Effect of Land Use Dynamics on the Distribution of Chromolaena Odorata (Asteraceae) and Mesosphaerum Suaveolens (Lamiaceae), Two Invasive Alien Species in Benin, West Africa

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Abstract

Invasive plants are now a major threat to biodiversity, agriculture and natural habitats around the world. It is now increasingly recognized that land uses are linked to invasion processes. Despite the various mutations and land cover changes observed in Benin, the expansion of invasive alien species in relation to land uses is poorly documented. This study, through systemic analysis and remote sensing, aims to investigate the link between land uses and the spread of *Chromolaena odorata* and *Mesosphaerum suaveolens*, two dominant invasive alien species in Benin, West Africa. This study sheds light on the structure of the different land cover classes and establishes the link between the distribution of invasive alien plants and the dynamics of land use in the study environment. A mapping of land use by object-oriented approach, a typology of landscape elements by a systemic analysis and verification on the ground were carried out. We noted that agricultural practices and the exploitation of natural resources are the main drivers of land use. Several land use units have been identified. It appeared that mosaics of crops and fallow land are the most dominated by invasive plants, followed by open forest, wooded and shrubby savannahs. The study also revealed that the degree of invasion is linked to antropic disturbance. This suggests that managed land should be reforested, and that heavy thinning in forests and savannahs should be avoided.

INTRODUCTION

An invasive alien species is a species that has a significant competitive advantage that allows it to proliferate and extend its range by becoming a dominant population in invaded environments (Vilà &Ibanez, 2011). Invasive alien species cause disturbances at different levels of organization within invaded ecosystems (Cucherousset & Olden, 2011). The consequences caused by these invasive species are devastating (Hulme *et al.*, 2013). Indeed, these consequences are ecological, economic and societal. The phenomenon of invasive species is nowadays a major threat to biological diversity at the global level (Maxwell et al., 2016). For good reasons, invasive plants act particularly on the specific diversity, services and interactions of ecosystems (Clavel et al., 2011). In addition, invasive plants pose a major threat to agriculture worldwide (Paini et al., 2016).

The geographical distribution of a plant species is determined by complex interactions between a series of biotic and abiotic factors, including climate, soil properties, interactions with biotic factors and dispersal limiting agents (Pratt et al., 2017). Several factors contribute to the spread of invasive alien species (Vilà & Ibanez, 2011). The introduction of invasive alien species into new biogeographical areas has been attributed to human activities, including trade, travel, and recreation (Hulme, 2008). With a recent intensification of such activities, introductions of invasive alien species are expected to increase (Hulme, 2008). In effect, the various changes in land use caused by human activities are one of the main factors favoring the proliferation and abundance of invasive alien species (Pysek et al., 2010). The vulnerability of a site to being invaded largely depends on the type of land use (Vilà and Ibanez, 2011). The establishment of invasive alien species can therefore be interpreted as an indicator of a site's vulnerability to invasion (Tassin, 2015). When an invasive alien species establishes itself over a large area, its eradication is rarely possible (Tassin et al., 2007). For this, strategies for preventing new invasions and controlling the proliferation of invasive species are considered the most effective and are the most recommended (Leung et al., 2002). To this end, understanding and predicting biological invasions is one of the main challenges for better protection of biodiversity. However, the phenomena of invasion by invasive alien species are not sufficiently documented in several regions around the world (Latombe et al., 2017). Despite the various studies already devoted to invasive alien species, additional efforts must be made to provide more knowledge and more suitable solutions (Bellard & Jeschke, 2016).

In Africa in general, and in West Africa in particular, more than 60% of natural habitats have been lost (Burgess et al., 2004). These observed changes in land use have not remained without consequences (Akodewou et al., 2019). Indeed, these actions have favored the spread of many invasive alien species (IUCN, 2013). It should be noted that to date, very little research has addressed the effects of land use on invasive alien species (Aboh et al., 2008). Similarly, little research has attempted to dig deeper into the ecology, spatial distribution and effective management of invasive alien species (Foxcroft et al., 2010; Holou et al., 2013). A better understanding of the interactions between human activities based on land uses and the spatial distribution of invasive species would allow a better understanding of the functioning of these species. This will contribute to the establishment of adequate management policies.

This study establishes an inventory of the geographical distribution of *Chromolaena odorata* and *Mesosphaerum suaveolens*. It aims to highlight the effect of land use dynamics on the distribution of invasive alien species. For that, this study seeks to answer the following research questions: 1) what are the surface and spatial arrangements of the different land-use classes within the environment? 2) What are the main landscape features of the environment, and how are they changing? 3) Do the richness and diversity of invasive plants vary according to landscape features? Answering those questions will help understand the land use dynamics and their relationship with the plant invasion and therefore advance knowledge on the management of invasive alien plants.

MATERIALS AND METHODS

Study area

The Republic of Benin is located entirely in the intertropical zone, between the parallels 6°30' and 12°30' of latitude North and the meridians 1° and 3°40' of longitude East (Neuenschwander & Toko, 2011). It is bordered to the North by the Republics of Niger and Burkina Faso, to the South by the Atlantic Ocean, to the West by the Republic of Togo and to the East by the Republic of Nigeria. In addition to the North-West zone in the Atacora ranges, the center in the hills department, Benin generally presents a slightly uneven relief. By its extension between the coast of the Gulf of Benin and the Niger valley (6°30 to 12°4 N), Benin presents a varied range of climates. In effect, Benin climates are characterized by a relatively low annual rainfall which shows a variation of 900 to 1300 mm per year. Figure 1 shows the location map of Benin with the major urban centers as well as the main road network of the country.

Benin has a varied geography, ranging from coastal plains in the south to central plateaus and higher hills in the north (Vissin *et al.*, 2007). The "Oueme" River crosses the country from north to south and is the largest river in Benin. Benin's biodiversity is remarkable and presents a variety of its ecosystems, which include coastal areas, savannahs, rainforests, mangroves, lagoons and wetlands (Tchibozo et al., 2008). This diversity of landscapes promotes a great richness in terms of flora and fauna. Indeed, Benin presents a variety of animal species including mammals, birds, reptiles, amphibians and fish (Amoussou et al., 2012). There are elephants, lions, leopards, cheetahs, hippos, crocodiles, antelopes, monkeys, pangolins and many other species of mammals. The birds are also numerous and varied, with migratory and resident species. In the coastal areas, you can observe different species of seabirds and of pelicans (Adomou et al., 2009). Benin's flora is diverse, with a wide variety of trees, of plants and flowers (Djossa et al., 2008). Tropical forests are home to species such as cheese, teak, iroko, mahogany and baobab, which is an emblematic symbol of Africa (FAO, 2001). Benin also has several protected areas and national parks (Bakarr et al., 2004).

Botanical description and origin of Chromolaena odorata and Mesosphaerum suaveolens

This description relates to Akoègninou et al., (2006) and Aboh et al., (2008). *Chromolaena odorata* belongs to the Asteraceae family. *Chromolaena odorata* is a colonizing species of open environments, flowering from November to May (Akobundu & Agykwa, 1989). It is propagated either by cuttings, by regeneration from stumps or by seed dispersal. Its dispersion is mainly anemochorous. The species is a semi-lignified perennial herbaceous, very fragrant, diffuse and fast-growing perennial that can reach 3 m to 3.5 m tall and spread by seed or basal shoots. The species is native to the West Indies and tropical America (Gautier, 1992). The first appearance would have taken place in Nigeria between 1936 and 1942 (Delabarre, 1977). On the other hand, in Ivory Coast and the Central African Republic, coffee planters and pepper planters would have voluntarily introduced the species to use it as a cover (Huguenin, 1993). The plant appeared in Benin in the early 1970s from Nigeria (Avlessi et al., 2012).

Mesosphaerum suaveolens is called "Gros baume" in French, "azongbi" in Fongbé (Akoègninou *et al.*, 2004). *Mesosphaerum suaveolens* belongs to the Lamiaceae family. It should be noted that it is an upright and very aromatic annual species. It can reach 1.5 m or even 2 m in height and spreads by seed. The stem is woody, polygonal, much branched, leafy, greyish, pubescent and marked with glandular dots. Originally from tropical America, this species is now widespread in tropical Africa and Asia (Hutchinson & Daziel, 1963). The species prefers fallow land, coastal sand and wooded savannah and colonizes quickly.

Analysis of local people's knowledge of the effects of land use on the proliferation of Chromolaena odorata and Mesosphaerum suaveolens

The causes of invasion by invasive alien plants are largely linked to human activities human activities that disrupt native ecosystems (IUCN 2004). Their seeds are transported voluntarily or accidentally by human activities or animal movements (Radji et al., 2010). Human activities include: road construction, land development, grazing, sowing fodder plants, erosion control work and the use of vegetation fires

(Pysek P et al., 2010). Global climatic and geological changes are also important factors contributing to the establishment of invasive alien species (Hobbs & Huenneke, 1992). It is important to analyze and understand local populations' knowledge on the spread of invasive species in relation to land use. To achieve this objective, a survey was carried out among the local population. The target groups were mainly the farming populations of the communes surveyed. The sample size was determined using the Dagnelie formula (Dagnelie, 1998).

$$\varvec{n} = \frac{\varvec{U}^2 \varvec{*} ((1 - \varvec{p}) \varvec{*} \varvec{p})}{\varvec{d}^2}$$

with n: the number of respondents; U: the value of the confidence level of a normal law (1.96); p: the proportion of people who know the species; d: margin of error set at 7% for this study (Singh et al., 2009).

Mapping and description of the structure of the different land cover classes: **Data analysis and processing**

The land cover map was produced from a 2022 Landsat image of 30-meter resolution downloaded from the Usgs website (www.usgs.org, on November 2022). Considering the complexity of the heterogeneity of our environment, the object-oriented approach was preferred, using Envi 4.7 software, unlike the classic approach based on a classification-oriented pixel from the spectrum (Adjonou et al., 2019). The object-oriented approach does not deal with the pixel in isolation. Indeed, the oriented approach treats the pixel in its spatial and spectral environment, by grouping pixels within objects interpreted based on spectral values, their size, shape, context (Benz et al., 2004).

Different steps were necessary for the processing of satellite images. Indeed, we have: (1) the Image Pre-processing which is a step that consisted of a radiometric correction of the Landsat image in order to correct any atmospheric biases and to go from the pixel value to the digital count to the reflectance value; (2) the colored composition: following several combinations, a colored composition presenting the best discriminations of the types of ground occupation (Sarr, 2009) was chosen; (3) classification and evaluation consisted of transforming the image into a thematic map. The classification was based on the spectral properties to group the different objects of the image into thematic class. To do this, the supervised classification was used with the maximum likelihood algorithm from the colored composition chosen for this purpose; (4) ranking validation: two ranking validation indices were calculated. This includes in particular the global precision (character the proportion of well-classified pixels, evaluated as a percentage) and the kappa index (character the ratio between the well-classified pixels and the total of the pixels probed) (Sparfel et al., 2008). In addition to these indices, field data were also used for validation.

Study of an association or non-association relationship between land use units and the abundance of Chromolaena odorata and Mesosphaerum suaveolens

In order to study the relationships of association or dependence between the land-use units and *Chromolaena odorata* and *Mesosphaerum suaveolens*, a remote sensing analysis of vegetation was carried out. Land use was mapped. The results were then cross-referenced with data on the presence of *Chromolaena odorata* and *Mesosphaerum suaveolens*, to highlight the habitats most frequently colonized. The land-use units considered refer to the classification of the different types of land and land uses present in the country.

Then, statistical tests were carried out to analyse the results. The Pearson's Chi-squared test was performed. A mosaic plot was used to represent the association relationships between species abundance and ecosystem type. Thus, depending on the value of the standardized residuals, the degree of association is assessed. Residual values between – 2 and 2 show an independent relationship and are represented graphically by a transparent color. Association relationships are observed when values are less than – 2 or greater than 2. Values below – 2 indicate an association with a low representativeness of the sub-group considered (red color), while values greater than 2 indicate a high representativeness of the sub-group (blue color).

The significance threshold is 5%, and the various tests were carried out using R 4. 2. 2 software (R Core Team, 2022).

Data used

Several data types were used. Indeed, it was occurrence and Landsat satellite image data. The occurrence data needed for this study were downloaded from the GBIF (Global Biodiversity Information Facility, https://doi.org/10.15468/dl.2c3kp6 & https://doi.org/10.15468/dl.mv8jfr) database. A search through the literature provided additional data. The data thus obtained were supplemented by data collected in the field.

As for the satellite image, it is a 2022 Landsat image. Landsat provides images of the earth's surface with a resolution of 30 meters. The sensors measure reflectance in different spectral bands, from the invisible to the infrared. These reflectance measurements enable us to distinguish between different types of vegetation and land use. This enables the precise mapping of agricultural areas, forests, urban zones, etc.

Supervisory classification techniques can be used to create highly accurate land-use maps. The scenes were chosen in the dry season when cloud cover is reduced to a minimum due to variations in the phenological phase of the vegetation (Clerici et al., 2007). Cartographic data consisting of a georeferenced digital layer essentially comprising road networks and administrative entities and localities were also used.

RESULTS

Analysis of local people's knowledge of the effects of land use on the proliferation of Chromolaena odorata and Mesosphaerum suaveolens

Land use can have a significant impact on the proliferation of invasive plants such as *Chromolaena odorata* and *Mesosphaerum suaveolens*. A total of 196 farming households were surveyed to analyze their knowledge and views on the effect of land use dynamics on the spread of invasive alien species, mainly *Chromolaena odorata* and *Mesosphaerum suaveolens*. All respondents (100%) agreed that land-use dynamics have an effect on the spread of invasive species. Intensive land use, such as unsustainable agriculture, deforestation and urbanization, leads to soil degradation. Degraded soils are often less competitive for native plant species, but some invasive plants, including *Chromolaena odorata* and *Mesosphaerum suaveolens*, can thrive in such conditions. Human activities that disrupt natural ecosystems, such as the creation of roads, industrial zones or other infrastructures, encourage the spread of these invasive plants. Soil disturbance creates opportunities for these species to colonize new territories. Soil use favors changes in the composition and structure of plant communities. In fact, agricultural practices such as monoculture and excessive pesticide use favor the proliferation of *Chromolaena odorata* and *Mesosphaerum suaveolens* at the expense of native plant species. These invasive plants have the ability to fix atmospheric nitrogen, which can give them a competitive advantage over native plants in terms of nutrients. The use of chemical fertilizers in agriculture also favours their growth. In some areas, *Chromolaena odorata* and *Mesosphaerum suaveolens* can compete with agricultural crops for water, which can reduce crop yields. In addition, *Chromolaena odorata* is known to increase the risk of fire as it is highly flammable. Fires destroy native vegetation and further encourage the proliferation of this invasive plant.

The invasive species *Chromolaena odorata* and *Mesosphaerum suaveolens* can be found in various land-use units, depending on their ecological preferences and ability to adapt to different environments. In order to analyze endogenous knowledge on the effect of land-use dynamics in relation to the expansion *of Chromolaena odorata* and *Mesosphaerum suaveolens*, respondents were asked to list and score the main land-use units where these species are most commonly observed. A numerical score was assigned to each response modality. Each modality is therefore associated with a number that represents its score according to the hierarchy of modalities cited. The modality cited first is given the highest score. It emerged that *Chromolaena odorata* is mainly found in abundance in mosaïc of cultivation and fallow, tree and shrub savannahs, and clear forest and wooded savannah (Fig. 2). As for *Mesosphaerum suaveolens*, it is mainly found in abundance in crop and fallow mosaics, agglomeration, and in wooded and shrubby savannahs (Fig. 3).

Mapping and description of the structure of the different land cover classes

Benin land cover units refer to the classification of the different types of land and land uses present in the country. These classifications are based on physical, ecological, and human characteristics of the territory. Land-use units include: the agglomeration, the swamp formations, the clear forest and wooded savannah, the dense forest, the forest gallery, the mosaic of cultivation and fallow, the planting area, the tree and shrubby savannah (tableau 1).

Figure 4 shows the land use units' map based on Landsat images (2022). A predominance of tree and shrubby savannahs is observed (49.66%) (Tableau 1). The other main land use units observed are the mosaics of cultivation and fallows (28,473%) followed by the open forests and wooded savannahs (13.19%).

Tableau 1 Surface area of land use units

Land use units	**Area**	
	in km²	**%**
Tree and shrub savannah	56956.298	49.656
Mosaic of cultivation and fallow	32659.046	28.473
Clear forest and wooded savannah	15129.968	13.190
Forest gallery	2877.854	2.509
Planting	2432.228	2.120
Swamp formations	1920.121	1.674
Lakes and streams	921.601	0.803
Agglomerations	846.519	0.738
Dense forests	713.501	0.622
Rocky surfaces	165.654	0.144
Bare ground	68.513	0.0597
Sandy beach	8.697	0.007
Total	**114700**	**100**

Spatial distribution of Chromolaena odorata and Mesosphaerum suaveolens according to different land-use units

All occurrence data for *Chromolaena odorata* and *Mesosphaerum suaveolens* were projected onto the land cover map. The number of occurrences of each species identified in each land-use unit was recorded (Figs. 5 and 6). The results of this analysis showed that both *Chromolaena odorata* and *Mesosphaerum suaveolens* are present throughout the territory, regardless of climatic zone. However, their abundance differs from one land-use unit to another. In fact, *Chromolaena odorata* mainly occurs in the land use unit "mosaic of cultivation and fallow" (26%°), followed by "trees and shrubby savannah" (21%), "planting" (20%) and "clear forest and wooded savannah" (14%) (Fig. 7). As for *Mesosphaerum* *suaveolens*, the majority of its occurrences are in the land use units “crop and fallow mosaic” (46%), “agglomeration" (24%) and “tree and shrub savannahs” (12%) (Fig. 8).

Relationship between land-use units and Chromolaena odorata and Mesosphaerum suaveolens

The Pearson's Chi-squared test was carried out in order to highlight the association or non-association between the different land-use units and the two species. The test probability (X-squared = 1254.8, df = 7, **p-value < 2.2e-16**) is below the 5% (0.05) significance level. We conclude that there is a strong relationship of dependence or association between the different land-use units and the abundance of *Chromolaena odorata* and *Mesosphaerum suaveolens*. In addition, the mosaic plot was used to represent these existing association relationships between species abundance and land use unit (Fig. 9). The degree of association is assessed according to the value of the standardized residuals. Residual values between – 2 and 2 show an independent relationship and are represented graphically by a transparent color. Association relationships are observed when values are less than – 2 or greater than 2. Values below – 2 indicate an association with a low representativeness of the sub-group considered (red color), while values above 2 indicate a high representativeness of the sub-group (blue color). Thus, *Chromolana odorata* is highly representative of the tree and shrubby savannah, planting and dense forest subgroups, while it is weakly representative of the agglomeration subgroup. *Mesosphaerum suaveolens* is strongly represented in agglomerations and mosaics of cultivation and fallow. However, it should be noted that *Mesosphaerum suaveolens* is absent from dense forests.These results confirm the findings of the surveys carried out, as well as the mapping of land-use units carried out.

DISCUSSION

Local people's knowledge of the effects of land use on the proliferation of Chromolaena odorata and Mesosphaerum suaveolens

There is still some debate among ecologists as to the precise definition of what constitutes an "invasive" species (Maroun, 2017). However, a broad consensus has emerged within the scientific community on the imperative need to adopt active management and control measures to preserve natural ecosystems from the uncontrolled spread of these exogenous taxa (Wakjira, 2011). However, public opinion and the population as a whole are much more mixed and contrasted on the complex issue of invasive species (Yao et al., 2017). In fact, according to several studies, perceptions of the phenomenon and attitudes to the action to be taken can vary greatly between those working directly in the field of biodiversity conservation and the rest of the population. For example, some members of the general public believe that all species, even introduced ones, have an equal right to exist and develop, and that Man should not intervene or seek to control natural processes within ecosystems (Von et al., 2002).

Most scientific research into the problem of invasive species still focuses mainly on ecological or economic aspects, such as their impact on native biodiversity or the damage caused in various sectors of activity (Aikpon et al., 2021). However, relatively few studies have so far focused on the social dimension of the phenomenon, in particular on how invasive alien species are perceived by the population, or on the socio-cultural benefits and costs associated with them by local communities (Vilatte, 2007). Yet an in-depth analysis of these societal aspects is of vital importance (Timbilla *et al.*, 2000). A detailed understanding of the public's perception of these taxa, and a rigorous assessment of both the positive and negative impacts caused by their spread, would enable us to design and implement invasive species management policies that are much better adapted to local realities, and thus significantly increase their effectiveness and sustainability (Vilatte, 2007). What's more, the absence of such societal knowledge can lead to counter-productive control measures, if they are not understood and accepted by the populations concerned. Public rejection or opposition is thus likely to emerge, which may hinder or even totally compromise the success of invasive species control strategies in the long term (Tiébré et al., 2014).

In other countries, a growing number of studies and awareness-raising campaigns have focused on the problem of invasive species, with the aim of better informing the general public about this little-known issue (Cordeiro et al., 2020). More specifically, certain research programs and communication initiatives have focused on reaching certain strategic audiences who play a key role in the involuntary dispersal of these invasive taxa (Crowley et al., 2017). This is particularly true of people who regularly work in contact with nature, such as environmental or horticultural professionals, whose activities are particularly likely to introduce, propagate or encourage the establishment and local spread of invasive exotic plant species. Raising awareness among these specific target groups is therefore of paramount importance (Eiswerth et al., 2011).

In less economically developed countries, a significant proportion of the population still lives in rural areas (Perrings, 2005). The spread of invasive alien species can therefore have a concrete and direct impact on the daily lives of these local communities (Inderjit 2005). Carrying out in-depth surveys of local people's perceptions of these invasive plants is therefore useful for several reasons. Firstly, it enables us to draw up a precise inventory of the situation on the ground regarding these troublesome taxa, and consequently to identify priorities for targeted action with a view to their future management. What's more, these rural populations are often in direct contact with these species in their daily lives. They may therefore possess valuable empirical knowledge of great scientific interest, particularly concerning recent changes in the degree of local invasion or the appearance of new invasive alien plants in their immediate environment. Gathering this vernacular ecological knowledge is therefore of great relevance (Estevez et al., 2015).

Protecting ecosystems from invasive alien species is a crucial global environmental issue (Akodewou *et al.*,2019). Invasive alien species are living organisms that originate from a geographical region other than the one to which they are introduced, and which have the capacity to establish and spread aggressively in their new environment (Zachariades et al., 2002). These species can cause major disruption to native ecosystems, jeopardizing biodiversity, ecosystems and the services they provide to humanity. The introduction of invasive alien species is often the result of human activity, whether through international trade, transport, agriculture, aquaculture or even horticulture (Gurevitch & Padilla 2004). Invasive alien species, specially *Chromolaena odorata* and *Mesosphaerum suaveolens*, can spread rapidly, crowding out native species, modifying natural habitats, altering ecological cycles and causing disturbances that affect the balance of ecosystems (Ganglo, 2005).

Over the years, rural communities in tropical regions where *Chromolaena odorata* and *Mesosphaerum suaveolens* proliferate have acquired in-depth knowledge of the interactions between these invasive plants and agricultural practices (Ganglo, 2005). Through their daily observation of plots and cropping cycles, farmers have observed that forest clearing, slash-and-burn cultivation and overgrazing of fallow land tend to rapidly encourage the spread of these weeds. Indeed, when the forest cover is removed and the soil is left bare, the seeds of these species find an ideal space in which to germinate. Once established, these fast-growing plants choke out young crop shoots by competing for space, light and soil nutrients. Even after harvesting, they densely colonize fallow land, compromising the land's potential to regenerate fertility. Their expansion is also encouraged by soil erosion and nutrient depletion. Although some communities have learned to use these hardy plants as green manures, most farmers see them as a calamity that greatly reduces the productivity of food crops (Andersen et al., 2004). It has become clear to them that the accelerated spread of *Chromolaena odorata* and *Mesosphaerum suaveolens* over the last few decades is closely linked to the intensification of slash-and-burn cultivation and land-clearing practices in cycles too short to allow genuine soil regeneration.

Analyzing of a population's perceptions is an essential methodological approach which enables us to systematically gather the opinions, attitudes and beliefs of each person surveyed on a specific subject or issue specific issue (Fischer et al., 2015). Implementing such an in-depth study by interviewing a representative sample of the population enables us to build up a rich database of qualitative and quantitative data. Indeed, having a detailed of the perceptions, arguments and informed opinions of the citizens and stakeholders concerned is a fundamental prerequisite for ensure optimal guidance for the development of future management plans (Zavaleta et al., 2001). On the other hand, failure to understand in depth the of people's perceptions and representations, we run the major risk of defining management objectives that are totally out of step, or at least with people's social and environmental expectations (Witmer et al., 2009). Increasingly popular, this approach to studying perceptions used routinely in the vast disciplinary field of invasion ecology to promote effective and socially responsible management of that is both effective and socially acceptable (Atlan and Darrot, 2012).

Structure of the different land cover classes and spatial distribution of Chromolaena odorata and Mesosphaerum suaveolens

This study precisely mapped the presence of *Chromolaena odorata* and *Mesosphaerum suaveolens*, two particularly invasive exotic plants, in various ecosystems, natural and semi-natural environments and other rural landscapes in Benin, and analyzed in detail the link between their level of invasion and anthropogenic land use and management patterns. More specifically, this research assessed the spatial distribution of these two introduced species in relation to the different land-use units found nationwide, from protected areas to cultivated areas, including fallow land, sacred forests and anthropized spaces. Data collected in the field and statistical analyses have enabled us to gain a better understanding of the environmental and landscape characteristics that influence the establishment of these troublesome taxa in Benin. This knowledge will support the development of sustainable strategies to manage the progression of *Chromolaena odorata* and *Mesosphaerum suaveolens* in socio-ecosystems. Indeed, this study highlights the problem of invasive alien plants in relation to land-use dynamics, with a particular focus on *Chromolaena odorata* and *Mesosphaerum suaveolens*, two invasive alien species. Studying the effect of land use on the distribution of invasive plants such as *Chromolaena odorata* and *Mesosphaerum suaveolens* is becoming increasingly important in the context of natural ecosystem management (Hooper et al., 2005). These two species have shown an ability to rapidly colonize diverse habitats, exerting pressure on biodiversity and native ecosystems (Vaisakh & Pandey, 2011). One of the key observations of this study was that *Chromolaena odorata* and *Mesosphaerum suaveolens* showed a marked preference for areas disturbed by human activities. These plants thrive in degraded environments such as abandoned farmland, disturbed open forests and savannahs, construction sites, roadsides and overgrazed pastures. This preference for disturbed areas is largely attributed to their ability to spread rapidly via light seeds and adapt to variable conditions (Goodal & Erasmus, 1996). Land use has a significant impact on the distribution of these invasive plants (Akodewou et al., 2019). For example, the conversion of forest land to farmland creates ideal conditions for the spread of *Chromolaena odorata* due to deforestation and soil disturbance. Similarly, overgrazing favours the dominance of *Mesosphaerum suaveolens* by creating bare areas where this plant can colonize (Aboh, 2008). Land management practices also influence the distribution of these two species (Didham et al., 2005). Control methods, such as cutting, chemical weeding or the introduction of biological agents, can have an impact on the density and distribution of *Chromolaena odorata* and *Mesosphaerum suaveolens* (Vaisakh & Pandey, 2011). However, these practices can be costly and require continuous monitoring to be effective. It's undeniable that land use has a significant impact on the distribution of *Chromolaena odorata* and *Mesosphaerum suaveolens*. These invasive plants show a preference for disturbed areas, making them particularly sensitive to human-induced changes, such as the conversion of forest land to farmland. Land management, including control practices, plays an essential role in limiting their spread. Future research in this field is crucial to developing effective management strategies to control these invasive plants and therefore protect native ecosystems.

CONCLUSION

Understanding the impact of human activities on the proliferation and distribution of invasive plants is essential in the current context of climate and global changes. Our study documented and mapped the different land-use units, as well as local residents' perceptions of biological invasion in relation to these land-use units. Our results revealed that agricultural practices, plantations, logging and urbanization are the main causes of landscape modification. Invasive species predominate in cultivation and fallow mosaics, open forest and wooded savannahs. In particular, *Chromolaena odorata* and *Mesosphaerum suaveolens* pose a real challenge, both for protected areas, for farmers and stockbreeders.

This study provides an ideal basis for developing invasive plant management strategies and for in-depth research into the effect of previous land uses on these invasive plants. It is clear from this research that remote sensing and systemic landscape analysis are crucial tools for better understanding of the problem of invasive species in various ecosystems.

Declarations

CONFLICT OF INTERESTS

The authors have declared no conflict of interests.

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Figures

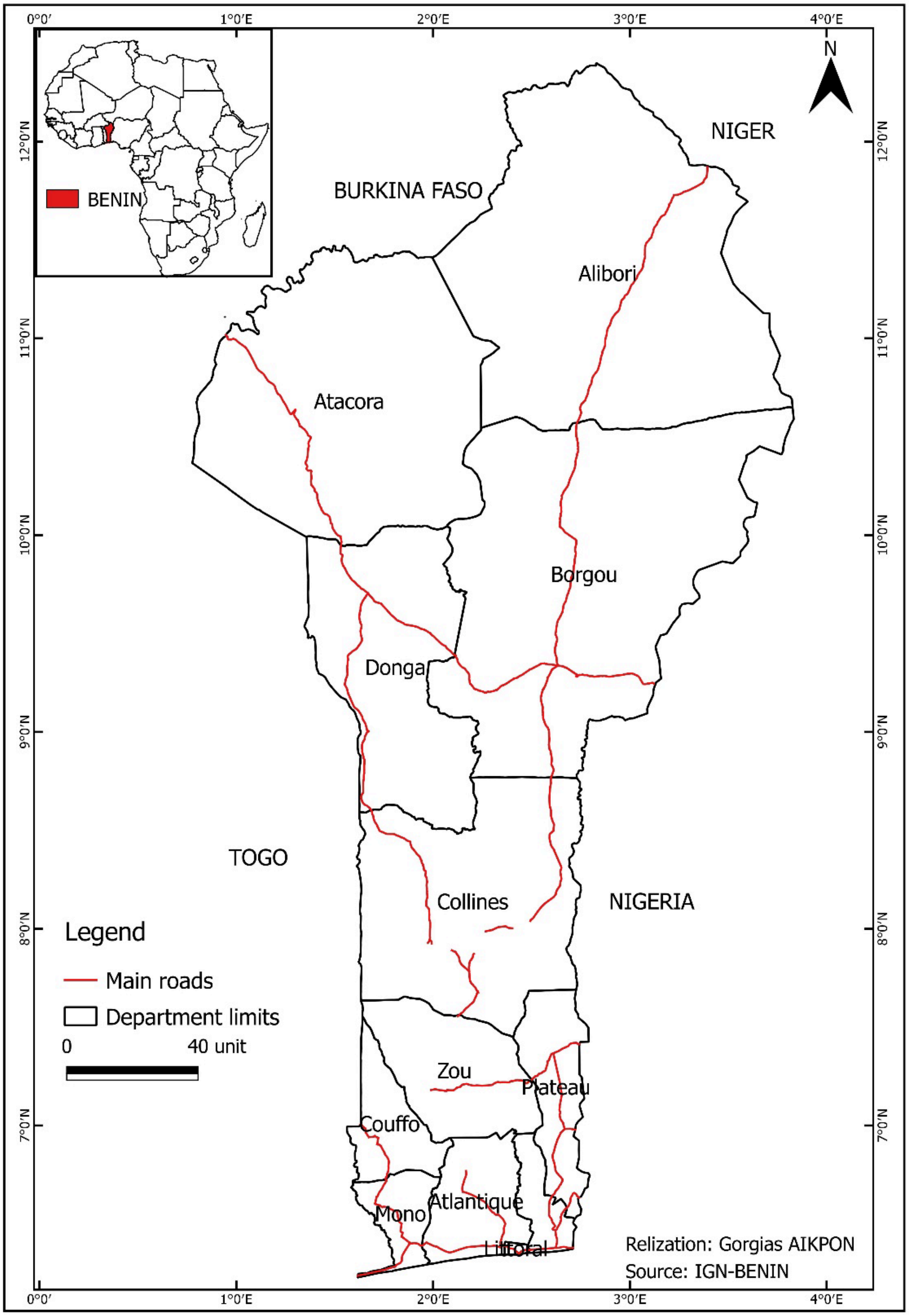

Figure 1

Location map of Benin

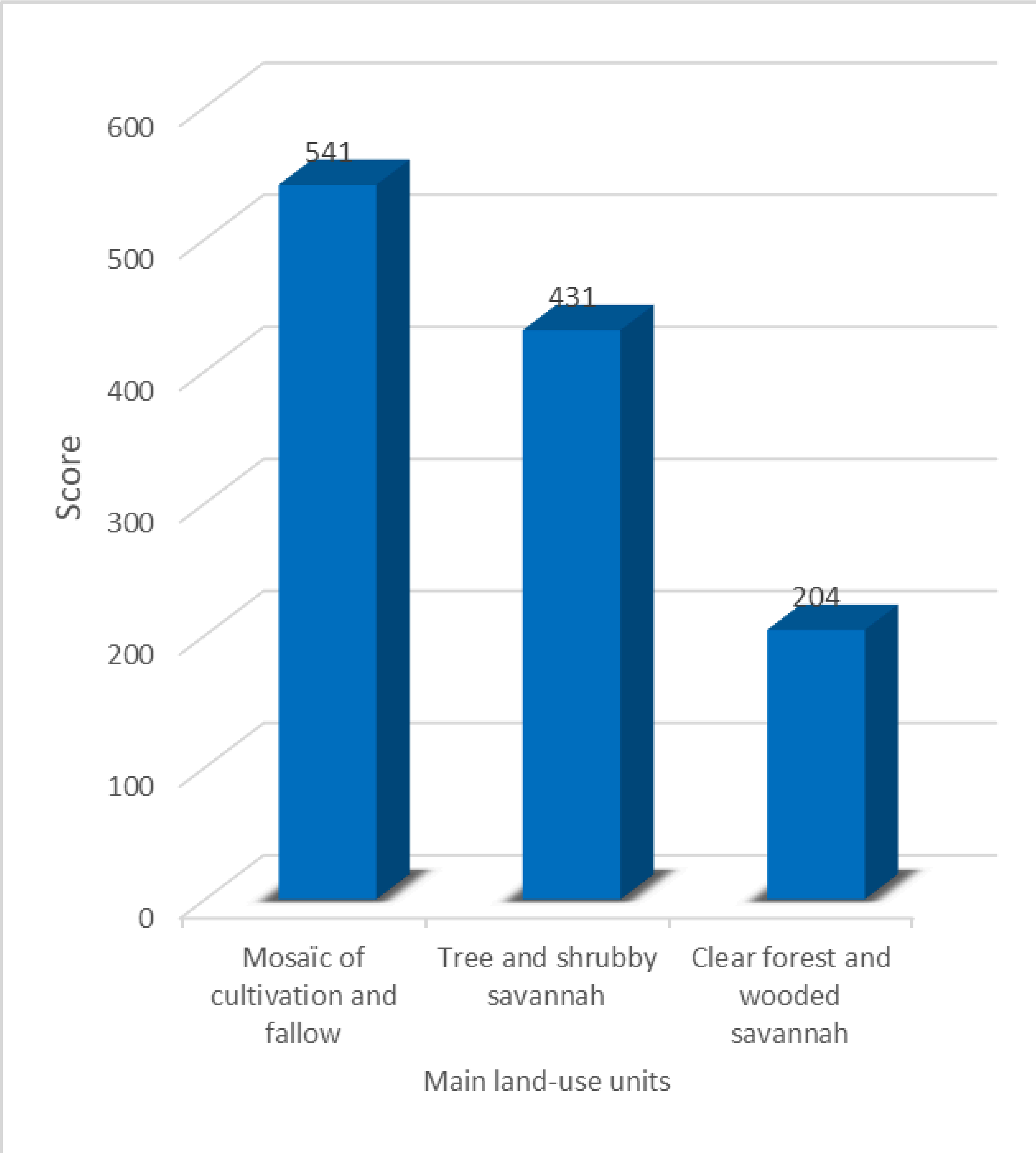

Figure 2

Main land use units favouring the invasion of Chromolaena *odorata*

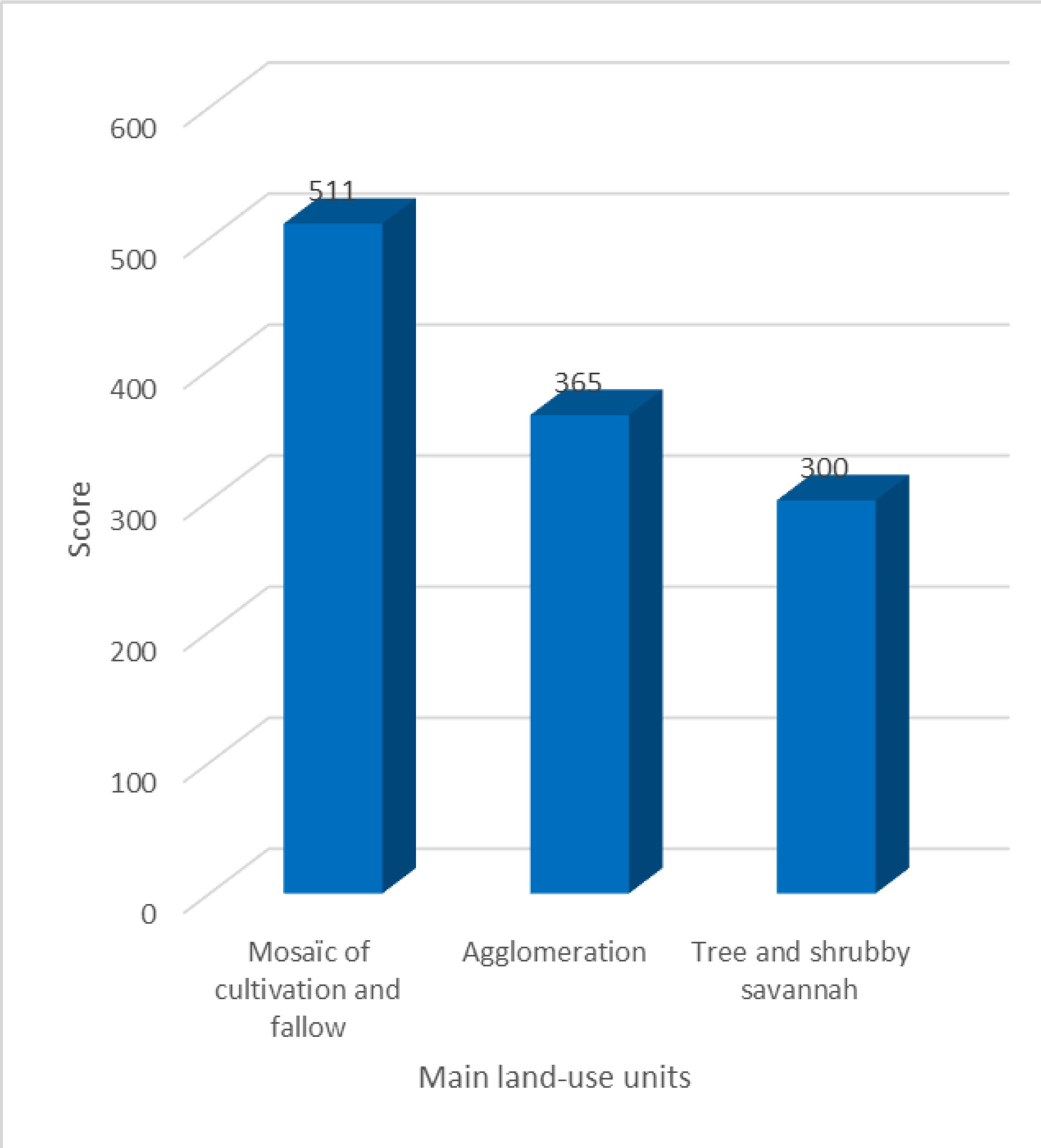

Figure 3

Main land use units favouring the invasion of *Mesosphaerum suaveolens*

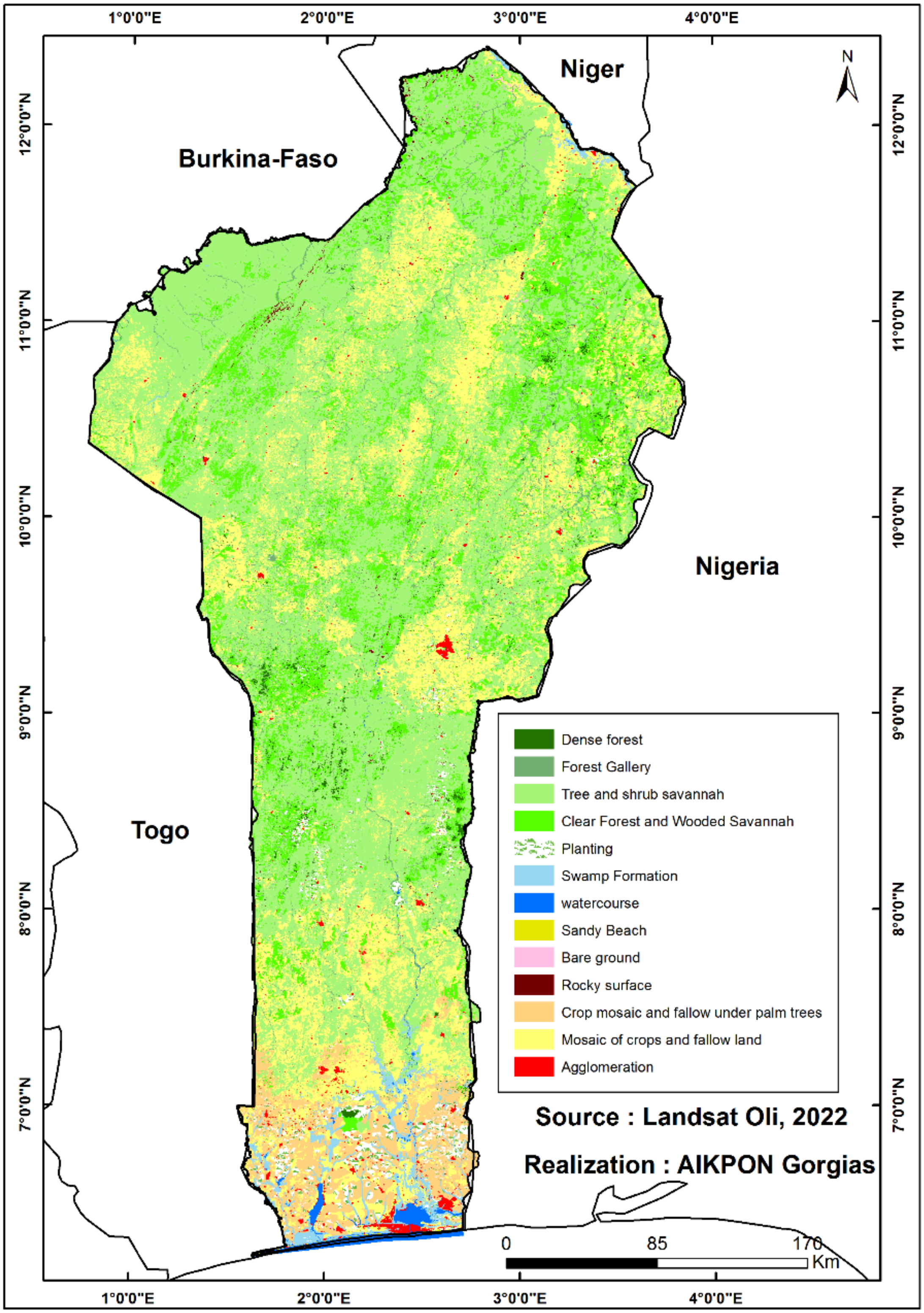

Figure 4

Map of land-use units (Landsat, 2022)

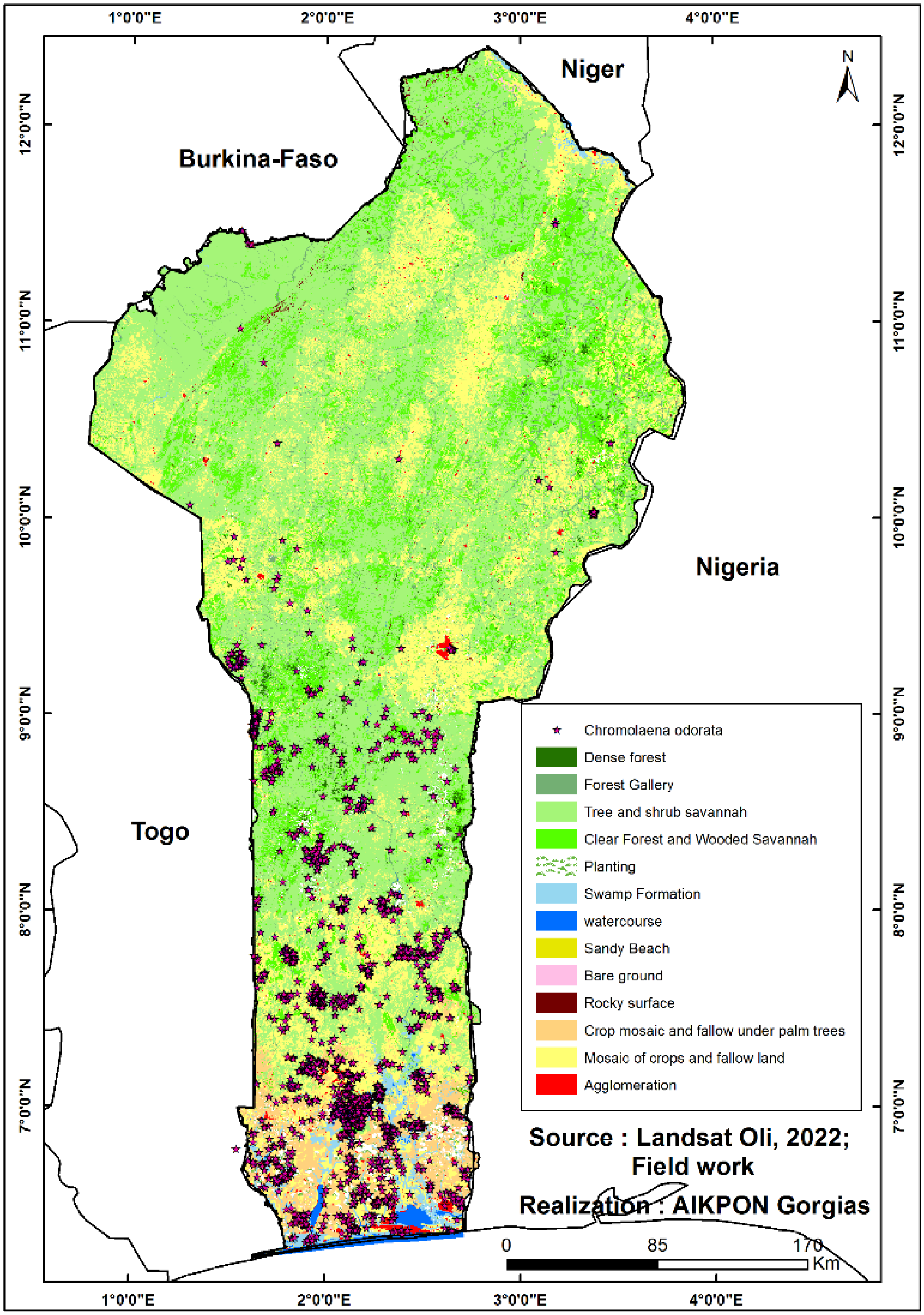

Figure 5

Projection of *Chromolaena odorata* occurrence data on land-use units

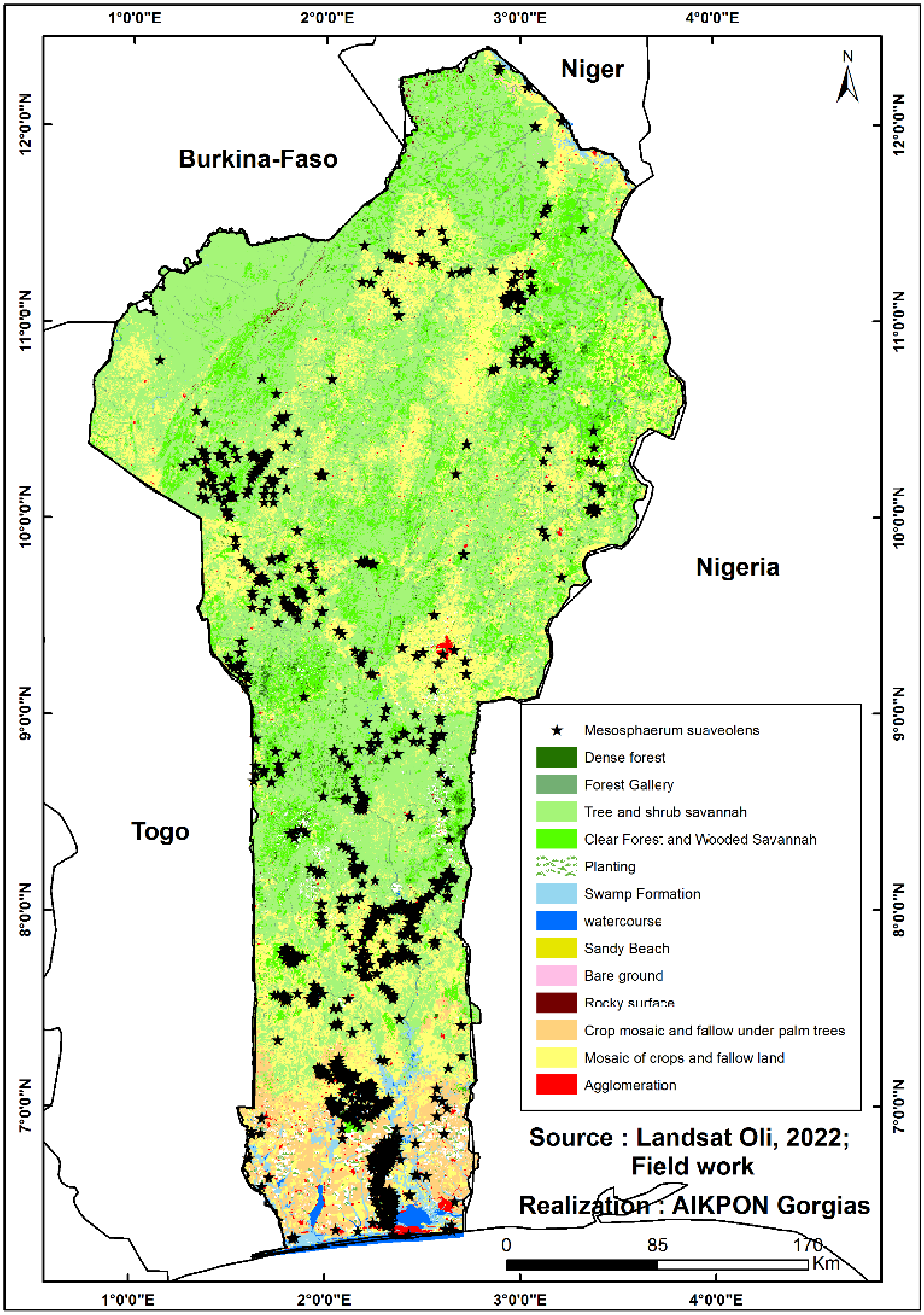

Figure 6

Projection of *Mesosphaerum suaveolens* occurrence data on land-use units

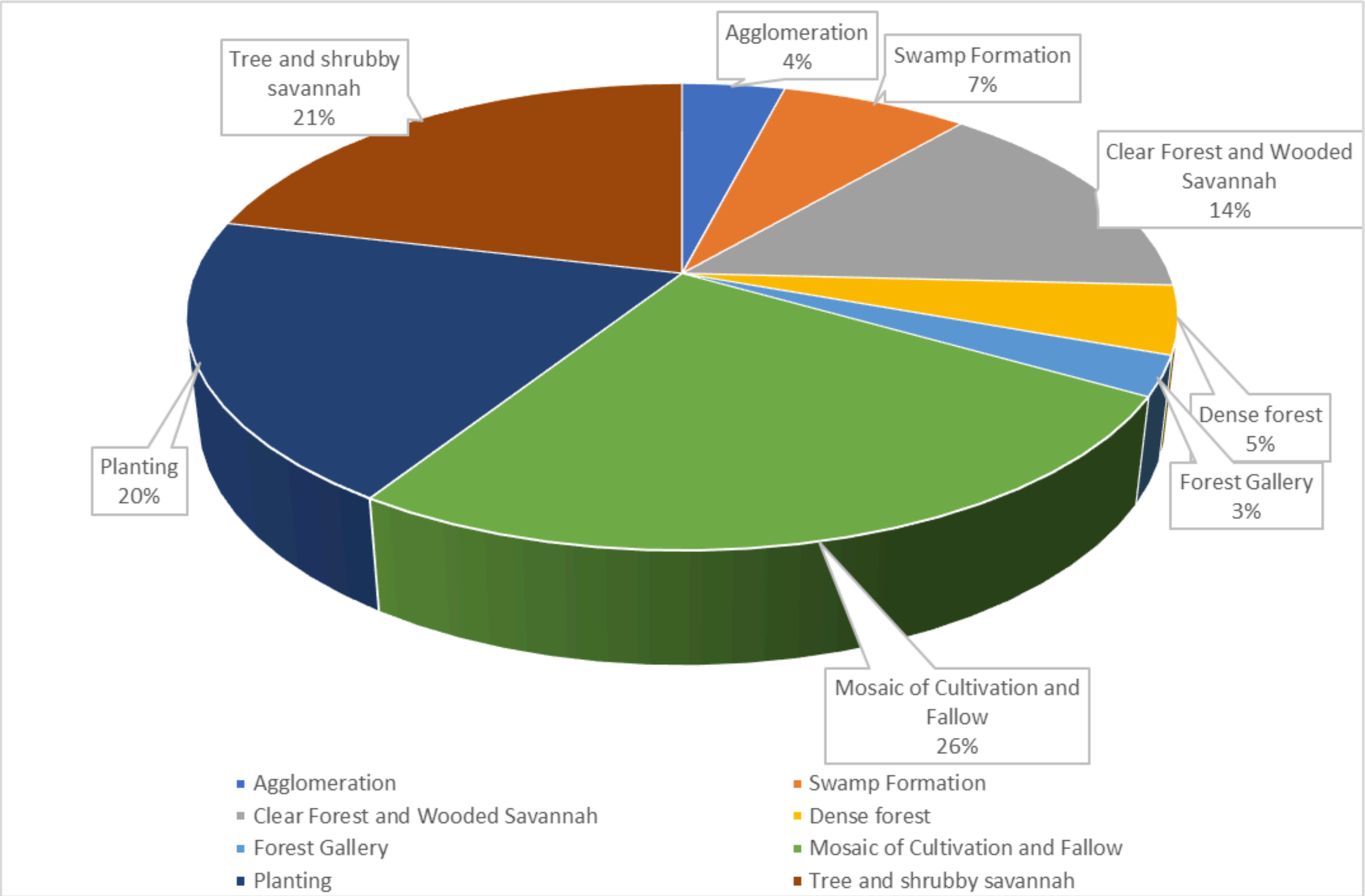

Figure 7

Distribution of *Chromolaena odorata*occurrence data by land-use unit

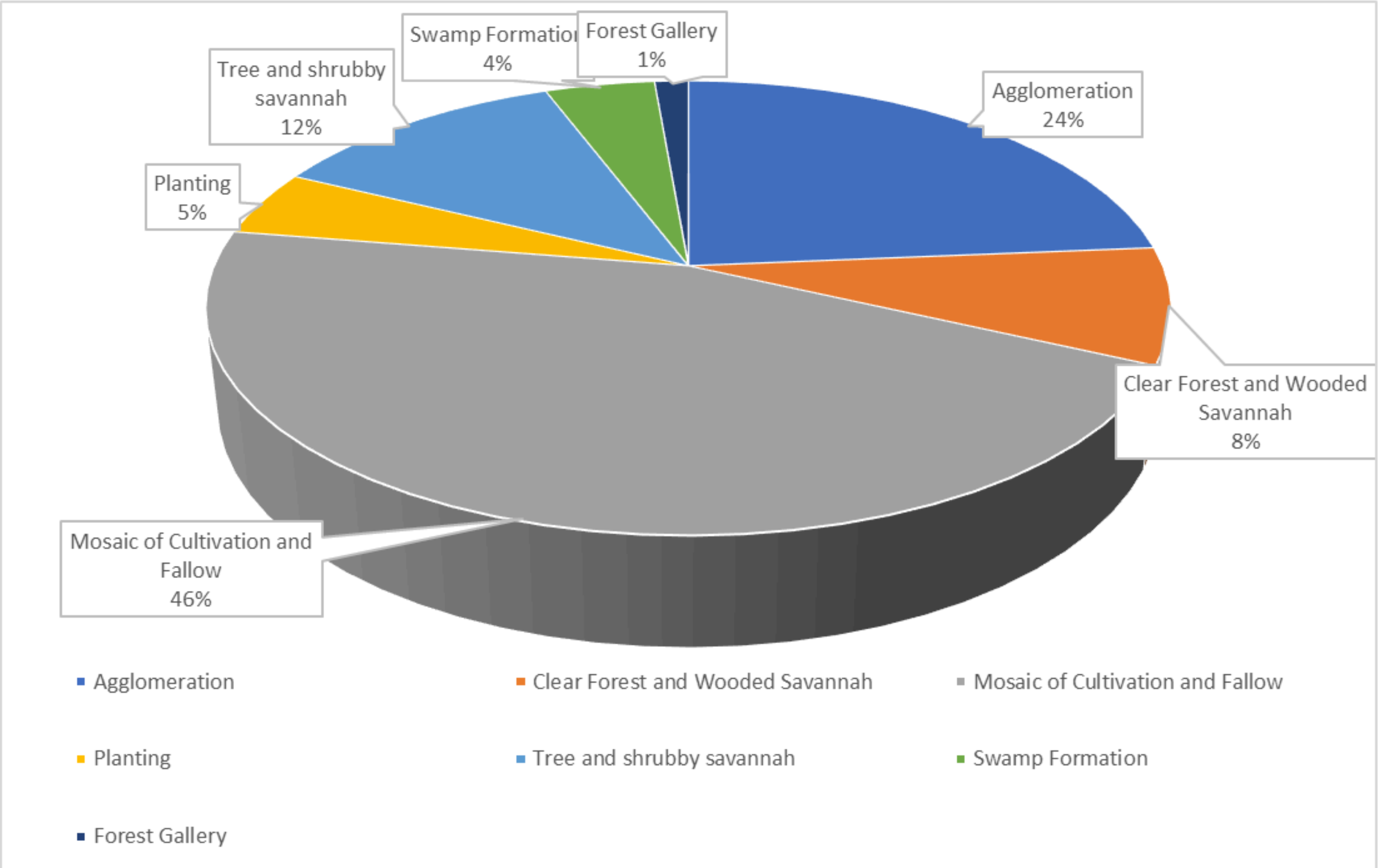

Figure 8

Distribution of *Mesosphaerum suaveolens* occurrence data by land-use unit

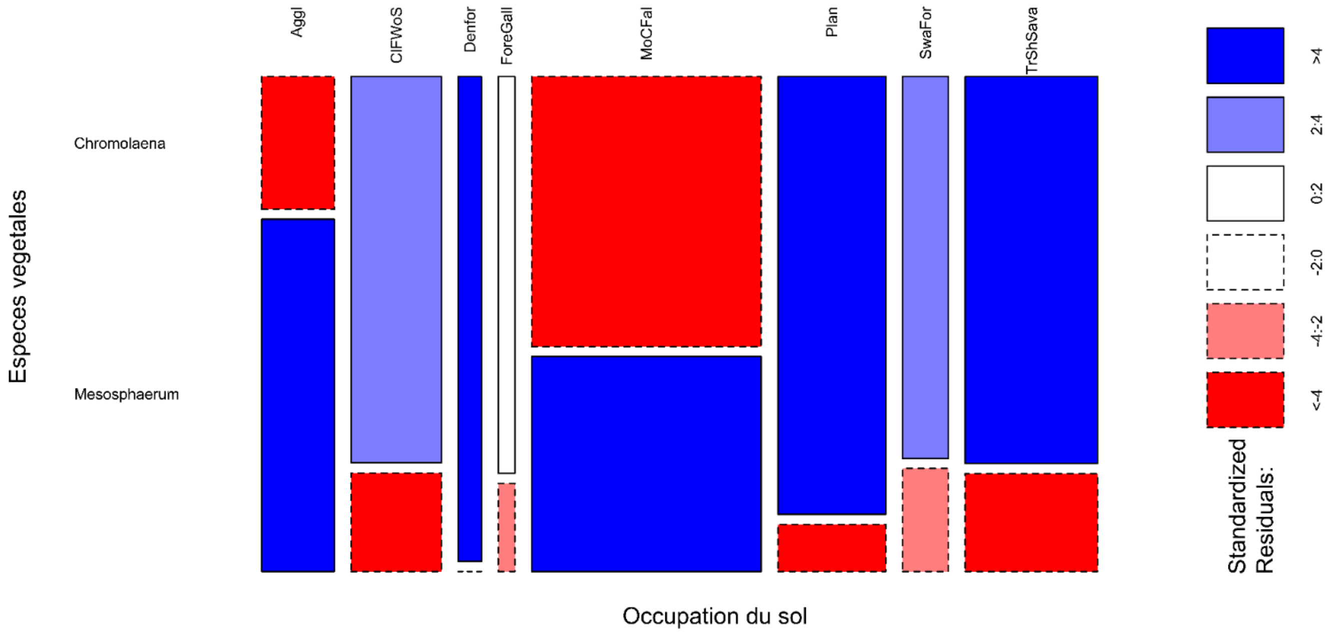

Figure 9

Relationships between *Chromolaena odorata* and *Mesosphaerum suaveolens* and the land-use units

Aggl: Agglomeration; SwaFor: Swamp Formations; ClFWoS: Clear Forest and Wooded Savannah; DenFor: Dense Forest; ForeGall: Forest Gallery; MoCFal: Mosaïc of Cultivation and Fallow; Plan: Planting; TrShSava: Tree and Shrubby Savannah.