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Research article

Effect of landuse on floristic composition and diversity of medicinal plants in the Guinea Savanna zone of Ghana

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ABSTRACT

The use of medicinal plants is the most accessible primary health care approach in rural communities with limited infrastructure for western medicine. Medicinal plants are therefore an integral component of traditional medicine in Ghana, but wild bushes where medicinal plants regenerate naturally are being converted to alternative landuse. Although most landuse changes are destructive to biodiversity, some indigenous land use systems are known to be environmentally friendly. The present study examined the diversity and abundance of medicinal plants in three landuse types (Protected Area, Fallow land and Farmland) of northern Ghana. Twenty-five quadrates of 30 × 30 m were randomly laid in each landuse and replicated in three communities. Leguminosae, Combretaceae and Rubiaceae occurred as the most dominant medicinal plant families in all landuse but woody plants were significantly abundant in protected areas ($p = 0.001$). Species richness, Shannon diversity index, alpha and gamma diversities were all higher in the protected areas. Species composition also varied between landuse in beta diversity ($p = 0.005$, $r^2 = 0.33$). Medicinal plant population have reduced significantly in farmlands, farmers should therefore adopt agroforestry practices to help conserve medicinal plant biodiversity.

1. Introduction

Indigenous health care system has been the main approach to treating ailments in Africa prior to the inception of western medicine (Abbiw 1990; Pan et al., 2014). An estimated 80% of the rural population in developing countries depend on medicinal plants for primary health care needs (WHO, 2017). The use of medicinal plants is particularly high among countries with low doctor patient ratios (Essegbey 2014). Aside easy access to medicinal plants, they are less expensive and most effective in treatment of some ailments (Voice of America News Bulletin 2006; Lucas 2010; Khan et al., 2011; WHO 2017).

The knowledge and practice of traditional healing is often linked with traditional beliefs which constitutes an integral part of culture. Although practitioners learn through the informal system, the practice of herbal medicine has grown into a large industry employing an estimated 40,000 practitioners in Ghana (Ghana Federation of Traditional Medicine Practitioners' Association, 2021). Many others are employed in the trade and marketing of herbal medicine which contributes to the socio-economic development of the country. The conservation of medicinal plants is therefore essential to the sustainability of traditional health care as well as livelihoods (Sarpong et al., 2018).

The Guinea savanna zone of Ghana, is endowed with diverse medicinal plant families (Ziblim et al., 2013) but anthropogenic disturbances such as logging and indiscriminate felling of trees are depleting the vegetation beyond its natural recovery (Aabeyir et al., 2016; Moomen and Dewan, 2016; Owusu and Essandoh-Yeddu, 2018). Despite the vulnerability of savanna ecosystems to bushfires, human induced bushfires are frequently recorded in the dry season which limits natural regeneration (Amoako et al., 2018). The changing landuse patterns with increasing expansion of agricultural land equally have negative impacts on plant biodiversity (Abunyewa et al., 2015; Agana et al., 2018; Amoako et al., 2018). Protected area is known to be one of the dominant landuse in semi-arid regions of West and Central Africa dedicated for the protection of flora and fauna (FAO, 2019). However, agricultural landuse is expanding rapidly at the expanse of the protected areas. Owing to this, change in landuse patterns is identified as a driver of woodland degradation in northern Ghana (Abunyewa et al., 2015; Agana et al., 2018).

Unlike protected areas that are characterised by in-situ conservation of biological resources, agricultural landuse starts with opening of dense

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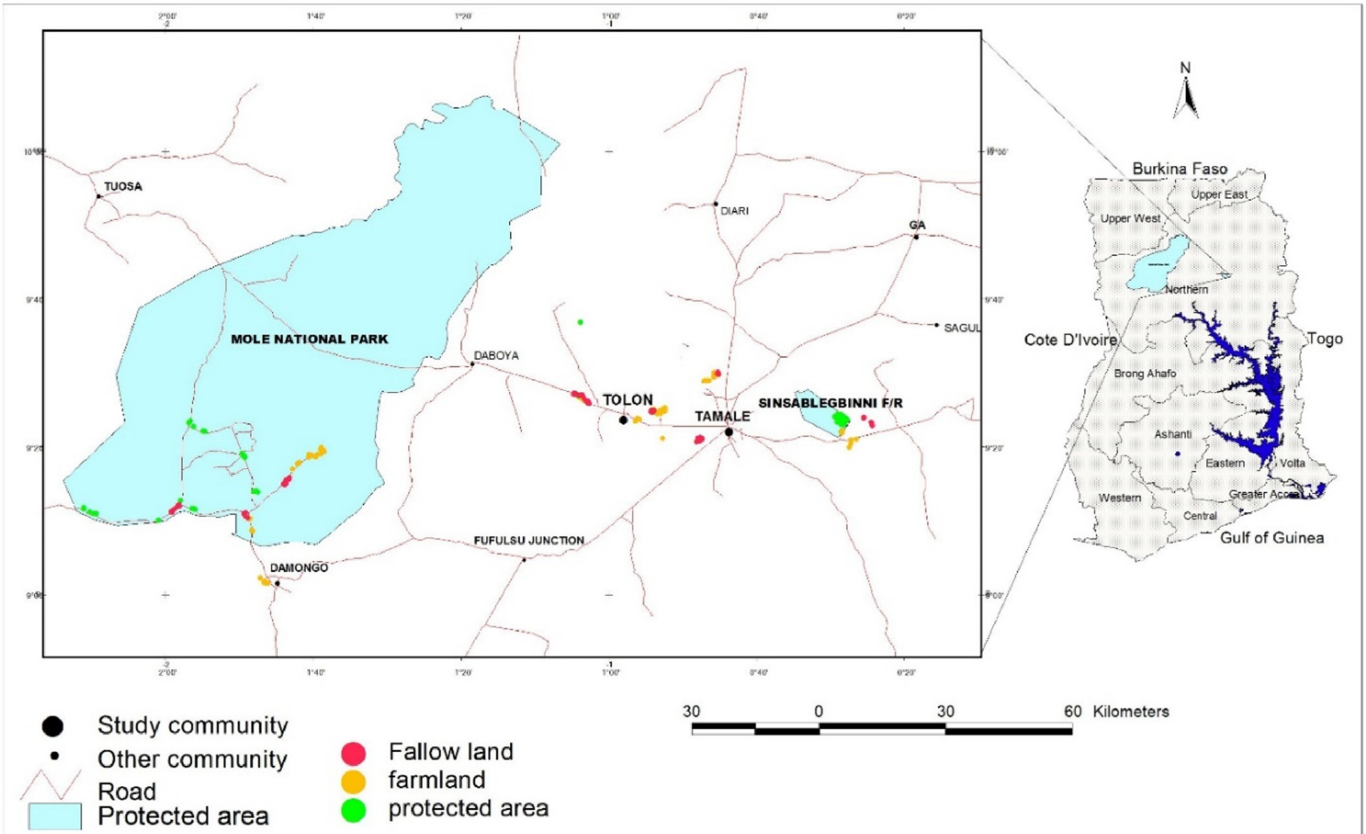

Figure 1. Map of the study area.

woody cover in land clearing (Nacoulma et al., 2011). This destructive land clearing however occurs concurrently with the recruitment of multipurpose trees and shrubs which are later retained and managed on the farmlands for medicinal and economic uses. This creates a traditional agroforestry system of indigenous trees intercropped with annual crops often termed as "agroforestry parklands". Although most landuse systems are destructive to biodiversity, some indigenous landuse systems particularly sacred groves contribute to biodiversity conservation (Khan et al., 2008).

Sacred groves are revered areas protected by customary laws which occurs as forest patches owned by a clan, community, or ethnic group (Aniah and Yelfaanibe 2016). Sacred groves have contributed significantly to biodiversity conservation serving as the only remnants of the original vegetation in some areas (Khan et al., 2008). They provide refuge for many endangered species of ecological and medicinal importance (Shengji 2010). Exploitation of biological resources in sacred groves is either forbidden or regulated by traditional beliefs and taboos (Van Andel 2010).

As land management practices are unique to landuse type, we hypothesised that medicinal plant diversity and abundance would differ significantly between landuse types. Research in the savanna zone of Ghana have focused extensively on the exploitation of economic fruit trees such as *Vitellaria paradoxa* (Naami and Naami 2018; Tom-Dery et al., 2018; Asare et al., 2019) with limited information on medicinal plants. The present study assessed the effect of different landuse systems on the floristic composition, abundance and diversity of medicinal plants.

2. Materials and methods

2.1. Study area

The study was conducted from June to November 2019 in three (3) districts (West Gonja, Tolon and Tamale Metropolitan districts) where Damongo (9° 5′ 0″ N, 1° 49′ 0″ W), Tolon (9° 26′ 0″ N, 1° 4′ 0″ W) and Tamale (9° 24′ 30.31″ N, 0° 50′ 25.63″ W) are the district capitals, respectively. The Tolon district and Tamale Metropolis are located in the Northern Region whilst the West Gonja District is located in the Savanna Region of Ghana. In each district, one community with the three landuse (Cultivated Land, fallow land, and protected area) was selected for the study. The Mole National Park and Kenikeni Forest Reserves are in the West Gonja district, whilst Sinsablegbinni Forest reserve and the Chinfoyiri sacred grove are in the Tamale and the Tolon Districts, respectively (Figure 1).

The mean monthly maximum temperature (35 °C) is recorded in March/April whilst the minimum monthly temperature (22 °C) is recorded in December/January (Savanna Agriculture Research Institute 2016). The dry season is characterized by the harmattan wind, which is dry, dusty and cold in the morning and warm at noon. Rainfall is unimodal with the annual mean rainfall ranging from 800 to 1200 mm. Peak rainfall occurs in June/July with a prolonged dry spell in August.

The vegetation of the area is predominantly grassland interspersed with some woody species. Some of the most common indigenous woody species include *Vitellaria paradoxa* (shea), *Adansonia digitata* (baobab), *parkia biglobosa* (dawadawa), *Pterocarpus erinaceus* (rosewood) and others (Savanna Agricultural Research Institute, 2004).

2.2. Inventory of medicinal plants

A stratified randomized design was used to lay a total of two hundred and twenty-five (225) quadrats of 30 × 30 m each consisting of twenty-five (25) nested quadrats per landuse in each community. Nine (9) experimental sites in three (3) communities (Mognori, Tolon and Tugu) and three (3) levels of land-use type (Protected Area (PA), Fallow land (FL) and Farmland (FA)) (Figure 2(a–c)). In each nested quadrat, 5 m × 5

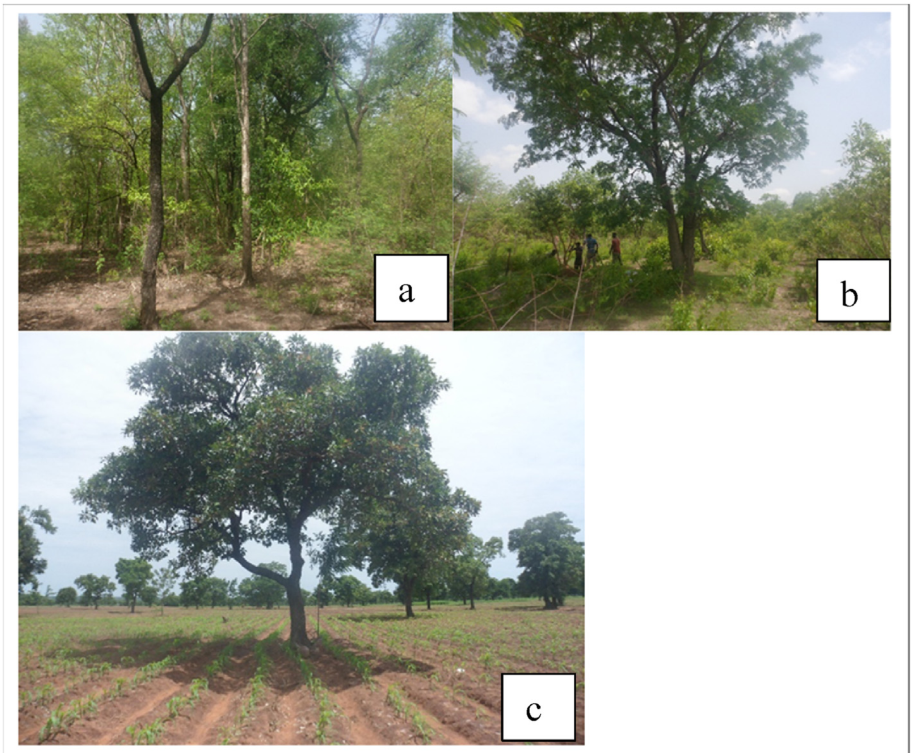

Figure 2. Land-use types in the Guinea Savanna zone of Northern Ghana: a = protected area; b = fallow land and c = farmland.

m and 1 m × 1 m quadrats were laid to assess shrubs and herbaceous or ground cover medicinal plant species respectively.

Each sample plot was systematically surveyed, the medicinal plant species were recorded, and voucher specimens of the plants used as medicines were collected and sent to the Herbarium of Faculty of Agriculture, University for Development Studies (UDS) for identification by a plant taxonomist. The nomenclature of species followed the International Plant Names Index (http://www.ipni.org) and the Plant List (http://www.theplantlist.org).

2.3. Data analysis

The Basal area (Eq. 1), Relative Dominance (Eq. 2), Relative Density (Eq. 3), Frequency (Eq. 4), and Relative Frequency (Eq. 5) of medicinal plants were estimated and compared between landuse parameters:

$$\textit{Basal Area} = \frac{\pi D^2}{4} \tag{1}$$

where D is the Diameter at breast height (1.3 m).

$$\textit{Relative Dominance}\ (RDo) = \frac{\text{Total basal area of species}}{\text{Total basal area of all species}} \times 100 \tag{2}$$

$$\textit{Relative Density}\ (RD) = \frac{\text{Number of individuals of a species}}{\text{Total number of all individuals}} \times 100 \tag{3}$$

$$\textit{Frequency}\ (F) = \frac{\text{Total Number of Quadrats in which a species occur}}{\text{Total number of quadrats}} \times 100 \tag{4}$$

$$\textit{Relative Frequency}\ (RF) = \frac{\text{The frequency of a species}}{\text{Sum of all frequencies}} \times 100 \tag{5}$$

Shannon's diversity index (H) and Pielou's evenness (J) were calculated using the following formulae:

Shannon's diversity index, (H)

$$\mathrm{H} = -\sum_{i=1}^{s} p_i \varepsilon p_i$$

where S = the total number of species in the community (richness), p_i = the proportion of S made up of the ith species or the relative abundance.

Pielou's evenness (J)

$$\mathrm{J} = \frac{\mathrm{H}}{\log S}$$

Additionally, Alpha, Beta and gamma diversities were calculated using the method of Whittaker (1972). Alpha diversity is the average species richness per plot, beta diversity is a measure of heterogeneity in the medicinal plant community data and gamma diversity is the estimated number of species across each treatment. The diversity indices (species richness, Shannon and evenness) for each quadrat and the alpha, beta and gamma diversities for each treatment were calculated using the "vegan" package (Oksanen 2015; Oksanen et al., 2015) in the statistical software R version 3.4.1 (R Core Team, 2017).

Bray-Curtis indices were used for analysis of similarity (ANOSIM) based on 999 permutations to compare the difference in medicinal plant species composition among land-use types in each community. Significance was determined at a 95% confidence interval ($p < 0.05$). Also, Permutational multivariate analysis of variance (PerMANOVA) using the "adonis" function in the "vegan" package (Oksanen 2015) was used to test the effects of land-use type and community on the medicinal plant species composition in each treatment. To visualize the differences in

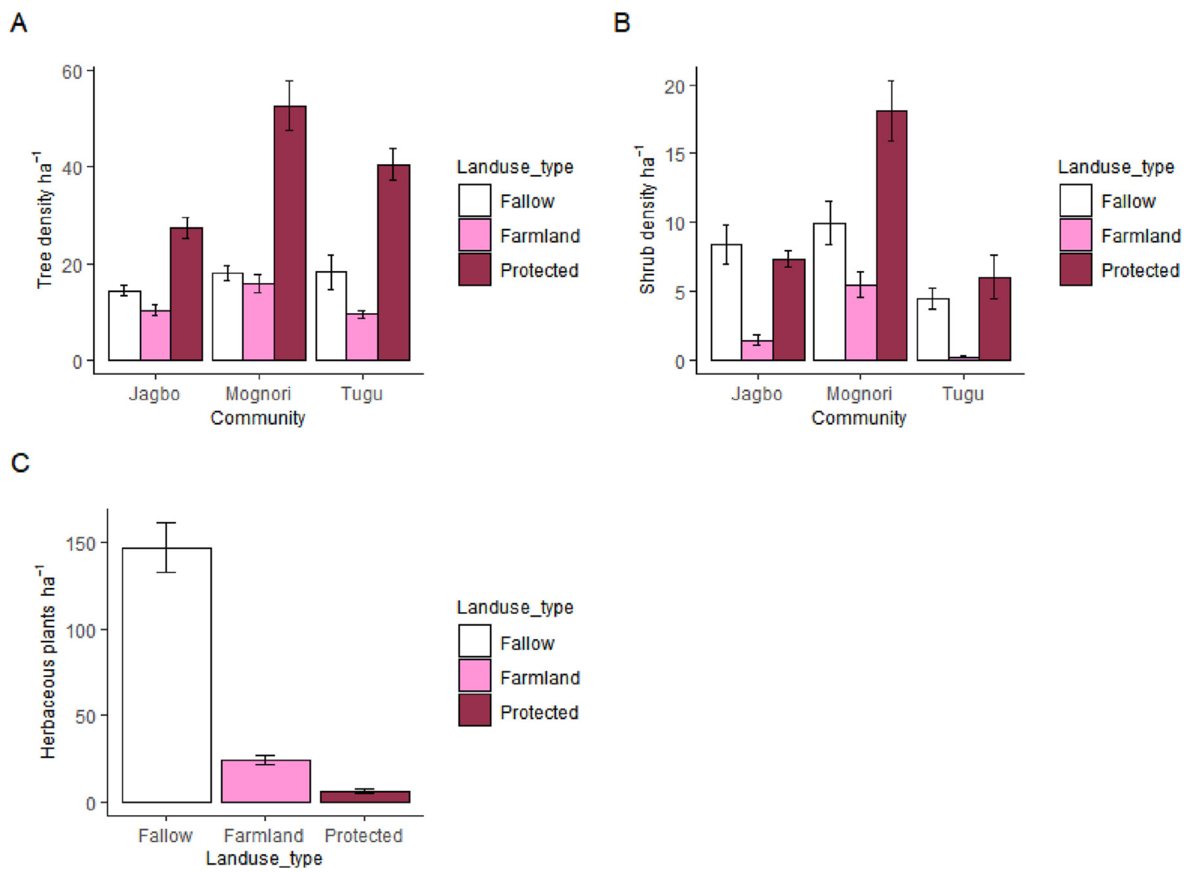

Figure 3. Interaction plot of medicinal plants densities (mean ± se) of A. Trees B. Shrubs in various communities and land-use types and C. Main effect plot of herbaceous plants in land-use types. Significance level $p < 0.05$.

species composition in the experimental sites, the function 'metaMDS' was used to create a non-metric multidimensional scaling (NMDS) plot. The NMDS is a useful ordination procedure for ecological community data analysis since it is devoid of the linear constraints that limit many of the ordination methods (McCune et al., 2002; Jenerette et al., 2016). Variable distributions that did not meet the assumptions of normality (abundance of tree, shrubs and herbaceous medicinal plants) were subjected to negative binomial regression under the Generalized Linear Model (GLM) at a significance level of 5%. Statistical analyses were performed with the software R version 3.4.1(R Core Team, 2017)).

3. Results and discussions

3.1. Landuse influence on floristic composition of medicinal plants

A total of 34,782 individual medicinal plants, belonging to 119 species, 100 genera and 46 families were identified. These were distributed in five life forms; trees (61.2%), herbaceous plants (26.6%), shrubs (9.8%), creepers (2.1%) and lianas (0.4%). The family Leguminosae (29 species), Combretaceae (9 species), and Rubiaceae (8 species) were the three most abundant plant families in the area. The occurrence of Leguminosae, Combretaceae and Rubiaceae among the most dominant medicinal plant families was equally reported in previous studies (Antwi et al., 2018). Aside from medicinal properties, the leguminous plants such as *P. biglobosa, P. africana, Faidherbia albida, Tamarindus indica* and *Detarium microcarpum* are frequently retained and managed on farmlands for their multipurpose uses including fuelwood, fodder for livestock and food values (Mustapha and Benisheikh 2019). The role of legumes in nitrogen fixation could have also contributed to their conservation in farmlands accounting for the dominance of Leguminosae.

3.2. Abundance of medicinal plants under different landuse types

The interaction effect between Land-use type and community had a significant influence on the abundance of medicinal tree plants ha^{-1} ($p = 0.020$) as well as medicinal shrubs ha^{-1} ($p = 0.000$). However, there was no significant interaction ($p = 0.342$) effect of land-use type and community on the abundance of herbaceous medicinal plants. Nonetheless, the main effect of landuse on medicinal plants was also abundance of herbaceous plants was significant ($p = 0.000$) (Figure 3c). Generally, the Protected areas had a higher abundance of medicinal plants compared to the agroforestry parklands (Fallow and farmlands) for all life forms except the herbaceous plants.

The relatively higher abundance of medicinal woody plants (trees and shrubs) in protected areas than other landuse is consistent with previous studies (Antwi et al., 2018; Adjossou et al., 2019). Similarly, higher abundance of herbaceous plants on farmlands was recorded in other studies (Leßmeister et al., 2019). Thus, the hypothesis that land-use type would have an impact on the abundance of medicinal plants was confirmed in this study. The differences in the abundance of medicinal plants observed were a result of the differences in the impact of the land-use types. For instance, the exploitation of plant resources in PA is restricted with limited anthropogenic disturbances accounting for a higher abundance of medicinal woody plants. On the contrary, landuse in off-reserve is poorly regulated resulting in the degradation of plant resources due to mining, logging, fuelwood collection, annual fires and overgrazing (Moomen and Dewan, 2016; Agana et al., 2018; Amoako et al., 2018; Dumenu, 2019).

Additionally, the intensive but low input agricultural activities, land clearing using manual and herbicides, persistent removal of the above−ground biomass for fodder, harvesting of fuelwood and poles for construction perhaps all contributed to the decline in medicinal plants in

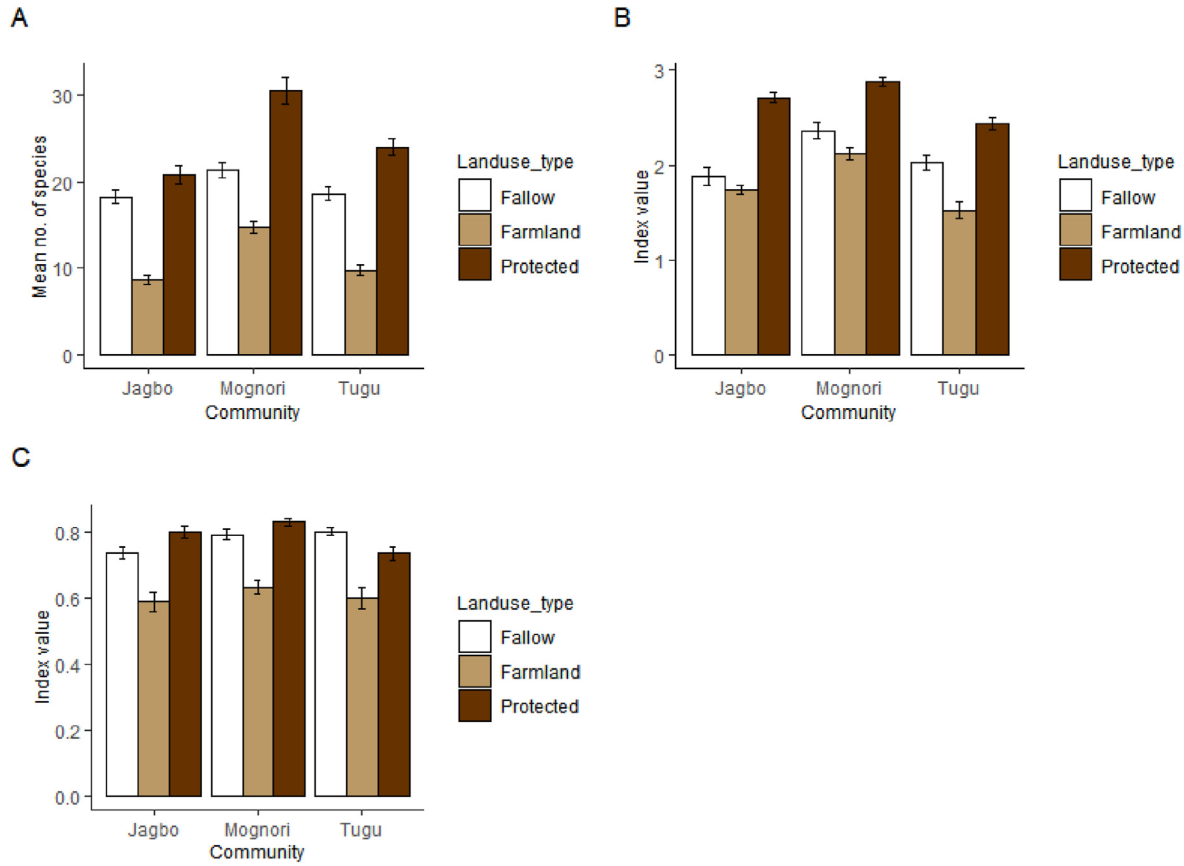

Figure 4. (a–c): Bar plots (mean ± se) of land-use types in three communities. A. Species richness (S), B. Shannon-Wiener diversity index (H) and C. Pielou's evenness (J) of medicinal plants.

unprotected areas. Other studies have indicated that the low input agriculture with the removal of crop residues and annual burning has degraded the soils in the farmlands. This has considerably reduced the seedling recruitment and establishment of medicinal plants (Abunyewa et al., 2015; Agana et al., 2018).

3.3. Diversity of medicinal plants under different landuse types

The interaction between Land use type and community significantly influenced ($F_{4,\ 216} = 3.403$, $p = 0.010$) medicinal plant species richness. The highest species richness (30.44 ± 1.54) occurred in protected area of Mognori whilst the least (8.64 ± 0.48) was recorded in Farmlands of Tugu (Figure 4). In Mognori, the species richness of medicinal plants in PA was significantly higher ($p = 0.000$) than that of the Fallow and Farmlands. However, in Jagbo, species richness did not differ significantly between protected areas and fallow lands ($p = 0.553$). Species richness also varied considerably across communities in all the land-use types except in the FL ($p = 0.257$).

There was a significant interaction effect ($F_{4,\ 216} = 2.867$, $p = 0.024$) between land-use type and community on the Shannon-Wiener index of medicinal plant species. The highest Shannon-Wiener index (2.87 ± 0.05) was recorded in protected area of Mognori whilst the least (1.53 ± 0.09) was recorded in farmlands of Tugu (Figure 4b). The Shannon-Wiener index of medicinal plants in the PA was significantly higher ($p = 0.003$) than the FL and FA across the three communities but there was no significant difference between FL and FA ($p = 0.000$) except Tugu community.

The Pieolu's evenness of medicinal plants showed a statistically significant interaction ($F_{4,216} = 2.787$, $p = 0.028$) between land-use type and community. The evenness ranged from 0.59 ± 0.03 in the Tugu FA to 0.83 ± 0.01 in the Tugu PA (Figure 4c). The evenness in the FA was significantly lower ($p = 0.000$) than the PA and FL lands across the communities.

Table 1. Species diversity of medicinal plants in three (3) communities under different land-use types in the Guinea Savanna zone of Northern Ghana.

Treatment	Alpha	Beta	Gamma
Mognori PA	30.44	2.29	100
Mognori FL	21.36	2.65	78
Mognori FA	14.72	2.87	57
Jagbo PA	23.96	1.84	68
Jagbo FL	18.56	2.13	58
Jagbo FA	9.8	2.57	35
Tugu PA	20.76	1.50	59
Tugu FL	18.24	2.23	52
Tugu FA	8.64	2.47	30

Alpha diversity ranged from 8.64 in the Tugu FA to 30.44 in the Mognori PA. The highest gamma diversity was recorded in the Mognori PA (100) and the least was in the Tugu FA (30). Generally, alpha and gamma diversities in the PA was higher than the FL and FA across the three communities whilst beta diversity was lowest in the PA (Table 1). The ANOSIM showed a significant difference (global R = 0.60, $p = 0.000$) in the species composition of medicinal plants under different land-use types. Similarly, permutational multivariate analysis of variance (PERMANOVA) also showed significant difference ($F_{8,216} = 3.431$, $p = 0.001$) in the composition of medicinal plant species between land-use types.

A non-metric multidimensional scaling (NMDS) revealed that the composition of the assemblages of medicinal plants differed most strongly between PA and FA, whereas the composition of FL lands was

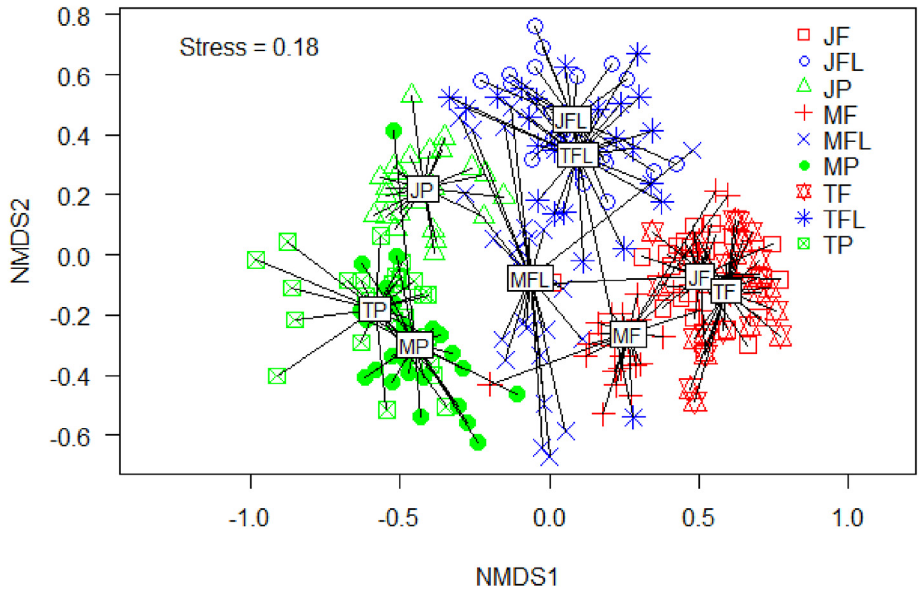

Figure 5. Non-metric multidimensional scaling (NMDS) based on dissimilarities calculated using the Bray–Curtis index of medicinal plants species composition for the relative abundance of the treatments. MP = Mognori protected area, MFL = Mognori fallow, MF = Mognori farmland, JP = Jagbo protected area, JFL = Jagbo fallow, JF = Jagbo farmland, TP = Tugu protected area, TFL = Tugu fallow, TF = Tugu farmland.

intermediate between these two extremes (Figure 5). A stress value of 0.18 obtained indicates a good representation.

The general high diversity of medicinal plants in PA is consistent with other studies where higher abundance, species richness and evenness of plant species in PA was higher than the other land-use types (Adjossou et al., 2019). According to the intermediate disturbance theory, the species diversity of medicinal plants would be expected to increase with an intermediate disturbance (Bongers et al., 2009). Particularly, it would facilitate the establishment of herbaceous and early-stage species or short-lived annuals (therophytes) with high growth and reproductive rates.

However, high-intensity disturbance will destroy even the hardiest species resulting in low species richness (Yuan et al., 2016). There is high disturbance (bush fires, manual and chemical weed clearing and overgrazing) on FA coupled with long drought periods. These factors accounted for the low abundance, species richness and Shannon-Wiener and evenness in Farmlands.

The homogenous distribution of medicinal plants in the FL and FA may be explained by the fact that some specific economic species *Vitellaria paradoxa, Parkia biglobosa*, *Khaya senegalensis, Diospyros mespiliformis* and *Detarium microcarpum* are often conserved on the FAs accounting for their dominance in woody species. This indicates that seedling recruitment of several medicinal plant species might be destroyed by the annual fires, manual clearing and the use of herbicides. In the FL, seedling recruitment may be low due to the dense grass layer which has depressing effect on the survival of woody seedlings due to competition for nutrients and light (Syampungani et al., 2019).

It was revealed that due to a high level of disturbance, the agroforestry parklands recorded lower alpha and gamma diversities than the PA across the three communities. However, beta diversity in the FA was higher than in the FL and PA. This could probably be due to the intensification of farming activities that reduces the abundance and species diversity of medicinal plants because many species are removed during the farming season and only a few multipurpose woody species are conserved on FA. When high-intensity land use reduces the total abundance of many medicinal plant species across the assemblage, beta-diversity can increase as species turnover increases (Socolar et al., 2016).

4. Conclusion

The study concludes that intensive land-use impacted negatively on the abundance, diversity and species composition of medicinal plants. The highest medicinal plant diversity and abundance occurred in protected areas whilst the least diversity occurred in farmlands. This suggests that the protected areas appear to be the best option for conservation. However, field observations revealed that the protected areas are being encroched due to population pressure and demand for medicinal plants, timber, fuelwood and other forest resources.

Therefore, there is the need to put in place measures to conserve medicinal plants in protected areas for continued supply and availability. In the farmlands, agroforestry practices could be diversified for the conservation of medicinal plants and sustainable crop production. Additionally, home gardens could be established to conserve medicinal plants around settlements.

Declarations

Author contribution statement

Samuel Owusu Yeboah: Conceived and designed the experiments; Analyzed and interpreted the data; Performed the experiments; Wrote the paper.

Latif Iddrisu Nasare: Analyzed and interpreted the data; Wrote the paper.

Akwasi Adutwum Abunyewa: Analyzed and interpreted the data; Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data.

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Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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