DIVERSITY OF AGROECOSYSTEMS AND ECOSYSTEM SERVICES GAIN FOR AGROBIODIVERSITY CONSERVATION IN AGRICULTURAL LANDSCAPE IN NORTHERN TOGO

B. P. DAO[1*], K. E. ABOTSI[2], A. KARGBO[1,3], K. KOKOU[2], D. KONE[4]

[1] Université Félix Houphouët-Boigny, UFR Biosciences.

[2] Université de Lomé, Faculté des Sciences, Laboratoire de Recherche Forestière.

[3] University of The Gambia, Physical and natural sciences, School of Arts and Sciences.

[4] WASCAL Capacity Building, CSIR Office Complex Agostino Neto Road, Airport Residential Area, PMB CT 504, Cantonments-Accra, Ghana.

* Corresponding Author: E-mail dao.prenibe@gmail.com ; Tel (228) 92632518.

ABSTRACT

To tackle food insecurity and alleviate rural poverty, the Togolese government initiated a novel form of land-based investment in rural agriculture named «Kara agropole», which promotes the cultivation of maize, rice, sesame, soybean and cashew mainly for commercial and industrial purposes. This study analyses the agricultural diversity as a baseline to foster the sustainable management of agrobiodiversity while implementing the project. The study was carried out in 11 counties from 4 districts (Bassar, Dankpen, Doufelgou and Kéran) in Kara region. A survey of 115 households was conducted to collect data about agricultural practices. Botanical inventory had been carried out in 60 square plots of 25mx25m to evaluate the current agrobiodiversity and to identify ecosystem services. Data analysis matching with empirical field observations showed that there are 6 types of agroecosystems (pure cropping – crop rotation, intercropping, agroforestry, forestry, fallow lands and pasture lands) in the area with pure cropping as the main agricultural practice. Provisioning services turn out to be of the highest interest to the survey respondents for annual and perennial species. Therefore, a landscape approach that strikes a balance between agricultural land use and conservation might help to conserve more agrobiodiversity and promote other categories of ecosystem services.

Keywords: Agroecosystems, ecosystem services, species, sustainable agriculture, Togo.

RESUME

DIVERSITE DES AGROECOSYSTEMES ET BENEFICE DES SERVICES ECOSYSTEMIQUES POUR LA CONSERVATION DE L'AGROBIODIVERSITE EN PAYSAGE AGRICOLE AU NORD TOGO

Pour lutter contre l'insécurité alimentaire et la pauvreté rurale, le gouvernement togolais a lancé une nouvelle forme d'investissement foncier en agriculture rurale, appelée « agropole de Kara », favorisant la culture du maïs, du riz, du sésame, du soja et de l'anacarde aux fins commerciales et industrielles. La présente étude analyse la diversité agricole comme référence pour favoriser la gestion durable de l'agrobiodiversité pendant la mise en œuvre du projet. L'étude est réalisée dans 11 cantons de 4 préfectures (Bassar, Dankpen, Doufelgou et Kéran) de la région de Kara. Une enquête menée auprès de 115 ménages a recueilli des données sur les pratiques agricoles. L'inventaire botanique est réalisé dans 60 parcelles carrées de 25mx25m pour évaluer l'agrobiodiversité présente et identifier les services écosystémiques. L'analyse de données couplées à l'observation empirique montrent l'existence de 6 types d'agroécosystèmes (culture pure, cultures associées, agroforesterie, sylviculture, jachère et pâturage) dans la zone, avec la culture pure comme principale pratique agricole. Les services d'approvisionnement sont d'un grand intérêt aux répondants enquêtés pour les espèces annuelles et pérennes. Par conséquent, l'approche paysage qui établit un équilibre entre utilisation et conservation des terres agricoles pourrait contribuer à conserver davantage l'agrobiodiversité et promouvoir d'autres catégories de services écosystémiques.

***Mots-clés** : Agroécosystèmes, services écosystémiques, espèces, agriculture durable, Togo.*

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INTRODUCTION

In most of the developing countries, food insecurity affects the poor and rural people prompting them to overexploit natural resources. FAO (2015) has reported that in developing countries, about 50 % of smallholder farmers are facing food insecurity, poverty, food and nutritional insecurity. Therefore, the Togolese government has opted through agricultural programmes to create agropoles to tackle the mentioned issues (PND, 2018). The first agropole being implemented is in the Kara region in northern Togo. It promotes the cultivation of maize, rice, soybean, sesame and cashew (MAEH, 2018).

Agriculture has been classified amongst the major drivers of biodiversity loss in the world (Erisman *et al.*, 2016). Many agricultural activities depends on the usage of chemicals, which helps to increase food production and at the same time contribute to biodiversity depletion. Thrupp (2000) argued that the conflicts between agriculture and biodiversity are inevitable. Biodiversity is defined by DeLong (1996) as an attribute of an area and specifically refers to the variety within and among living organisms, assemblages of living organisms, biotic communities, and biotic processes, whether naturally occurring or modified by humans. It can be measured in terms of genetic diversity and the identity and number of different types of species, assemblages of species, biotic communities, and biotic processes, and the amount (e.g., abundance, biomass, cover, rate) and structure of each. An important subset of biodiversity under human intervention is agrobiodiversity that can be used to mitigate biodiversity loss (Armah *et al.*, 2013). Agrobiodiversity is defined as the variety and variability of animals, plants, and microorganisms that are used directly or indirectly for food and agriculture, including crops, livestock, forestry, and fisheries (FAO, 1999).

Agrobiodiversity is however threatened in agricultural landscapes and its loss exacerbates biodiversity loss (Thrupp, 2000; Jackson *et al.*, 2005; Pascual and Perrings, 2007; Armah *et al.*, 2013). Hence, its conservation engages another struggle. It has been reported that globally 7000 species are cultivated plants, 150 species are grown for commercial purposes, 30 species are feeding the world, 12 species constitute 75% of food and only 4 species comprise 50% of food people eat worldwide (Brush *et al.*, 1988; Pullaiah *et al.*, 2015). Agricultural diversity conservation needs varietal and specific diversity cultivation, meaning the *in situ* conservation. The diversity of agricultural plants is important because every living species has a valuable role in the food chains and crop diversification reduces the negative impacts of agricultural production on the environment (Cutforth *et al.*, 2001). Conservation of agrobiodiversity is essential to achieve sustainable agricultural systems and improve ecosystem functions (Thrupp, 2000; FAO, 2006; Akpavi *et al.*, 2012; Monfared and Armaki, 2015; Mburu *et al.*, 2016). Moreover, conserving agrobiodiversity contributes to adapt to environmental disasters and requires sustainable management of agroecosystems and the diversity they contain (Woegan *et al.*, 2013; Bola *et al.*, 2014; Mekonnen and Kassa, 2019).

Regarding to the area of implementation of agropole project in Togo, several questions need to be raised. What diversity of agroecosystems do farmers practice in the area? Do these agroecosystems promote the presence of tree species in farmland? Could farmer's knowledge about ecosystem services foster the conservation of agrobiodiversity during the implantation of the agropole project? This paper aims to present the diversity of agroecosystems in the Kara agropole in Togo. It assesses specifically (i) the diversity of agroecosystems in the study area, (ii) the diversity of cultivated species and wild plant species within agroecosystems and (iii) ecosystem services that farmers target from these species. The study contributes to biodiversity conservation by suggesting strategies for sustainability in the context of agricultural development. For with sustainable farming practices and changes in agricultural policies and institutions, the conflicts between agriculture and biodiversity can be overcome (Thrupp, 2000).

STUDY AREA

The study area is Kara agropole. It is located in the Kara region in the northern part of Togo (Figure 1). The area is under a tropical Sudanian climate with one dry season from November to April and one rainy season from May to October; the rainfalls vary between 800 and 1500 mm (Ern, 1979). The site of the agropole covers approximately 165,000 ha. Only four of the seven districts of the Kara region are part of the agropole: Doufelgou, Kéran, Dankpen and Bassar.

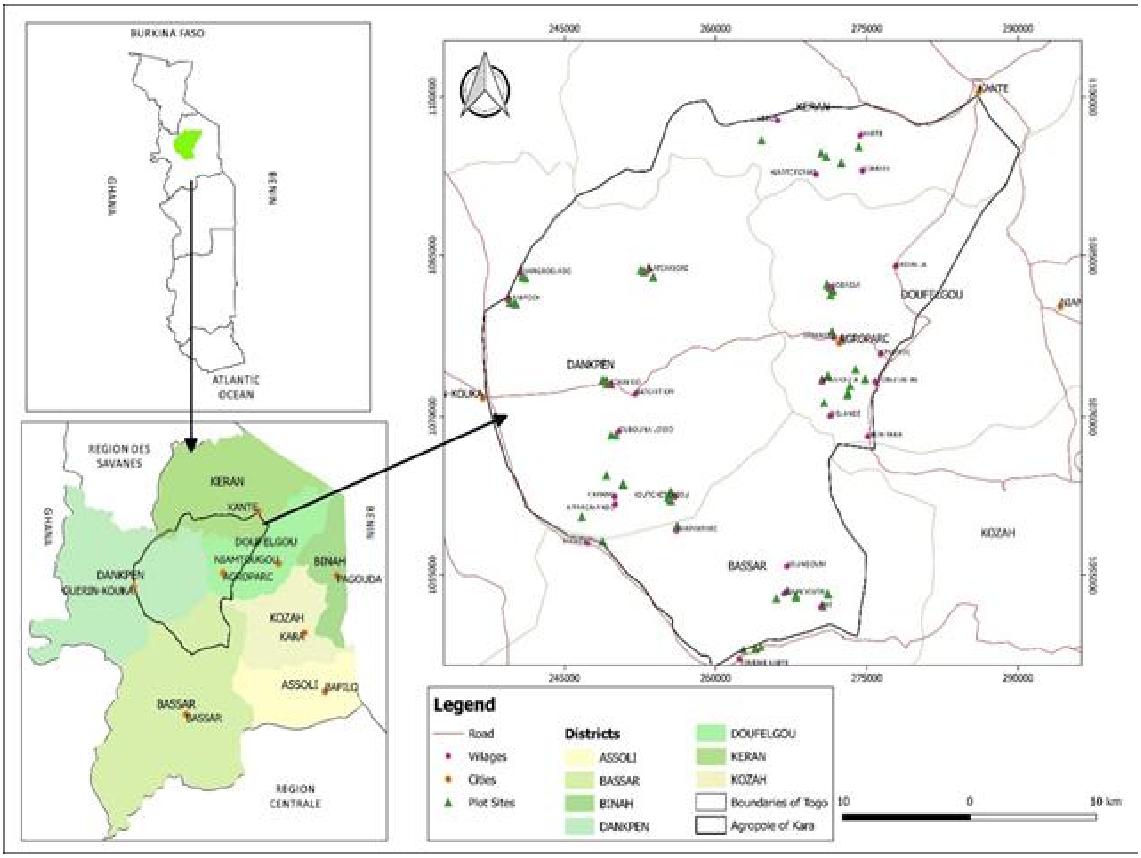

Figure 1: Map of the study area showing the site of plots.

Source: conceived by the authors from field data.

METHODS

DATA COLLECTION

Two approaches (surveys and floristic inventories) have been used to collect data for the study between October and November 2019. During data collecting period, most of the crops are mature and some are growing or blooming. However, few species have been already harvested. Questionnaires were used to interview farmers in their households in order to characterize them socially and to collect data about their livelihood and agricultural practices. Ideally, the heads of households were interviewed, but in instance they were absent, another adult member of the household substituted them. Four districts namely: (Doufelgou, Kéran, Dankpen and Bassar) are involved in this study. Within these districts, data were collected in eleven counties based on their proximity to the sites of the intervention of the Kara agropole.

The quota-sampling method was used (Acharya *et al.*, 2013) to determine the number of farmers to interview in each county. Therefore, proportions were determined based on the sample size, the land surface of each county included in the Agropole map and the number of households in each county given by the national census of 2010. In total, 115 households have responded to the questionnaires within the 11 counties of the study area. Within each county, households were chosen following the simple random sampling (Hansen and Hauser, 1945; Acharya *et al.*, 2013) and geographic dispersal.

In farmland, plots and participative observation were used to collect data. Therefore, square plots of 625 m² (25m over 25 m) were set up in visited farms (Woegan *et al.*, 2013; Adou Yao *et al.*, 2016). In total, 60 plots were inventoried in farmlands in order to characterize agro-ecosystems of the study area. It permitted to identify crops present in plots and the accompanist trees. Their uses, ecosystem services and other related information have been collected (Fongnzossie *et al.*, 2018).

DATA ANALYSIS

After data collection, the first step was the building of database using Excel software. It is also used to calculate frequencies following the formula F=n/N*100 (Badjaré *et al.*, 2018); where *n* is the number of times a parameter of a variable is counted, and *N* the total number counted in the variable. Then the Ascending Hierarchical Classification (AHC) was executed using R to display the diversity of agroecosystems and the way farmers combine them. QGIS 2.18.9 software was used to map out the study area with the sampled sites of plots. Classification of inventoried species into their corresponding families was performed through World flora online. The results are presented in graphs and bar charts.

RESULTS

TYPES OF AGROECOSYSTEMS WITHIN THE KARA AGROPOLE AREA

Farmers in the study area perform six different types of agroecosystems namely: pure cropping, intercropping, agroforestry, forestry, fallow land and pastureland.

Pure cropping

Pure cropping is a type of agroecosystem that almost all farmers use for annual crop rotation. Only one species of crop is cultivated per plot in that agroecosystem. Such annual crops are in fact one-side cash crops (*Gossypium hirsutum* farmed for its fibers, *Sesamum indicum* and *Glycine max* farmed for their seeds). On another hand, this system is used for food crops that are cereals (*Zea mays*, *Sorghum bicolor*, *Oryza* sp, *Digitaria* sp, etc.), pulses (*Vigna unguiculata*, *Vigna subterranean*, *Arachis hypogaea*) and tuber (*Dioscorea* spp).

Photo 1: Crops in pure cropping agroecosystems: a) Cotton; b) Maize.

Source: field work-2019.

Intercropping

Intercropping or mix cropping agroecosystem is a system in which two or several annual crops are grown together in a plot during the same cropping year. In this system, mixed crops can have the same growing cycle or not. Some crops are mixed in a way that, when the first crop is ready to be harvested, the second one continues its growth (e.g. Sorghum and groundnut). However, some mixed crops can develop together and can be harvested at the same time (e.g. yam and millet; maize and soybeans). Through farmers' reports and the observation in the field, only cotton is not accepted in the mix cropping system.

Photo 2: Mix cropping agroecosystems: a- Sorghum – Groundnut; b- Maize-Sesame; c- Yam -Cassava – Sorghum.

Source: field work-2019.

Agroforestry

This agroecosystem is represented by 93% of agrosylviculture that is mainly home gardens. Palm tree (*Elaeis guineensis*) or other fruit plants and annual crops are farmed in home garden systems. In other agrosylviculture, annual crops are grown under young plants of *Anacardium occidentale* and *Tectona grandis*. Sylvopastoralim (5%) and agrosylvopastoralism (2%) are less represented in the area.

Photo 3: Agroforestry systems: a- Rice under Eucalyptus; b- Maize under Cashew; c- Home garden.

Source: field work-2019.

Forestry

Forestry is one of the least represented agroecosystems (27%) in this study area. This system is made mainly of forests of *T. grandis*, *E. camaldulensis*.

Photo 4: Forestry agroecosystem: a- a forest of Teak; b- a forest of Eucalyptus.

Source: field work-2019.

Fallow land

Fallows can be defined as an uncultivated land kept for fostering the restoration of soil fertility. Some farmers use such fallows for grazing of small ruminants

Photo 5: Sheep grazing in fallow land.

Source: field work-2019.

Pastureland

Surveyed farmers mentioned that they raise livestock such as cattle, sheep and goat. To feed these ruminants farmers need pastureland. However, some farmers keep their livestock at home, collect grass and leave for them. Half (50%) of respondents reported using pastureland for their livestock grazing. Pastureland is a non-cultivated savannah land where ruminants can graze.

Photo 6: Cattle grazing in pastureland.

Source: field work-2019.

DIVERSITY OF AGROECOSYSTEMS

Homogenous clusters of farmers are built according to the way they combine different agroecosystems to crop various species and the number of plots for each system (Figure 2). The cluster C1 concerns farmers (24 households) characterized by fallow land and combining of all the six types of agroecosystems. In the cluster C2, farmers (30 households) use the least number of plots for pure cropping and combine four types of agroecosystems. The cluster C3 is typical for farmers (13 households) with the highest number of plots in agroforestry and the lowest number of plots in intercropping. The cluster C4 concerns farmers (25 households) who use more pastureland combined with the intercropping and the high number of plots in pure cropping. The cluster C5 is constituted of farmers (23 households) having the highest number of plots in pure cropping, intercropping, and forestry.

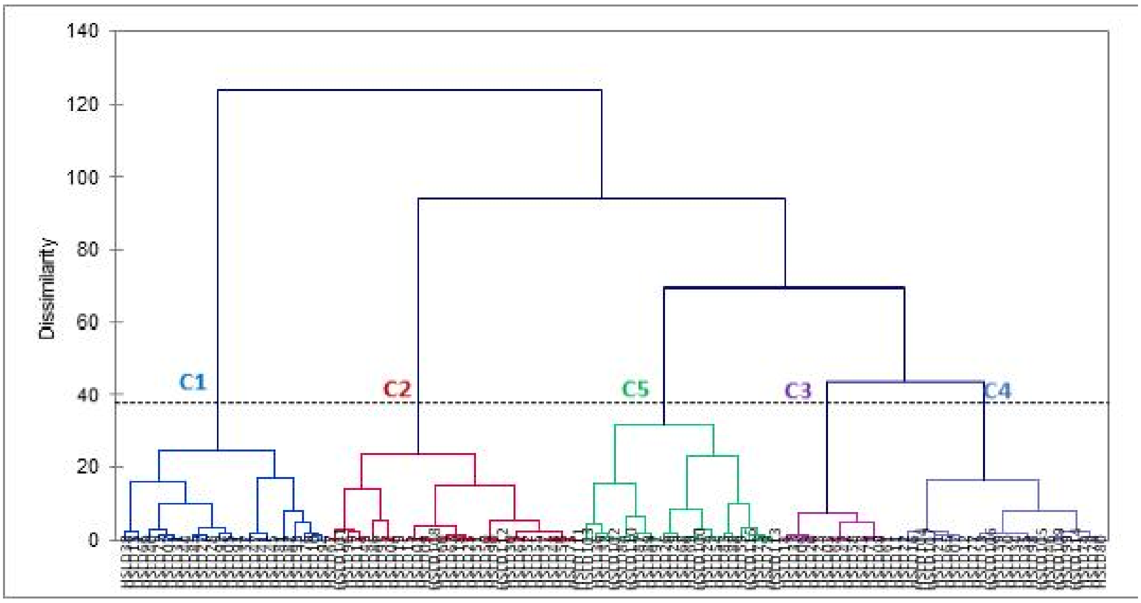

Figure 2. A cluster of households through ascending hierarchical classification showing five clusters of farmers base on how they combine various agroecosystems and the number of plots in each agroecosystem.

Source: field data analysis.

Respondent farmers of the study set up more than one agroecosystem to crop various species they want. The agroecosystem highly used is a pure cropping system reported by around 98% of respondents (Figure 3). Intercropping occupies the second rank with 61% of respondents using that system. Almost half of the respondents use pastureland while agroforestry, forestry and fallow land are respectively mentioned by 48%, 27% and 21%.

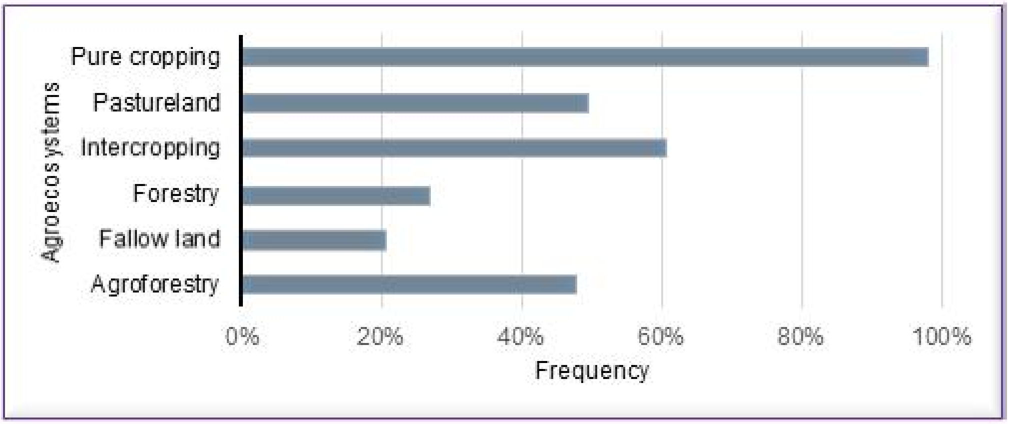

Figure 3: Repartition of surveyed farmers according to their agroecosystems practices.

Source: field data analysis.

BIODIVERSITY IN AGROECOSYSTEMS OF THE KARA AGROPOLE

Annual crop species and tree species have been identified in the inventoried farms. For annual crops, 19 species from 9 families have been inventoried. The Fabaceae, the Malvaceae and the Poaceae with 4 species each one are families with high number of species.

For perennial plant species, 37 species from 17 families have been inventoried. The family of Fabaceae (8 species) has the highest number of species, followed by the family of Malvaceae (5 species).

V. paradoxa and *P. biglobosa* are plant species widespread in the landscape and observed respectively within 58% and 32% of plots.

ECOSYSTEM SERVICES PROVIDED BY AGROECOSYSTEMS COMPONENTS

Agrobiodiversity provides ecosystem goods and services that are the aim of their cultivation or conservation. Trees found in farmland provide farmers with three types of ecosystem services for what they are kept or introduced. Therefore, 96.8% of plant species provide provisioning services; 21.6% provide supporting services and 45.6% provide regulating services. One plant species can provide more than one service according to respondents' reports.

Ecosystem services provided by annual crops

Crop species inventoried are mainly introduced for food supplies. Therefore, ecosystem services reported for these species are fertility, food, medicinal uses, fiber, fodder and other minority services. Many crops such as *Dioscorea* sp, *I. batatas*, *Oryza* sp, *Z. mays* provide only food according to the respondents. Pulses species are reported to contribute to soil fertility apart from food provisioning. *G. hirsutum* provide to its farmers only fiber for commercial purpose. Apart from food, *S. bicolor* provides fodder according to 10% of its farmers.

Ecosystem services provided by tree species

Farmers introduce or keep trees species in their farms mainly for food and firewood supplies. Medicinal uses and shadow providing are also reported. Timber provisioning is reported for species such as *Afzelia Africana*, *Azadirachta indica*, *Bombax costatum*, *Daniellia oliveri*, *Diospyros mespiliformis*, *Eucalyptus camaldulensis*, *Tectona grandis* and *Vitex doniana*. According to the respondents, some species enhance soil fertility through nutrients cycling from their lives; it is the case of *A. africana* (33.3%), *B. costatum* (25%), *D. oliveri* (33.3%), *Parkia biglobosa* (63.2%), *Prosopis africana* (100%) and *Vitellaria paradoxa* (31.4%). Few species' leaves are used as fodder; some farmers reported that they use *A. Africana*, *Ficus gnaphalocarpa*, *Pterocarpus erinaceus*, *Securidaca longepidoncula* and *V. paradoxa* for that purpose.

DISCUSSION

Diversity of agroecosystems and their components

Farmers in the Kara agropole area use various agroecosystems to produce goods they need. The analyses showed that pure cropping system is highly spread. This result may be partly due to climatic characteristics of the area, which is characterized by a Sudanian tropical climate with only one raining season from May to October (MERF, 2014). Therefore, to maximize yields, farmers grow their main food crops such as maize in the single or pure cropping system. Moreover, the main cash crop in the area is cotton for which association is logically forbidden because it requires highly hazardous chemical inputs.

Agricultural products are the main source of livelihood of farmers, for their domestic consumption and financial need. Though they opted for crop diversification to satisfy the market demand, they could not abandon completely their traditional crop species and techniques (Brush, 1995; Bouba *et al.*, 2012). Almost all the farmers combine various agroecosystems which led them to obtain a high agrobiodiversity richness (Nasser Baco *et al.*, 2007) known for its importance in securing food supplies (Mburu *et al.*, 2016) and financial incomes. As reported by Mburu *et al.* (2016) and Bola *et al.* (2014), apart from pure cropping, farmers usually adopt other cropping systems simultaneously. Otherwise, mix cropping contributes to tackle many issues like the lack of land, time, workers and to fight weeds or pests (Gurr *et al.*, 2003). For instance, some farmers combine soybean and sorghum to overcome *Striga hermonthica*'s harmful effect. The lack of land (MAEP, 2014) especially for foreign farmers contribute also to mix many systems and to avoid fallows.

Livestock possessing lead 50% of farmers to use pastureland because their animals can graze there better than in fallows or when they are camped. Even though agroforestry is mentioned by 48% of farmers, this agroecosystem is underrepresented in the landscape because farm visitation revealed that most of the agroforestry systems mentioned by farmers are home gardens of relatively small sizes. The low representation of agroforestry and forestry agroecosystems may be linked to the insufficiency of sensitization explaining the benefits of these systems. Besides the lack of market demand for products of some systems can affect their presence because market availability influences highly farmers in their choices (Pascual and Perrings, 2007; Bouba *et al.*, 2012). Thrupp (2000) noticed that there has been a decline in traditional agroforestry, polyculture home gardens, indigenous shifting cultivation systems and other mixed farming practices for the benefit of monoculture.

In the landscape these agroecosystems are established into small patches, there is not any zone affected to a particular system (mostly for annual crops) because each farmer decides which crops to grow in his plots each year base on his personal needs, the market needs and the characteristics of its land. Most of the tree species found in farms such as *V. paradoxa* (in 58% of plots) and *P. biglobosa* (32% of plots) remains from the initial natural ecosystems. This rate is close to the results of Neya *et al.* (2018) in Burkina Faso and those of Koumoi and Lare (2014) in the Centrale region of Togo.

Ecosystem goods and services: the fruits of agrobiodiversity provided to farmers

Farmers by targeting some products introduce and maintain specific species in agro-ecosystems. These products are provisioning services that agroecosystems supply in their complexity. Therefore, farmers seek some ecosystem services by leaving perennial species or by introducing them to their fields (Baul *et al.*, 2013). In general, two groups of factors determine crop diversity in an agroecosystem: the environmental factor according to Dufour *et al.* (2006) and the socio-economic factors (Albuquerque *et al.*, 2005; MEA, 2005). Nine species identified in farmlands are part of species highlighted by MERF (2011) and Badjaré *et al.* (2018) as useful species frequently met in the natural habitat of the ecological zone I and II of Togo. Results show that 96.8% of plant species supply provisioning services comparative with 45.6%, which provides regulating or environ-mental services and finally only 21.6% of identified species are reported as playing a supporting role. It is proof that farmers perceive more provisioning services that are tangible than other services or have more interest in this category of ecosystem service. This situation aligns with the findings of several authors who signified that provisioning services functions of agrobiodiversity are better understood than supporting and regulating services (MEA, 2005; Jackson *et al.*, 2007; Pascual and Perrings, 2007). For annual crops, food is the type of provisioning service that is mainly reported by farmers. Apart from food provisioning, legumes are known for their contribution to soil fertility as an important supporting service for agriculture. In fact, through their leaves and harvesting residue, legumes inter into the nutrient cycling process. Furthermore, legumes are well known in atmospheric nitrogen fixation through the association of their roots with bacteria (Rhizobium) in nodules. This important function played by legumes justify their association with other crops in mix cropping systems in the study area.

Likewise, most of the ecosystem services attributed to perennial species are from the category of provisioning services and they provide a large range of products. Firewood is the most highlighted type of ecosystem service attributed to plants species because firewood is the main source of energy to prepare food in the rural area (Adou Yao *et al.*, 2016). Furthermore, many women sell it or use it to make charcoal that is also a non-neglected income generation source in rural communities. Unfortunately, many plants used for timber or firewood provide also food, medicine, shadow, fodder, etc. at the same time. For instance, results show that *V. paradoxa* and *P. biglobosa*, which are species widely met in farmland provide fertility, firewood, food, medicinal and shadow goods and services. Koumoi and Lare (2014) reported the same result from Tem communities in the central part of Togo. *V. doniana* provides at the same time, firewood, food, shadow and timber goods and services. This situation can lead to the overexploitation of these species within farms but also in the natural habitat because the same plant is a source of many resources; this fact is supported by the study of Badjaré *et al.* (2018), where it was obvious that species with high use value have a high index of vulnerability. As livestock is very important in the area, some species such as *P. erinaceus*, *S. longepidonculata*, *F. gnapha-locarpa* and *A. africana* are providing fodder that is very important to many farmers who tie or lock their sheep and goat for feedlot during cropping period. The issue is that even though supporting and regulating services are fundamental for provisioning services, farmers do not capture them as they do with the last one. It could be the result of a lack of awareness raising about various goods and services played by biodiversity globally in a landscape.

CONCLUSION

This study presents the diversity of agro-ecosystems and their compositions in the Kara agropole area in order to propose strategies that harness sustainable agriculture. Farmers generally use 6 agroecosystems with a dominance of pure cropping and intercropping. They use pure cropping system for their main commercial crop where they target high yield. However, they resort to other systems to fulfill their need. Regarding ecosystem services targeted by farmers, they have a high interest in provisioning services for both annual and perennial species. A landscape approach with good practices is to be recommended to promote sustainable agriculture. These practices contribute to the mainstreaming of biodiversity into the agricultural sector in Togo during the second phase of implementation of the agropole project. This landscape approach is crucial not only for agrobiodiversity conservation but also to reduce the negative impact of agriculture on biodiversity. To increase supporting and regulating services within agroecosystems, it is important to promote the agroforestry system with fruit trees or native species such as *V. paradoxa*, *P. biglobosa* and other multipurpose trees that are useful in soil fertility and fodder.

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