Vulnerability of woody plants in the agrosystems of the Mandara Mountains, Cameroon

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1 ABSTRACT

The aim of this work is to contribute to the long-term survival of woody plants in the agrosystems of the Mandara Mountains for their sustainable management. In order to understand the vulnerability of woody plants in the agricultural production systems of the Mandara Mountains, ethnobotanical surveys followed by floristic inventories were carried out in four zones, each subdivided into four collection units (Tokombere, Guider, Mogode and Mokolo). A total of 335 people were surveyed and 96 plots were set up to determine which individuals had died or been cut down in the agrosystems. The results show that poor farming practices alone degrade almost 51% of plant cover in the entire study area. This is followed by logging, sometimes accompanied by bush fires, and the felling of trees for charcoal and firewood. Gathering the bark, leaves and flowers of edible plant families is a practice responsible for habitat imbalance. The mortality rate of trees varied greatly depending on the area and plant formation. The dead individuals were highest in the fields of Mogode (17.01%), followed by the fields of Tokombere (16.04%). Nearly 29.81% of the species used have a vulnerability index greater than or equal to 2 and relative frequencies of between 10 and 50%. They are therefore said to be vulnerable. Highly vulnerable species include *Tamarindus indica* (IVu = 3.082; F=16.05%), *Diospyros mespiliformis* (IVu 3.01; F=10.09%), *Khaya senegalensis* (IVu = 3.00; F= 12.11%), *Haematostaphis barteri* (IVu = 3.00; F=10.16%) and *Balanites aegyptiaca*. This study is used in the decision-making process for sustainable strategies for preserving woody species in agrosystems.

2 INTRODUCTION

In the African Sahel, agricultural land is made up of different zones: inhabited areas, cultivated areas, rangelands, protected areas. (Youl, 2015). Cultivated areas are those in perpetual activity, with a huge number of species frequenting them. The management of these areas, known as agrosystems, is based on the diversification of productivity, thanks to the ecological, economic and social interactions between the various components of these systems. (Josiane and Jean-Michel, 2019). Agricultural systems of all kinds are sources of income for farmers. In addition to the food and economic value that these systems provide, they also contribute to satisfying the need for medicinal products, service wood and energy, and to combating climate change and protecting soil fertility through trees (Chevallier *et al.*, 2015). However, the Mandara Mountains is one of the Sudano-Sahelian zones most vulnerable to natural and anthropogenic factors. This vulnerability is linked to the rural population's dependence on rain-fed agriculture. This agriculture is weakened by multiple constraints, in particular the inter-annual and inter-seasonal variability of rainfall (Funcitree, 2013). With a growing population and increasing food needs, pressure on resources is increasing (Teweché, 2017). Given that the majority of today's population are farmers (FAO, 2009). There is an urgent need in this study area to raise awareness of in situ conservation and the sustainable use of plant species. The current rate of timber harvesting is becoming increasingly high, and the species that are cut are disappearing. The distance penetrating the savannah is increasing every year. The use of wild fruit trees as firewood is an indicator of the increasing scarcity of wood fuels in the savannahs (Tchobsala *et al*., 2016). Certain wood harvesting techniques make it difficult for the species to regenerate. This is the case for species that are completely stumped, such as *Piliostigma thonningii*, *Anogeissus leiocarpus*, *Prosopis africana*, *Boswellia dalzielii* and *Sclerocarya birrea* (Todou *et al*., 2019). Recurrent harvesting weakens the woody individuals and makes them vulnerable to bad weather (wind, fire, drought) and parasite attacks. The resulting poor health results in partial or total desiccation of the individuals (Sagna *et al*., 2019). Other species are threatened by the pressure of excessive seed collection. For example, *Xylopia*, *Vitellaria paradoxa* and *Parkia biglobosa* no longer have enough seeds to guarantee satisfactory natural regeneration (FAO, 2008). These negative effects, which cause a drop in density and a loss of floristic diversity in the woody populations, are quickly noticeable in the woody species that make up the permanent component of the site's agrosystems. The multifaceted crisis has led to increased demand for charcoal and firewood, increasing the rate at which large quantities of wood are removed from natural formations, leaving them no time to recover (Tchotsoua *et al*., 2006). Cultivated areas have not been spared this phenomenon of clear-cutting. The rate of afforestation of woodland cover has slowed from 1972 to the present day (Doua, 1999; Josiane and Jean-Michel, 2019). In areas occupied by spontaneous settlements, the plant cover has practically disappeared, even species of socio-economic interest have not been spared. This is the case for *Borassus aethiopum*, *Vitellaria paradoxa*, *Ximenia americana* and *Parkia biglobosa*, whose distribution area is becoming increasingly restricted to a few refuges far from the villages. The general objective of this work is to contribute to the perpetuation of ligneous species in Sahelian agrosystems, with a view to their sustainable management. Specifically, the aim is to determine the factors responsible for the reduction in biodiversity in agrosystems; Assessing the vulnerability index of agrosystem species.

3 METHODOLOGY

3.1 Study area: The Mandara Mountains constitute a chain of mountains and plateaus, located between 9°50' N and 11°35'N and between 13°E and 14°15'E, and backed by Nigeria to the west. They slope towards the Benue basin in the south and the Chad plain in the north. In the east, they become somehow blurred in the Diamare plain (PDRM, 1996). (Figure 1). The Mandara Mountains form a group of mountainous massifs with an average altitude of 900 m (with a peak of 1200 m), between the Benue basin and the Chad plain. Average annual rainfall is between 950 and 1000 mm, with an average of 60 days of rain per year, and the temperature is highest in March (23.90°C) and April (23.70°C) (Samantha and Bolivard, 2017). The vegetation is characterised by shrubby and thorny steppes composed of trees, shrubs, and Poaceae (Letouzey, 1985). Characteristic woody plants include *Anogeissus leiocarpus*, *Boswellia dalzielii*, *Balanites aegyptiaca*, *Acacia albida*, *Acacia nilotica*, *Ziziphus* spp. and *Combretum* spp (Todou *et al*., 2019).The main ethnic groups are: Mafa, Guiziga, Mofou, Daba, Guidar, Fali, Moyeng, Mada, Zoulgo, Malko, Kapsiki, Bana, Moudang, Toupouris and Mandara (Seignobos *et al*., 2005). the village surveyed and their geographical coordinates are shown in table 1.

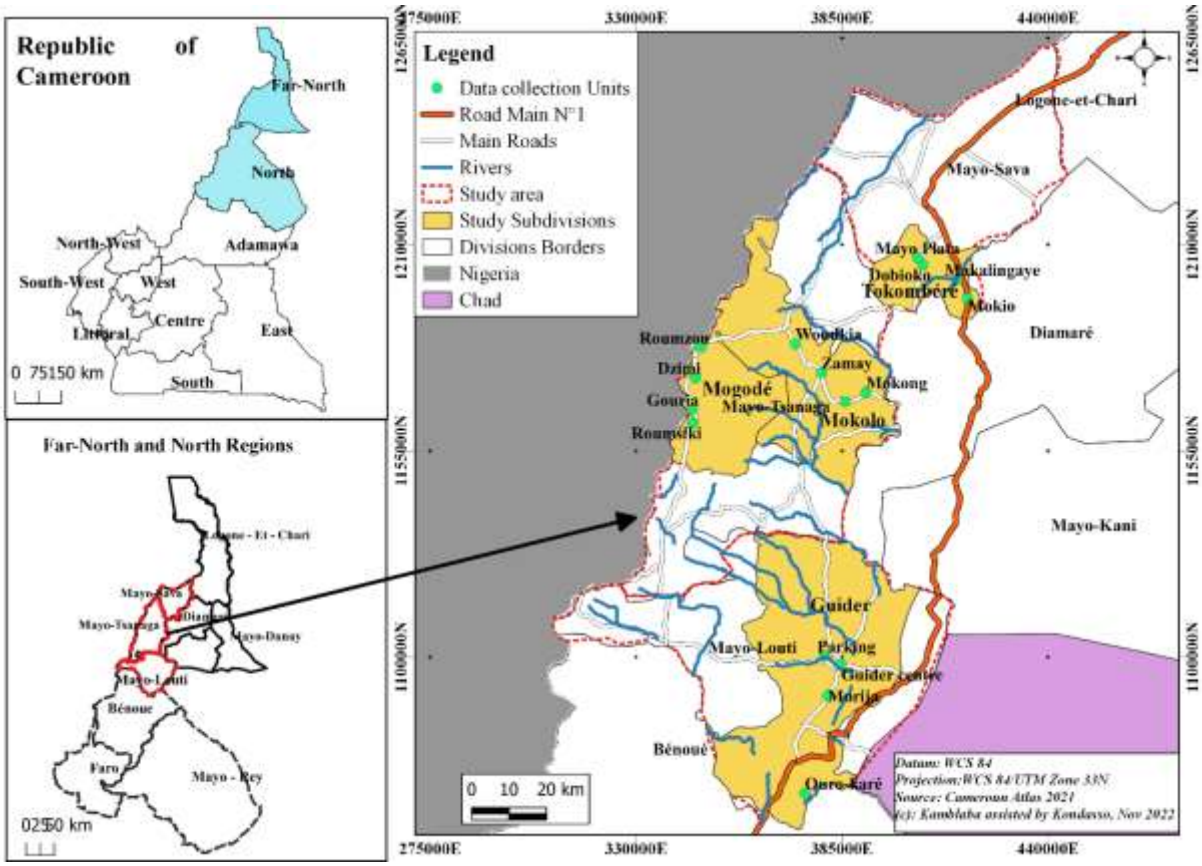

Figure 1: Location map of the study area

Table 1: village surveyed and their geographical coordinates

Collection units	**villages**	**Latitude (North)**	**Longitude (East)**
TOKOMBERE	Mayo-Plata	14°01'28.107"	10°93'32.411"
	Dobioko	14°08'49.458"	10°55'22.926
	Makilingaye	14°14'14'01.902	10°51'57.450
	Mokio	14°15'32.716"	10°49'52.218"
MOKOLO	Woudkia	10°40.873'	13°50.925"
	Zamay	10°45.361'	13°48.465'
	Katamsa	10°43.991'	13°44.953'
	Mokong	10°62.90.221"	14°32'94.654"
MOGODE	Rhoumzou	10°37'02.036	13°35'27.198"
	Dzimi	10°28.376'	013°34.565
	Gauria	10°34'56.622"	13°34'35.406"
	Rhoumsiki	10°32'58.908	13°31'33.580"
GUIDER	Parking	9°57'04.704"	13°54'29.874"
	Peripheral Guider	9°56'44.148"	13°55'20.682"
	Morija	9°53'58.932"	13°57'05.952"
	Wouro-Kare	9°56'19.620"	13°59'00.690"

3.2 Data collection: The methodological approaches adopted involved ethnobotanical surveys and floristic inventories. Ethnobotanical surveys were carried out through interviews. It consisted of travelling to all the villages selected and interviewing individually the people met who were over 20 years old using a survey form with open and closed questions following the method of Mapongmetsem *et al.* (2010). The study site was subdivided into 4 collection units distributed according to the four cardinal points: Mogode (West), Guider (South), Mokolo (East) and Tokombere (North) of the Mandara Mountains (Figure 1). Each collection unit consists of 4 villages that were selected according to the repeated presence of agrosystem types (cultivated fields, fallows and orchards). Preliminary surveys were carried out with different socio-professional categories, namely: 3 Divisional Delegates of agriculture; 4 Delegates of forestry and environmental protection. These choices are based on the idea that these people have vital information about these areas and have undergone professional training. In each farm, data relating to socio-economic aspects, number of trees (barked, pruned, cut in ha), different agricultural practices and functional characteristics of the agrosystems (mode of maintenance, tree management, types of fire) were determined. Thus, as regards traditional management, a direct assessment was made in the field according to the cropping calendars of the areas concerned, as well as the evaluation of the impacts of human pressures on the resources of the agrosystems.

3.3 Sampling method: A preliminary study was carried out on a sample of 120 people taken at random from all the localities. This survey made it possible to determine the proportion of people who have knowledge about agrosystems and their multifaceted contributions. The effective sample size was then calculated from the survey results using the formula of Dagnelie (1998):

$$n = \frac{t^2 \times p(1-p)}{e^2}$$

where: **n** = sample size; **t** = estimated confidence level for the proportion (**t** = 95% corresponds to 1.96 read from the Student-fisher centred normal distribution table); **p** = is the proportion of people who have knowledge about agrosystems and their uses (the survey results gave **p** = 34.05%); **e** = estimated margin of error for the proportion (margin of error of 5%)

$$n = \frac{(1{,}96)2 \times 0{,}3124(1-0{,}3124)}{(0{,}05)2^3} \cong 334{,}56 \text{ people}$$

Collection of our sample size gave n = 334.56 people which we rounded up to 335 people

3.4 Analysis of the collected data: Factor in the degradation of plant biodiversity in the agrarian system

3.4.1 Mortality rate (M): This is the count of dead plants per site expressed as a percentage of the total number of individuals on the site (Baggnian, 2013). It is expressed as follows:

$$M = \frac{\text{Nomber of dead plants}}{\text{Total number of individuals on the site}} \times 100$$

3.4.2 Vulnerability rate of woody species in agrarian systems: The Vulnerability Index for species i (IVu) was calculated using the Betti (2001) formula, modified by Traoré *et al.* (2011). The value of each parameter (N) varies from 1 to 3 according to the vulnerability scale. The average of the values of 6 parameters representing major indicators of pressure and threat on the species. These parameters are Frequency of use of the species (N1), number of uses (N2), plant part used (N3), harvesting method (N4), development stage (N5), relative frequency (N6) (table 2).

The IVi were interpreted according to the interpretation thresholds proposed by Traoré *et al.* (2011) for ligneous species in south-west Burkina Faso: for IVi < 2 the species is said to be weakly vulnerable; for 2 ≤ IVu < 2.5 the species is moderately vulnerable and for IVu ≥ 2.5 the species is very vulnerable.

Table 2: Important parameters taken into account in calculating the vulnerability index.

Vulnerability to uncontrolled exploitation			
N1 : Frequency of use	Fu<20%	20%≤Fu≤60%	Fu≥60%
N2 : number of uses	Nu<2	2≤ Nu≤4	Nu≥5
N3 : plant part used	leaves, latex	Fruits, branches	Roots, seeds, bark, flowers, wood
N4 : harvesting method	Collection	-	harvesting, cutting
N5 : development stage	old or senescent	Adulte	young
N6 : relative frequency	$Fr \geq 2/3Fm$	$1/3Fm \leq Fr < 2/3Fm$	$Fr < 1/3Fm$

Fu: frequency of use (number of people having cited species i out of the total number of informants); **Nu**: Number of uses, **Fr**: Relative frequency (number of records in which the species is present out of the total number of records); **Fm**: Maximum relative frequency.

The vulnerability of species is also confirmed by the assessment of woody frequencies according to the IUCN red list. The IUCN uses eleven species classification categories to give an idea of a species' state of extinction. In this study, it is the vulnerability criterion (IVu) that is taken into account. Each Red List category is used, for example, in one of the monitoring indicators of the Convention on Biological Diversity (Butchart *et al.*, 2004; Butchart *et al.*, 2007).
The specific frequency of each plant species is assessed on the basis of the information gathered. This frequency is an initial indicator for assessing the conservation status of plant species. (Oumarou *et al.*, 2021).

$$FS = \frac{\text{Number of surveys where the species was found}}{\text{Total number of readings}}$$

Species are classified as vulnerable when their frequency is between 10% < FS ≤ 50%.

3.4.3 Statistical data processing: All analysed data were processed with several statistical software: Xlstat for the factorial analysis of correspondences (AFC), SPSS software (Statistical Package for Social Sciences) for qualitative data, the analysis took into account statistical variables of the surveys. The map of the study area was produced using ArcGIS sofware.

4 RESULTS

4.1 Direct determinant of the degradation of plant biodiversity in agrarian systems: The agrarian systems of the Mandara Mountains, like any other area, are increasingly exposed to the effects of human activity. Surveys have shown that more men than women farm this system. Rural farmers in the Mandara Mountains are well aware of the degradation of vegetation cover and the factors causing it. This factors vary from one area to another and from one person to anothjer. Firstly, agriculture and its practices alone degrade nearly 51% of the plant cover in the entire study area. In addition, some people confirmed that tree felling is a significant factor in the reduction of vegetation cover in the agrarian systems of the people of the Monts Mandara. Tree felling is very high in Guider (73% of those surveyed) and very low in Mogodé (34% of those surveyed). (Figure 2). This wood cutting is sometimes accompanied by bush fires and the felling of trees to make charcoal and firewood. The supply of NTFPs (collection and gathering) is essentially based on the collection of bark, leaves and families of edible plants (such as *Grewia* sp) or the collection of fruit, caterpillars and dead wood and the removal of lianas for making furniture and baskets a practice responsible for the imbalance in the habitat. In fact, parasitic sun-loving plants are among the plants destroyed. The rate of degradation of the flora by this factor is estimated at around 22%. (Figure 2).

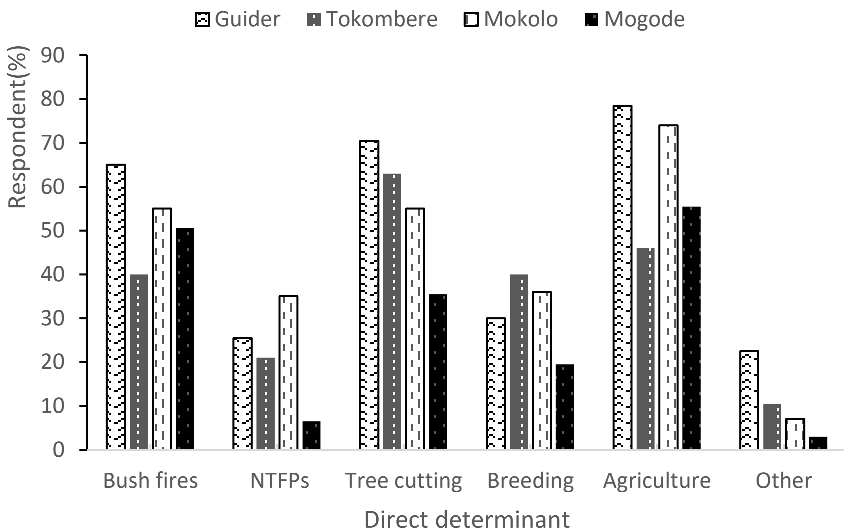

Figure 2. Direct cause of plant cover degradation in agrosystems

4.2 Indirect determinant of the degradation of vegetation cover in agrosystems: Local people believe that the arrival of migrants (Mogodé 37.5% and Tokomberé 38%) and population growth (Mogode 45.4% and Guider 35.5%) (Figure 3) are the most important indirect causes of vegetation degradation. They increase the need for agricultural land, non-timber forest products (NTFPs), game meat, fish products, firewood, timber and services. The areas of the Monts Mandara are facing demographic densification, which is resulting in a daily spatial expansion. Natural vegetation and community forests are being systematically destroyed to be replaced by other uses, generally housing, fields and other facilities. The ever-increasing food and energy needs of populations mean that more and more land has to be cleared. These buyers are in favour of allocating the land to agricultural activities. To solve the problem of insufficient food, farmers are growing western plants in orchards, mainly for economic purposes. The introduction of non-local trees can in some cases inhibit the normal development of local species and consequently reduce their proliferation. The rate of species reduction due to this factor is estimated at around 11.5% in Guider and 4% in Mogode (Figure 3). In the Monts Mandara, fodder cultivation remains marginal and the essential basis of animal feed remains natural fodder, supplemented by crop residues. The carrying capacity of the grasslands has been exceeded, given their characteristic appearance (bare, compacted soils, overgrowth).

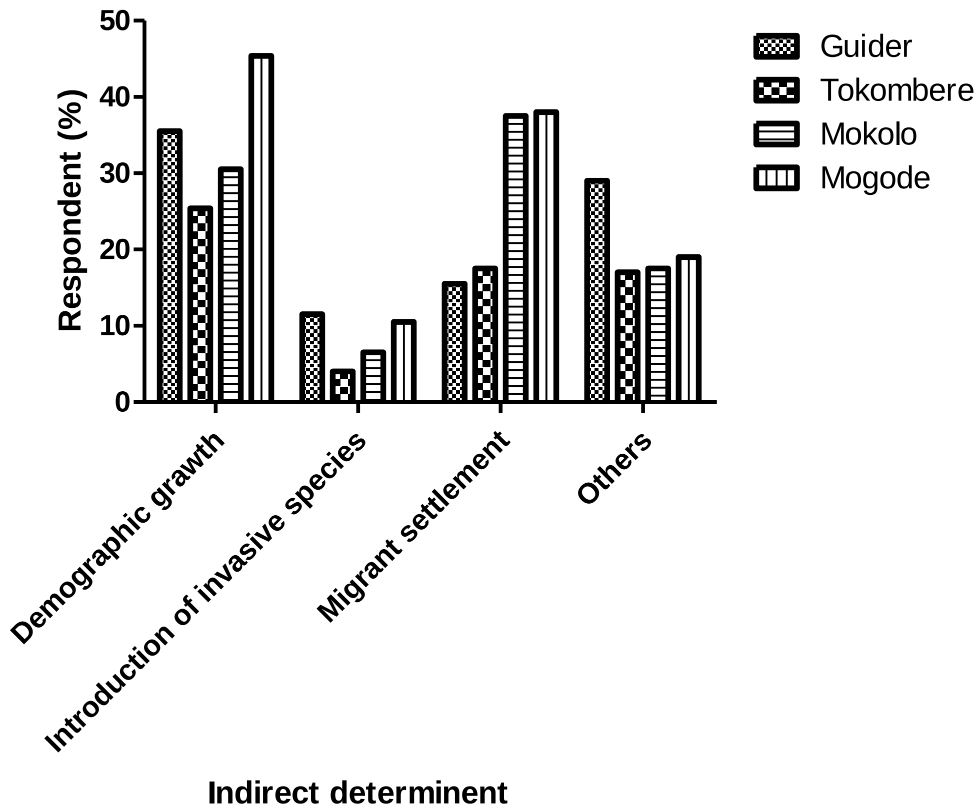

Figure 3. Indirect cause of the degradation of plant cover in agrosystems

4.3 Tree mortality rates in agrosystems: The rate of tree mortality varied from one collection unit to another and from one plant formation to another. Dead wood was counted much more in the fields of Mogodé (17.01%), followed by the fields of Tokomberé (16.04%). And the low mortality of plants has been inventoried in the Guider orchards (1.79%). (Figure 4). These tree deaths are caused by activities linked to the establishment of crops and much more anthropogenic needs. The most common of these are the clearing of land for camps, the cutting of trees for cattle fodder and the over-exploitation of tree bark. This explains the high mortality rate of trees in the fields. The low mortality rate observed in orchards is due to the fact that this landscape unit is under strict control and many are privately owned, with access strictly forbidden by third parties. Ngueguim *et al* (2015) report similar facts in the Mangombe forest station (Cameroon). In their view, the degradation of resources and the environment is certainly linked to the increased mortality (natural and anthropogenic) of trees by local people.

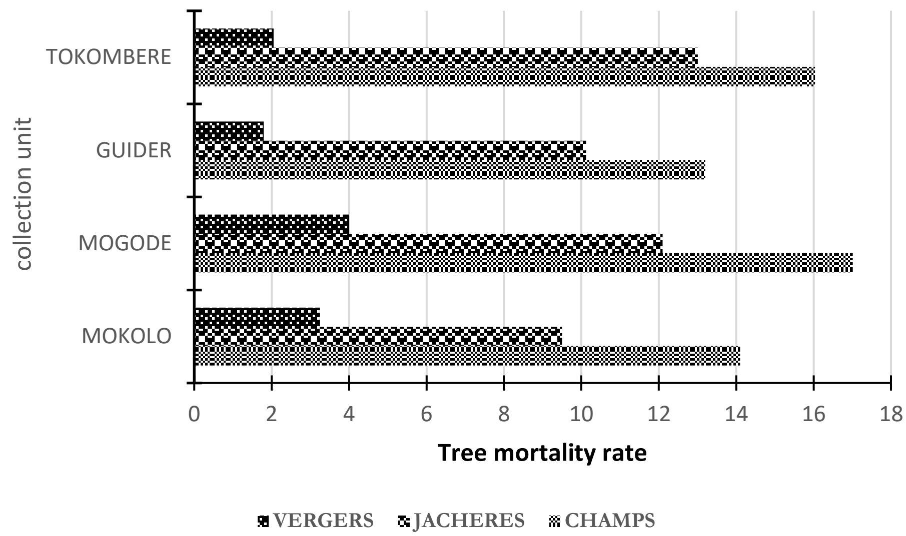

Figure 4. Tree mortality rate (%) by collection unit and plant formation

4.4 Vulnerability rates of woody species in agrarian systems: The vulnerability indices (IVui) calculated were used to produce the vulnerability spectrum for the species used (Figure 5). The results show that 29.81% of the species used have a vulnerability index greater than or equal to 2, with a relative frequency of between 10 and 50%. They are therefore said to be vulnerable. Of these species, 37.50% (6 species) are weakly vulnerable (IVu ≥ 2). And 50% (8 species) are highly vulnerable (IVu≥2.5). Among the highly vulnerable species, there are : *Tamarindus indica* (IVu = 3.082; F=16.05%)), *Sclerocarya* birrea (IVu = 3.01; F=49.1%), *Diospyros mespiliformis* (IVu 3.01; F=10.09%), *Khaya senegalensis* (IVu = 3.00; F= 12.11%), *Haematostaphis barteri* (IVu = 3.00; F=10.16%), *Balanites aegyptiaca* (IVu = 3.02; F=34%). It should be noted that the majority of these highly vulnerable species are wild edible fruit trees whose overuse makes them vulnerable (Figure 5). Other species are vulnerable because of the nature of the organs harvested (wood, seeds, bark, roots and/or flowers). On the other hand, the vulnerability of certain species such as *Parkia biglobosa* and *Balanites aegyptiaca* is also due to the fact that they are used in all the categories of use identified. Similarly, the vulnerability of certain species in the Mandara Mountains can also be explained by the fact that they are much in demand in several areas of use, particularly in energy, construction and utilitarian crafts, where the main method of exploitation remains the partial or total destruction of individuals. This is the case for *Haematostaphis barteri* (IVu = 3.00; F= F=10.16%), *Tamarindus indica* (IVu = 3.01; F=21.34%) and *Pterocarpus erinaceus* (IVu = 1.76; F=13.5%).

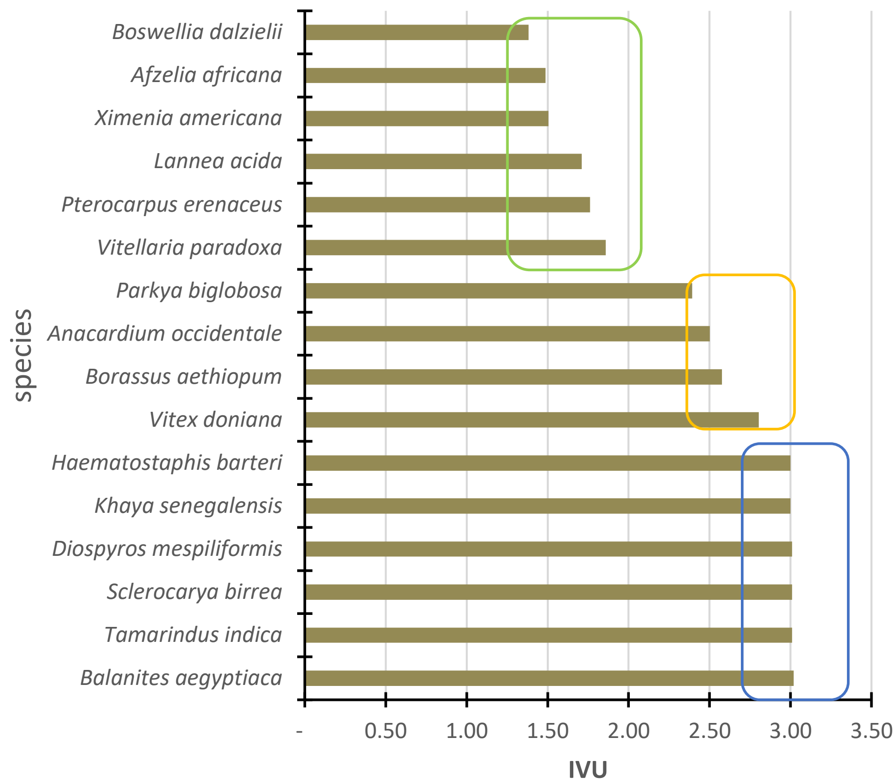

Figure 5: Spectrum of vulnerability distribution by species

5 DISCUSSION

5.1 Factors reducing biodiversity in agricultural systems: The livelihoods of the people of Mandara Mountains are mainly agriculture and livestock. Farmers in search of farmland and fodder for their livestock use plant species illegally. Diallo *et al*, 2011, in the Nakambé-Dem watershed in Burkina Faso, point out that the clearing of fields is sometimes accompanied by bush fires and the felling of trees to make charcoal and firewood. Agricultural activities lead to a significant reduction in plant diversity in these environments (Binsangou *et al.*, 2018). Overgrazing also leads to a reduction in the natural regeneration of woody plants, a decline in herbaceous cover, and the stripping and hardening of the soil (Kessler & Geerling, 2006). Other studies in the south of the W National Park in Benin, Houessou *et al* (2013), found that agriculture is the main driving force behind vegetation cover change in the region. Ayena *et al.* (2017) concluded that the increase in population and the search for fertile land to meet their subsistence needs are bringing about profound changes in the various land-use units. Overexploitation and the adoption of inappropriate management methods for individual species by farmers make them vulnerable (Todou *et al.*, 2022). The reduction in plant biodiversity has a number of consequences, including reduced rainfall, lower agricultural productivity, increased drought, higher temperatures, lower plant productivity, drier watercourses and more regular flooding. Mortality of overexploited individuals

5.2 Vulnerable species in the Mandara Mountains, Cameroon: The vulnerability spectrum drawn up on the basis of the data collected shows that pressure on resources due to their socio-economic importance makes them more vulnerable. Recurrent harvesting weakens the woody individuals and makes them vulnerable to bad weather (wind, fire, drought) and parasitic attacks. The resulting poor health of the trees leads to partial or total desiccation. These results differ from those of Traoré *et al* (2011) in the same phytogeographical zone in Burkina Faso, who found 60 vulnerable species and 15 very vulnerable species compared with 16 vulnerable species and 8 very vulnerable species respectively in the present study. Of the 8 highly vulnerable species identified, 6 are already classified as endangered in Cameroon. In addition, the vulnerability of production systems has many consequences, including degradation of farmland, lower crop yields, low farmer incomes and farmer poverty. Traditionally, however, people have turned to infusions, decoctions and macerates made from the leaves, bark and roots of certain species for their health care (Oumarou *et al*., 2021). This traditional therapy has a significant impact on plant reproduction, and as a result is considerably reducing plant biodiversity.

6 CONCLUSION

Finally, this work has made it possible to assess the factors that make plant genetic resources vulnerable in the agricultural systems of the Mandara Mountains. Activities such as inappropriate agricultural practices, the supply of NTFPs and the settlement of refugees have contributed to the vulnerability of species in agrosystems. The introduction of non-local trees can in some cases inhibit the normal development of local species and consequently reduce their proliferation. Yards are agrosystems where the rate of vulnerability is low. Farmers who depend on rain-fed agriculture are therefore called upon to promote the creation of orchards, which will enable them to avoid exploiting natural resources that have become vulnerable. The long-term survival of species in the agrosystems of the Mandara Mountains requires energetic intervention through planting operations and the protection of natural regeneration.

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8 COMPETING INTERESTS

Authors have declared that no competing interests exist.

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