on labour force. However, Lao Loum were higher on household head age, living in the village and year of school which mean Lao Loum were more knowledge and higher skills than Hmong. There were significant different on homegarden structure, agrobiodiversity, homegarden income and marketing orientation among Lao Loum and Hmong. Our study should be perceived in the light of following limitations. First, the number of sample size between two study sites was unequal, equal sample size are more powerful than unequal sample size, the positive pairings tend to be the most powerful and negative pairings the least powerful. This will lead to greater the imbalance and greater difference in power among two

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groups of research (Rusticus & Lovato 2014). Therefore, we would like to recommend that the sample size should be organized as equal number between two ethnic groups. Second, Cultural and language use for data collection in Hmong homegarden owners were influenced to our primary data as them given us by bias information because of they are not understand Lao language as well, this could potentially lead to misunderstanding of plant species names and their impact to household income and most of respondents on our interview were women in Hmong households but based on their culture or empowerment within their family are still not equal to men like Lao Loum women. From this point would be also affected to the bias answer. Third, our finding was lack of the cost analysis and gender involvement on homegardens. Last, we would like to express that they are the most limitation in our study, time and seasonal as our data collection was implemented only one month (August – September) and was been raining season. Therefore, some species which grown during in dry season were not recognized by respondents and were not included in our questionnaire. To this problem, it would be nice if we have the group discussion for data collection.

7.   Conclusion

The results of this study imply that there were significant different between Lao Loum and Hmong on household resources use for homegarden producing. The household resource characteristics were positive and negative influenced to the homegarden structure characteristics. The bigger household size, younger household head age and more number of labour force of Hmong were strongly positive effected to the homegarden size. In our study showed that the average number of homegarden size was highest in Hmong. However, the larger homegarden size was not implied to have more plant species diversity. Our results showed that there were depended on the age of homegardens, the knowledge and experience of homegarden owners, and including location, socio-economic and cultural. Those factors, in Lao Loum were much better condition than Hmong. Lao Loum homegardens were more diversity and contributed to household income more than Hmong homegardens and significant different. However, Shannon-Wiener diversity index showed at higher than one, we concluded that there was more diversity of plants species in both study sites. Based on the cluster analysed, we found that there are five types of homegardens, the highest number homegarden was type 3, the highest species was type 2 with contained 25 homegardens, the larger size was type 4 and was highest income. We were considered only five species as the most dominance species in both study sites and they were difference between Lao Loum and Hmong homegardens. Furthermore, they were different on market orientation, Lao Loum was preferred to sell products at farm gate and local market while Hmong was preferred to sell at local market and farm gate. Finally, we concluded that household structure was affected to homegarden structure characteristics and plant species diversity. Homegarden structure also effected to plant species diversity and family income. In summary, all factors of households and homegardens are correlated effected to each other. Thus, the complex policies should be applied to homegardens for the sustainable development with maintains the plant species diversity and household income.

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Appendix

Appendix 1. Households survey and homegardens survey in northern of Laos

Name of village:		Date:		Time:	
Interviewee:		Questionnaire #:		GPS:	
Interviewer		Record # of HG		Area (m2)	

I.   Household members and history

Q: Can you specify which people live together with you in your house now/during last year?

No.	Member	Gender [M/F]	Born [age]	School attendance [years]	Ethnicity		**Q:** Were you born in the village?			Lao language		
					Lao Loum	Hmong	Born here	Since [year]	Place of origin	Know	Read	Write
1	HH head				☐	☐	☐			☐	☐	☐
2	Wife/Spouse				☐	☐	☐			☐	☐	☐
3												
4												
5												
6												
8												
9												

Note: Ask farmer for gender, age (or when member was born) and number of years of school attendance. Than continue with data on ethnicity (which are expected to correlate with study sites).Good to know from where parents of HH head and his wife came if they were not born in the same village.

II.   Overview of assets and capital

Value-chain, Market	Note	Information	Note	Animals	Heads	Use …???
Vehicle (car, truck)		Phone		Cow		☐ Food ☐ $ ☐ Draft
Motor bike		Phone+Internet		Buffalo		☐ Food ☐ $ ☐ Draft
Bicycle		TV		Goat		☐ Food ☐ $ ☐ Milk
Drying place, dryer		Radio		Pigs		☐ Food ☐ $ ☐ Babies

Milling drill				Duck/Goose		☐ Food ☐ $ ☐ Eggs
Fridge				Poultry		☐ Food ☐ $ ☐ Eggs

III. Main activities and income diversification

Q: Can you specify what activities are important for your family?

Overview of the activities, let farmer speak and describe the most important ones	**Q:** Which HH member is very much involved in particular activity?	**Q:** Is there a need of hired labour?	**Q:** How much money this activity bring you?
Home gardens			
Rice			
Annuals – crops harvested every year			
Plantations/perennial (rubber, acacia …)			
Livestock production (meat, eggs …)			
Products from forest			
Fire wood collection			
Fishing (nature: river, lake)			
Fishing (own: pond)			
Handicraft			
Salary/Wage			
Government support			
Friends or relatives			
Others (minor, not further specified)			

IV.   Farming calendar …for the whole farm and finish with home garden

Q: Describe me how main activities and events are distributed throughout the year

	1	2	3	4	5	6	7	8	9	10	11	12
Most important plant species	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Land preparation, seeding												
Harvest												
Not enough money	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Not enough food from farm	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Not enough rice to feed household members	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
In which months you feel lack of water for household	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Home gardening (crucial months)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Note: Above mentioned activities could be linked to calendar …

Or you can ask other way round …Enough money, Enough food …positive questions

V.   Further information on home garden and perception of home garden by household members

When your HMG was established (age of home garden)?_____

Did you inherited it?   ☐ Yes,   ☐ No

Ownership of land for garden? ☐ Yes,   ☐ No (if no please specific _____)

What types of watering systems do you have for home garden production?   ☐ River   ☐ wells ☐ drip water   ☐ pond and ☐ other

Do you use home gardens products in food preparation, cooking every day?

Perception of main roles of home gardens by household members (or at least farmer and his wife):

Food benefits	Very much	Rather yes	Not really	No
Provides food for household member				
Provides specific plants making food tasty and healthy				

Use plants from garden reduce food expenses				
Social benefits	**Very much**	**Rather yes**	**Not really**	**No**
I can relax in my garden				
I love my garden because it is beautiful place (flowers)				
I love to work in home garden, it is my hobby				
I love to keep the tradition of my parents and grandparents				
Economic benefits	**Very much**	**Rather yes**	**Not really**	**No**
I can get easily food for household than from the market				
I can sell products from the garden to increase my income				
I can exchange the production with my neighbours				
Environmental benefits	**Very much**	**Rather yes**	**Not really**	**No**
It provides nice environment (shade, windbreak …)				
I consider more species as important				

VI.   Home garden challenges/expectations

From whom you learnt gardening and provide you information about the home garden?

Can you remember any changes in crop species from the past, e.g. after having children?

Which species you would like to grow in the future? Or when you are retired?

What would you like to change in your home garden?

Do you want to extend the size? Or make it smaller?

Are your plants being attacked by animals? Insects?

Do you have enough water?

Do you need to hire extra labour? Why, When?

Do you still have other problems in your home garden?

VII. Home garden utilization (agro-biodiversity, use and economics)

Overview of the species grown in home garden (Let farmer name all species he/she knows and ask his/her to show you them in the garden …you can ask for those who were not mentioned)

Lao title / Hmong title	Number of individuals	Part used	What is the main use of the plant?	Is there any other use?	If used as a food, how?	Estimated annual production	How much do you sell?	Who cares about the species

Note(s): part used: let him tell/show you, than ask how this part is used, underline the main use and ask for annual production and try to convert it into SI units, than ask for commercializationRespect to food/nutrition: ask whether species is used fresh, cooked, fermented …you'll see soon after first pilot testing what are the typical answers. Good for further classification of use categories as well as for documenting food security. Take a photo of the garden, collect GPS (if it differs from house), try to measure the size let farmer show you the garden and species, count individuals …

Commercialized species: cost-benefit, processing, value-chain

Lao title / Hmong title	Who sells? Who is involved in selling?	Who decided to grow this crop?	Where you sell the product and for what price?								Costs/Expenses							
			Farm gate		Middleman		Local market		Distant market (city?)		Transport	Seeds	Chemical fertilizer	Plant protection	Other material	Own manure	Hired labour	Household labour input in days
			[%]	Price	[%]	Price	[%]	Price	[%]	Price								

Note(s):   Species with high market orientation …

Main expenses categories would be obtained from FGDs
Other material: wooden sticks, plastic material, fence …

Appendix 2. all plants species name and frequency in of homegardens

Family name	Scientific name	English name	Local names		Frequency in HG	
			Lao Loum	Hmong	Lao Loum	Hmong
Alliaceae**	*Allium tuberosum Rottler ex Spreng.*	Garlic chives	Phak paeng	Zaub nyiam	3	_
Alliaceae***	*Allium sativum L.*	Garlic	Phak tiam	Qzaub qij	22	2
Amaranthaceae**	*Amaranthus blitum subsp. oleraceus L.*	Amaranth	Phak hom	Zaub txhwb	15	1
Amaranthaceae**	*Amaranthus tricolor L.*	Chinese spinach	Phak homdeng	Zaub txhwb liab	3	_
Amaranthaceae*	*Amaranthus viridis L.*	Amaranth	Phak homyai	Zaub txhwb loj	_	1
Amaryllidaceae***	*Allium cepa L.*	Green onion	Phak boa	Dos	52	22
Amaryllidaceae*	*Bunching onion*	Welsh onion	Phak boaliey	Zaubnpuaj law	_	1
Anacardiaceae**	*Mangifera indica L.*	Mango	Mak moung	Txiv mov nkua tw	27	8
Apiaceae**	*Apium graveolens L.*	Celery	Phak celery	Zaub xoon nab lis	10	_
Apiaceae**	*Eryngium foetidum L.*	Culantro	Phak hompae	Zaub hoom pe	5	_
Apiaceae***	*Coriandrum sativum L.*	Coriander	Phak hompom	Zaub txvhwb qaib	49	21
Apiaceae*	*Centella asiatica Urb.*	Gotu kola	Phak nork	Lauj vag	1	_
Apiaceae*	*Anethumgraveolens Linn.*	Dill	Phak zee	Zaub txhwb nyug	4	3
Araceae*	*Colocasia esculenta (L.) Schott*	Cocoyam	Bone	Qo de	2	1

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Family	Scientific name	English name	Local name	Hmong name		
Araceae*	*Colocasia esculenta (L.) Schott*	Taro	Pieurk	Qos tsw ha	2	2
Araceae*	*Colocasia gigantea*	Elephant's ear plant	Lumtoon	Qos yaj ywm	5	4
Arecaceae**	*Livistona saribus*	Palm	Mak khore	Txiv kuj	19	3
Arecaceae*	*Cocos nucifera L.*	Coconut	Mak pow	Txiv tuab yib	1	1
Asteraceae	*Tagetes erecta L.*	African marigold	Dork dowhieang	Pai hau sam	6	1
Asteraceae	*Helianthus annuus L.*	Sunflower	Dork taven	Paj hnoob hli	1	_
Asteraceae**	*Lactuca sativa L.*	Lettuce	Phak salad	Zaub xav lav	13	1
Asteraceae**	*Lactuca sativa L.*	Red leaf lettuce	Phak saladdeng	Xav lav liab	1	1
Asteraceae**	*Chrysanthemum coronarium L.*	Chrysanthemum greens	Phak tung o	Zaub sauv ntsim	3	
Basellaceae*	*Basella rubra L.*	Ceylon spinach	Phak pung	hmab ntsha	1	1
Basellaceae	*Basella alb.*	Malabar spinach	Phak shung	Zaub zhaung	1	_
Bignoniaceae*	*Mayodendron igneum (Kurz) Kurz*	Tree jasmine	Dork leav	Paj liv	10	3
Bignoniaceae	*Oroxylum indicum (L.) Kurz*	Broken bones tree	Mak linhmai	Txiv nplai zaj	2	
Brassicaceae**	*Raphanus sativus L.*	Daikon	Carrott kao	Haw paus zaub	_	1
Brassicaceae***	*Brassica oleracea var. botrytis L.*	Cauliflower	Phak kaddorkhao	Zaub qhwv paj daib	2	
Brassicaceae***	*Brassica oleracea var. capitata L.*	Cabbage	Phak kalumpee	Zaub qhwv	33	5
Brassicaceae***	*Brassica juncea*	Chineses mustard	Phak kardhai	Zaub ntsuab teb	_	20

Brassicaceae***	*Brassica rapa subsp. pekinensis*	Chineses cabbage	Phak kardkaohor	Zaub qhwv daub	8	9
Brassicaceae***	*Brassica rapa var. chinensis)*	Chinese white cabbage	Phak kardkhao	Zaub dawb	12	1
Brassicaceae**	*Brassica integrifolia (West.) O.E.*	Kale	Phak kardkhiew	Zaub ntsub	2	1
Brassicaceae**	*Brassica oleracea L. Cv. Alboglabra Group*	Chinese broccoli	Phak kardna	Zaub liaj	1	_
Brassicaceae***	*Brassica Chinensis Linn.*	Choi sum	Phak kardsom	Zaub paj	19	4
Brassicaceae***	*Brassica juncea*	Chineses mustard	Phak kardteenmea	Zaub ntsuab	39	6
Bromeliaceae**	*Ananas comosus (L.) Merr.*	Pineapple	Mak nut	Quv luj	2	3
Cactaceae*	*Hylocereus undatus (Haw.)*	Dragon fruit	Mak mungkhone	Txiv zaj laug	6	_
Caesalpiniaceae	*Tamarindus indica L.*	Tamarind	Mak kharm	Txiv quav miv	5	_
Caricaceae**	*Carica papaya L.*	Papaya	Mak hong	Txiv tob ntoo	34	10
Commelinaceae	*Tradescantia spathacea Sw.*	Boat-lily	Wan zonh	Txiv vab xuon	4	_
Convolvulaceae***	*Ipomoea batatas (L.) Lam.*	Sweet potato	Manh dang	Qos liab	10	22
Convolvulaceae***	*Ipomoea reptans Poir.*	Morning glory	Phak bong	Zaub kab ntsig	22	5
Cruciferae**	*Brassica oleracea var. italica*	Broccoli	Phak kaddorkkiew	Zaub paj ntsuab	6	2
Cucurbitaceae**	*Luffa cylindrica (L.) M.Roem.*	Sponge gouard	Mak burb	Xwb kuab	7	10
Cucurbitaceae*	*Momordica cochinchinensis Spreng*	Spiny ground	Mak khoaw	Txiv taub aj txiaj	4	_
Cucurbitaceae**	*Momordica charantia L.*	Bitter gourd	Mak sai	Txiv duaj	3	1

Cucurbitaceae**	Cucumis sativus L.	Cucumber	Mak teng	Dib	4	
Cucurbitaceae***	Cucumis sativus L.	Cucumber	Mak tenghai	Dib teb	_	24
Cucurbitaceae***	Cucurbita moschata Duchesne	Pumpkin	Mak eu	Taub	26	26
Cucurbitaceae***	Sechium edule (Jacq) Swartz.	Chayote	Mak zou	Txiv maum thaib	30	13
Cucurbitaceae**	Momordica charantia	Small bitter gourd	Mak sai	Txiv xai	1	1
Cucurbitaceae*	Coccinia grandis Voigt.	Coccinia	Phak tamnin	Zaub tam nin	2	_
Ebenaceae**	Diospyros kaki L.f.	Persimmon	Mak ko	Txiv kub	1	_
Euphorbiaceae	Euphorbia splendens Bojer ex Hook.f.	Christ Thorn	Dork sethtea	Paj xev thij	3	_
Euphorbiaceae*	Manihot esculenta Crantz	Cassava	Manh ton	Qos ntoo	3	_
Euphorbiaceae*	Ricinus communis L.	Castor	Mak hongdeng	Tob ntoo liab	3	_
Euphorbiaceae*	Phyllanthus acidus Linn.	Star goose berry	Mak yom	Txiv mav nyoo	8	_
Fabaceae*	Sesbania grandiflora (L.) Pers.	Agasta	Dork khae	Paj iob	4	_
Fabaceae	Caesalpinia sappan	Sappanwood	Fang deng	Paj liab	1	_
Fabaceae*	Leucaena leucocephala (Lam.) de Wit	Ipil-ipil	Mak katinh	Txiv kab thij	1	_
Fabaceae***	Arachis hypogaea L.	Peanut	Mak toadinh	Taum av	2	10
Fabaceae**	Lablab purpureus (L) Sweet	Hyacinth bean	Mak toapeb	Taum mog	3	_
Fabaceae**	Psophocarpus tetragonolobus (L.) DC.	Winged bean	Mak toapoo	Taum roob	6	2

Fabaceae**	*Phaseolus vulgaris L.*	Common bean	Mak toasunh	Taum luv	7	5
Fabaceae***	*Vigna unguiculata L. Walp.*	Yard long bean	Mak toayow	Taum ntev	16	11
Fabaceae*	*Acacia pennata (L.) Willd.*	Climbing wattle	Phak kha	Zaub twj	1	_
Fagaceae**	*Castanea spp.*	Chestnut	Mak korfalung	Txiv mika	3	_
Gramineae**	*Zea mays Line.*	Corn	Mak salee warn	Pob kws qab zib	14	_
Lamiaceae*	*Perilla frutescens (L.) Britton*	Perilla	Phak baimengkae	Zaub me khem Zaub npaunlab	8	_
Lamiaceae*	*Ocimum basilicum L.*	Thai basil	Phak boalafa	pla	10	2
Lamiaceae**	*Ocimum × africanum Lour.*	Lamon basil	Phak eatou	Zaub tswv xya	43	14
Lamiaceae**	*Mentha × villosa Huds.*	Kitchen mint	Phak homlarb	Pum hup	21	3
Lamiaceae**	*Ocimum citrioddourum*	Holy basil	Phak kapout	Zaub txig taum paj	3	1
Lauraceae*	*Persea americana Mill.*	Avocado	Mak avocado	Txiv as vus ka dus	12	10
Leguminosae*	*Pachyrhizus erosus (L.) Urb.*	Yam bean	Manh pouw	Qos mab sao	2	_
Malvaceae**	*Abelmoschus esculentus L.Moench*	Okra	Mak mieak	Txiv mawv	1	1
Malvaceae*	*Hibiscus sabdariffa Linn.*	Roselle	Sompordee	Qaub tab tom	2	_
Malvaceae	*Gossypium herbaceum L.*	Cotton	Fay	Paj khi te	1	_
Menisper-maceae*	*Tinospora crispa Miers ex Hook.f.*	Heart leaved moonseed	Kiea kaohor	Hmab	2	_

Moraceae*	*Artocarpus heterophyllus Lam.*	Jackfruit	Mak mee	Txiv mam mij	9	1
Moraceae	*Morus alba Linn.*	Mulberry tree	Mone	Txiv zaub kab	2	1
Moringaceae**	*Moringa oleifera Lam.*	Drumstick tree	Phak ea houm	Zaub ihoob	2	_
Musaceae**	*Musa paradisiaca L.*	Banana	Mak khouy	Txiv tsawb tsob ntoo	41	20
Myrtaceae*	*Psidium guajava L.*	Common guava	Mak sida	Txiv cuab thoj	11	3
Orchidaceae	*Dendrobium spp.*	Orchid	Dork fueng	Paj ntoo tawb	2	_
Oxalidaceae*	*Averrhoa carambola L.*	Star fruit	Mak fieung	Txiv puam leej	4	_
Passifloraceae**	*Passiflora edulis Sims*	Passionfruit	Mak nord	Txiv nuav	5	2
Pedaliaceae*	*Sesamum indicum*	Sesame	Mak nga	Tsib muaj	1	_
Phyllanthaceae*	*Sauropus androgynus (L.) Merr.*	Star gooseberry	Phak warn	Zaub qab zib	4	_
Piperaceae*	*Piper betle Linn.*	Betel Piper	Bai poo	Nploooj roob	3	_
Piperaceae**	*Piper sarmentosum Roxb.*	Wildbetal Leafbush	Phak ealert	Zaub ilwv	6	1
Poaceae**	*Cymbopogon citratus (DC.) Stapf.*	Lemongrass	Sykhai	Tauj dub	34	21
Poaceae***	*Zea mays*	Maize	Mak salee khaeng	Pob kws tawv		31
Poaceae**	*Saccharum officinarum L.*	Sugarcane	Oiy	kab tsib	12	6
Poales*	*Dendrocalamus spp.*	Bamboo shoots	Nor mai	Ntsuag xyoo	21	7
Polygonaceae*	*Polygonum odoratum Lour.*	Vietnamese coriander	Phak peow	Zaub phia	17	3

Punicaceae*	*Punica granatum L.*	Pomegranate	Mak pila	Txiv phib	3	_
Rosaceae*	*Rosa x damascena*	Damask rose	Dork koularb	Paj ntshua nplaion	2	_
Rosaceae**	*Pyrus pyrifolia*	Asian pear	Mak chong	Txiv mav coos	21	8
Rosaceae*	*Prunus domestica ssp. Italica*	Green Plum	Mak katanh	Txiv kab than	1	_
Rosaceae**	*Prunus persica (L.) Stokes*	Peach	Mak khay	Txiv kaij	11	7
Rosaceae***	*Prunus domestica*	Common plum	Mak manh	Txiv nyuj me Txiv pos	33	10
Rosaceae*	*Fragaria vesca L.*	Strawberry	Mak storbery	nphuabnyeg	3	_
Rubiaceae**	*Coffea arabica L.*	Coffee	Café	Kafe	10	1
Rublaceae*	*Oldenlandia corymbosa L.*	Diamnel flower	Phak laefae	Zaub lin ngoo	1	_
Rutaceae*	*Citrus hystrix DC.*	Kaffir lime	Mak kheehood	Txiv tsawb	1	_
Rutaceae*	*Citrus sinensis Osbeck*	Orange	Mak kieng	Txiv kab ntxwv	1	_
Rutaceae**	*Citrus aurantifolia (Christm.) Swingle*	Lime	Mak now	Txiv mav nau	18	2
Rutaceae**	*Citrus maxima merr.*	Pomelo	Mak pouk	Txiv lws zoov	23	5
Sapindaceae*	*Dimocarpus longan Lour.*	Longan	Mak lamyai	Txiv lwm tsib	20	7
Sapindaceae**	*Litchi chinensis Sonn.*	Lychee	Mak lychee	Txiv lib ci	2	_
Saururaceae**	*Houttuynia cordata Thunb.*	Plu Kaow	Phak kowthong	Zaub kab rua	7	1
Scrophulariaceae*	*Limnophila aromatica (Lam.) Merr.*	Rice paddy herb	Phak kayeng	Zaub qhab nye	4	1
Solanaceae*	*Solanum stramoniifolium Jacq.*	Solanum	Mak euk	Txiv euk	4	1

Solanaceae**	*Solanum torvum Sw.*	Pea eggplant	Mak khaeng	Txiv posquavdai ib	19	8
Solanaceae**	*Solanum trilobatum L.*	Brinjal	Mak khaengkhom	Txiv pos quav dai ib	5	5
Solanaceae***	*Solanum virginianum L.*	Thai Eggplant	Mak khiea	Txiv lws	39	19
Solanaceae*	*Solanum melongena L.*	Eggplant	Mak khieahumma	Txiv lws ntev	3	1
Solanaceae**	*Solanum aculeatissimum Jacq.*	Dutch eggplant	Mak khieakhom	Txiv lws iab	−	2
Solanaceae**	*Lycopersicon esculentum Mill.*	Tomato	Mak lenh noy	Txiv lws suav	12	5
Solanaceae***	*Capsicum frutescens L.*	Chilli	Mak phet	Kua txob	50	27
Solanaceae**	*Capsicum annuum L.*	Sweet pepper	Mak phetyai	Kua txob loj	2	−
Solanaceae*	*Capsicum annuum L.*	Bird pepper	Mak phet ki noo	Kua txob quav na	2	−
Solanaceae*	*Solanum nigrum L.*	Black nightshade	Phak toumtem	Zaub toob tej	2	3
Sopotaceae*	*Pouteria lucuma*	Souteria lucuma	Mak monekhai	Txiv mov kuam	6	1
Thymelaeeaceae*	*Aquilaria malaccensis*	Agarwood	Mai ketsana	Ntoo kov xaij naj	1	−
Unknown**	*Unknown*	Unknown	Mak lord	Txiv nyuj me	11	1
Unknown*	*Unknown*	Unknown	Mak mard	Txiv phab las	13	4
Unknown*	*Unknown*	Unknown	Yalaosoung	Tshuaj hmoob	4	2
Zingiberaceae**	*Alpinia galanga (L.) Willd.*	Ginger	Kha	Qhiav daum	24	18
Zingiberaceae**	*Zingiber officinale Roscoe*	Ginger	Khing	Qhiav daum	23	24
Zingiberaceae*	*Curcuma long L.*	Turmeric	Khi minh	Qhiav daj	1	−

Notes: **(*)** Food plant species, **(**)** Cash crops species , and **(***)** Top 20 most dominant cash crops