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# Abundance, richness and use of medicinal plants under different land uses in the Guinea Savanna zone of Northern Ghana

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## ABSTRACT

Change in land use affects the conservation of medicinal plants. We assessed the abundance and richness of medicinal plants under different land-use systems in Ghana. The land-use types consisted of protected area (PA), Fallowed Land (FL) and Farmed area (FA). A total of 45 quadrats (30 m × 30 m) were laid randomly and medicinal plants identified. Soil samples (0–15 cm) were also collected from nested quadrats for physicochemical analysis. Additionally, ethnobotanical survey of 210 key informants was carried out using Snowball sampling method to identify plant parts used and ailments treated. The result identified 107 species of medicinal plants, and the roots (34.4%) and bark (33.3%) were mostly used. PA had higher ( $P < 0.05$ ) abundance ( $81.75 \pm 6.74$ ) and richness ( $19.80 \pm 0.96$ ) while FA had the least. The principal component analysis (PCA) showed that PC<sub>1</sub> accounted for 48.7% of the variance with abundance (0.8092), richness (0.9168), TN (0.9312) and ECEC (0.7789) positively loaded on it. The PC<sub>2</sub> accounted for 24.1% of the variance in the soil physical properties. We established that integrating medical plants into crops as Agroforestry system can improve their conservation. Our findings have implications for the attainment of the sustainable development goals (SDGs) 3, 13 and 15.

## ARTICLE HISTORY

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## KEYWORDS

Biodiversity; conservation; sustainable development goals (SDGs); fallowed land; agroforestry

## 1. Introduction

A crucial point related to the preservation and protection of our environment is plant species richness and abundance in land-use changes with anthropogenic interventions that usually led to the extinction of native species. Plant species richness and abundance is an essential biodiversity in Africa that provide essential ecosystem goods and services to indigenous livelihoods (Coulibaly et al., 2021; Atumane & Cabral, 2021; Garcia-Vega and Newbold, 2020; Tekalign et al., 2017). Unfortunately, changes in land-use practices have been identified as a major cause of biodiversity loss (Cebrián-Piqueras et al., 2017; Siebert et al., 2021) and are of grave concern in Africa.



It is worth mentioning that the sustainable development goal (SDG) 15.3.1 aims to combat desertification and land degradation and to promote soil and habitat conservation and restoration. Among the key indicators, however, are land-use changes, land productivity and above- and belowground carbon stocks (Pandit et al., 2020). Therefore, knowledge on tree species abundance and richness is critical for sustainable land management, biodiversity conservation (Coulibaly et al., 2021) and the ultimate achievement of SDG 15. For instance, Negash et al. (2012) suggested


that tree species abundance and richness could be affected by land-use types and climate/soil factors. However, there has been few studies to assess the effect of land use on the edaphic (soil) properties and plant species richness, even in recent times (Buhk et al., 2017; Knudsen et al., 2017; Triantafyllidis et al., 2020).

In that regard, Rodrigues et al. (2018) expressed concern about the large knowledge gap regarding the relationship between attributes of plant communities and soil characteristics in the same landscape. They further suggested that future studies need to include the distribution of species and their respective abundances in relation to edaphic (influenced by the soil) variables in order to better understand the processes involved in the soil–vegetation relationship.

It is important to state that there is evidence (Egeru et al., 2019; Nwaogu et al., 2016; Smith et al., 2019) to suggest that tree species could give an indication of differences in soil physicochemical properties.

Therefore, we assessed the abundance and richness of medicinal plants as influenced by variation in the physicochemical properties of soils and land-use types in the Guinea Savanna zone of Northern Ghana. Land-use change and soil conditions may threaten the supply of medicinal plants, especially in semi-arid Savanna zone of Northern Ghana where significant number of

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people depend on herbal medicine as source of income, health and livelihood (Agbodeka et al., 2016; Dogor et al., 2018).

The Guinea Savanna zone of Northern Ghana is considered the driest region of Ghana with unimodal rainfall lasting for only 4 to 6 months. As per our review, this is the first study that has looked at both medicinal plant species structural richness and abundance in relation to soil physiochemical properties in dryland environment. For instance, a recent study by Coulibaly et al. (2021) reported that there is scanty data on abundance and richness of tree species in different land management types in the savannah landscape of Ghana. In addition, García-Vega and Newbold (2020) posited the need for more studies to be conducted in drylands in order to determine with more confidence whether richness and abundance differ across land uses. Such a study is important since the consequences of such land-use changes affect ecosystem functioning, given the great human demographic importance of dryland environments (United Nations Environment Management Group, 2011).

Our focus on medicinal plants stems from the fact that they are widely utilised in Ghana for a wide range of ailments (Agyei-Baffour et al., 2017; Amponsah et al., 2016; Appiah et al., 2018; Boadu & Asase, 2017; Boateng et al., 2016; Mensah et al., 2019).

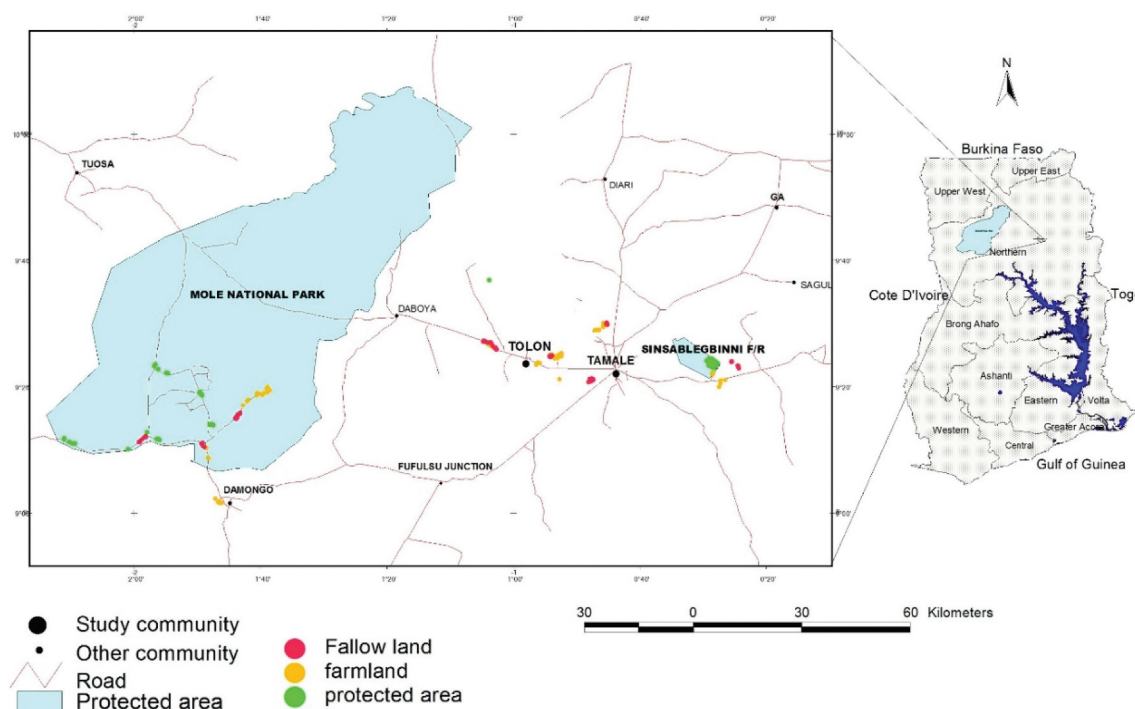
In this regard, the Traditional and Alternative Medicine Directorate (TAMD), Centre for Plant Medicine Research (CPMR) and the Traditional Medical Practitioners Council (TMPC) have been

established to promote, control and regulate the traditional/herbal medicine industry in Ghana. Unfortunately, there is growing concern about the loss of medicinal plants (Agbodeka et al., 2016; Amujoyegbe et al., 2016; Dogor et al., 2018; Youmsi et al., 2017) due to changes in land-use and soil properties. We believe that an improved understanding of the community ecology of medicinal plants across land-use types will indicate how these plants are affected by land-use changes and how they can be maintained under increasing land-use pressure and drought considering the role they play in the health and wellbeing of rural people. We hypothesised that the abundance and richness of medicinal plants would be influenced by variation in the physicochemical properties of soils and the different land-use types.

## 2. Materials and method

### 2.1. Study area

Three communities of the Guinea Savanna zone of Northern Ghana were selected for the study (Figure 1) based on the changes in land use, the abundance and role of medical plants in the health needs of the people. In addition, medicinal plants have economic importance in the lives of the people in these communities. For instance, medicinal plant collectors (suppliers) and vendors depend on the sale of these medicinal plants for income, while traditional healers either charge or get voluntary payment after patient are healed.



**Figure 1.** Map of Ghana showing the selected districts (in circle) of the study areas in the Guinea Savanna zone of Northern Ghana.

The communities were Mognori in the Mole National Park in the West Gonja District (9° 5' 0" N, 1° 49' 0" W), Jagbo-Apleyi near the Chinfoyiri Sacred Grove in the Tolon District (9° 26' 0" N, 1° 4' 0" W) and Tugu near the Sinsablegbinnni Forest Reserve (9° 24' 30.31" N, 0° 50' 25.63" W), in the Tamale Metropolis.

The natural vegetation of the Guinea Savanna zone of Northern Ghana is predominately tall grasses with scattered trees and shrubs with well-defined wet and dry seasons. The mean annual rainfall ranged 900–1100 mm. The wet season starts in April/May and ends in October, with maximum rainfall occurring around the month of August to September.

The dry season, where there is no rainfall with high temperature (29–33 °C), usually starts in November and ends around April/May. The mean monthly temperatures are high throughout the year ranging from 25°C to above 33°C. Relative humidity ranges from 75% in the raining season to 35% in the dry and hot periods (Nketia et al., 2018).

## 2.2. Description of land-use types

The land-use types consisted of protected area (PA), fallowed land (FL) and farmed area (FA) (see pictures in Supplementary Material 1). The PAs were lands that were secured from human disturbances. They are sacred groves that are conserved and maintained through a mechanism of beliefs, taboos, prohibitions and restrictions. Burning, cutting of grass and fuelwood are prohibited in these areas. These traditional beliefs have led to the preservation of numerous tree and shrub species in the study areas. The PA provides some ecological services to fringing communities in the form of purification of water in rivers and streams, conservation of biodiversity, prevention of natural hazards like windstorms, climate regulation, soil formation and nutrient cycling, erosion control and provision of genetic resources.

Farmlands were agroforestry parklands that have been under cultivation continuously for at least the past five years. Tree species such as *Parkia biglobosa*, *Faidherbia albida* and *Vitellaria paradoxa* are selectively preserved, maintained and managed on croplands by farmers and are used as a regular source of fuelwood, fodder, herb or other timber products. In addition, the biomass of the legume trees and shrubs is used as a source of organic manure for soil fertility enrichment. The common crops grown include maize, cowpea, groundnut, yam, Pigeon pea, millet and cassava.

The FLs are lands that had been left uncultivated (fallow) for not less than five years. These are previously Agroforestry parklands that have exhausted their fertility and farmers allow the soil to regain its productivity through natural regeneration, thus, forest undergoing natural regeneration following agricultural land use or on former croplands and grazing Lands. On

few occasions, farmers intervene with the planting of perennial legumes, like Pigeon pea (*Cajanus cajan* (L.) Huth) to help facilitate the regeneration process or enrichment of the soil fertility.

The existing tree provide some products (shea fruit, dawadawa fruits, etc) to women in the community but cropping is prohibited during the fallow period.

## 2.3. Sampling procedure

A reconnaissance survey was carried out in July and August, 2018 during which the study plots were identified, and the soil samples were taken in September, 2018. The study sites were identified based on the availability of PAs that were well monitored and secured from human disturbances, and it also had fallow lands which were previously agroforestry parklands that had been left fallow for not less than five years. The farmlands were identified with the help of the farm owners who confirmed that they had been cultivating that same piece of land continuously for at least the past five years.

In the first comparative studies, a total of 45 quadrats of 30 × 30 m each were laid randomly within a field following the process of Pérez-Salicrup et al. (2001), which consists of nine (9) quadrats each, laid in the PA, fallow lands (FL) and farmlands (FA) in the three communities. In each community, the land-use types were about 500 m apart. The main factor consisted of the three (3) levels of land-use type (protected, fallow and farmlands) and the second factor also consisted of three (3) different locations Mognori, Jagbo and Tugu in the Gonja West, Tolon Community and Tamale Metropolis, respectively, giving a total of nine (9) treatments.

Soil samples were collected using a soil augur at depths of 0–15 cm in each of the 45 quadrats. For each quadrat, five soil samples were obtained from 5 × 5 m nested quadrats which were placed at each of the four corners and one in the centre. For each quadrat, the five samples were thoroughly mixed and two subsamples were taken for soil analysis in duplicates giving a total of 90 samples.

The samples were air-dried for three (3) days, ground and sieved with a 2-mm mesh to remove extraneous materials like roots and pebbles and mixed thoroughly.

Some soil physical and chemical properties such as soil texture, pH, soil organic carbon, total nitrogen, available phosphorus, extractable bases (Ca, Mg, K and Na), exchangeable acidity (EA) and effective cation exchange capacity (ECEC) were determined.

## 2.4. Abundance and richness of medicinal plants/inventory of medicinal plants

A stratified randomised design was used to lay a total of 225 quadrats of 30 × 30 m each following the Pérez-Salicrup et al. (2001) method, consisting of 25 nested

quadrats from June to September 2018. A total of nine (9) treatments were obtained consisting of three (3) levels of communities, namely, Mognori, Tolon and Tugu and three (3) levels of land-use type denoted by PA, FL and FA. Within each nested quadrat, 5 m × 5 m and 1 m × 1 m quadrats were laid to assess shrubs and herbaceous or ground cover medicinal plant species, respectively.

Each quadrat was systematically surveyed and the abundance of medicinal plant species was recorded. Voucher specimens of the plants of medicinal value were collected to verify their identity by a taxonomist at the Herbarium of the Faculty of Agriculture, University for Development Studies (UDS) after preliminary visit to medicinal market, vendors and healers in each selected community. Names of the identified plant species followed the International Plant Names Index (<http://www.ipni.org>) and the Plant List (<http://www.theplantlist.org>) which was established by a collaboration between botanical communities spearheaded by the Kew and Missouri Botanical Gardens.

### 2.5. Ethnobotanical survey of medicinal plants

The ethnobotanical survey of medicinal plants was carried out in the three (3) selected districts (West Gonja, Tolon and Tamale Metropolis). A total of 210 key informants in 30 villages, consisting of seven respondents per village, were interviewed using semi-structured questionnaires (Supplementary material 2). The Snowball sampling method was used to identify respondents comprising of the major players in the medicinal plant community.

These consisted of herbal practitioners, medicinal plant collectors (suppliers) and vendors.

The ethnobotanical survey helped to know how people use such plants, parts of plant used for herbal remedies, mode of preparations, administration routes and the categories of uses.

For example, key questions were 'Which medicinal plant species are used for the treatment and prevention of various diseases and ailments?', 'Which plant parts are used in the preparation of herbal remedies?', 'Is there a consensus agreement between the informants regarding the uses of particular medicinal plant(s) for the treatment of particular disease categories?' 'What is the extent of availability and perceived dynamics of medicinal plants by local people in the study area?' and 'Which species are of great concern and need to be prioritized for conservation?'

### 2.6. Data analysis

The data were subjected to two-way analysis of variances (ANOVA) using the 'car' and 'MASS' packages of the R statistical software version 3.4.1 to test for significant differences between means with a 5% significance level. Where there were significant interactions, Tukey's HSD post hoc tests for multiple comparisons were carried out

to show significant differences in the means of the various treatments ( $P < 0.05$ ). Additionally, Pearson's correlation analysis was performed to explore the relationships between the physicochemical properties of the soil samples. Additionally, principal component analysis (PCA) was performed to explore the relationship between the physicochemical properties of the soil and the abundance of medicinal plants in the three land-use types and the major cause of the spatial variability using the 'FactoMineR' and 'factoextra' packages of the statistical software R version 3.4.1 (R Core Team, 2017).

## 3. Results

### 3.1. Richness of medicinal plants

A total of 107 distinct species, 87 genera and 40 families of medicinal plants were identified (Table 1). These were distributed in five life forms, namely, trees (69.2%), shrubs (23.4%), herbaceous plants (2.8%), creepers (0.9%) and lianas (3.7%). The Leguminosae family was the most represented (29 species), followed by Combretaceae (9 species), Rubiaceae (8 species), Anacardiaceae, Apocynaceae, Meliaceae and Moraceae (4 species each); Euphorbiaceae and Loganiaceae (3 species each) and the remaining 31 families were represented by either two or a single species (Table 1).

### 3.2. Abundance and richness of medicinal plants

The abundance ( $\text{ha}^{-1}$ ) of medicinal plants was significantly influenced by land-use type ( $F_{2,36} = 27.316$ ,  $P = 0.000$ ) and community ( $F_{2,36} = 22.903$ ,  $P = 0.000$ ). The abundance of medicinal plants ranged from  $35.21 \pm 7.64$  in the FA to  $81.75 \pm 6.74$  in the PA (Figure 2). The PA tended to have a higher abundance of medicinal plants than the FL and FA. The abundance of medicinal plants in the communities started from  $45.77 \pm 5.26$  in Jagbo and it increased to  $83.09 \pm 7.70$  in Mognori as the highest (Figure 2).

Similarly, species richness was significantly influenced by the different land-use types ( $F_{2,36} = 122.904$ ,  $P = 0.000$ ) and communities ( $F_{2,36} = 18.529$ ,  $P = 0.000$ ). Species richness ranged from  $11.20 \pm 1.10$  in the FA to  $19.80 \pm 0.96$  in the protected (Figure 3). The PA tended to have a higher species richness of medicinal plants than the FL and FA.

In the communities, the Mognori ( $24.53 \pm 2.41$ ) had the highest species richness of medicinal plants than the Tugu ( $17.67 \pm 2.12$ ) and Jagbo (Figure 3).

### 3.3. Principal component analysis of abundance, species richness of medicinal plants and physicochemical properties of soil

The PCA of the abundance and species richness of medicinal plants and 14 physicochemical properties of soil in the different land use types yielded five

**Table 1.** Medicinal plants and ailments used for treatment in the Savanna zone of Northern Ghana.

Family	Species	Part(s) used	Ailment(s) treated
Amaranthaceae	<i>Alternanthera pungens</i> Kunth	Wp, St	Gonorrhoea, Abdominal Pains
Anacardiaceae	<i>Lannea acida</i> A.Rich.	Ba, Ro, Le	Venereal Diseases, Jaundice, Sterility
Anacardiaceae	<i>Lannea barteri</i> (Oliv.) Engl.	Ba	Diarrhoea, Paralysis, Epilepsy
Anacardiaceae	<i>Haematostaphis barteri</i> Hook. f.	Le	Malaria
Anacardiaceae	<i>Mangifera indica</i> L.	Ba, Ro, Le, Ba	Diabetes, Weakness, Insomnia, Sore throat
Anacardiaceae	<i>Sclerocarya birrea</i> (A.Rich.) Hochst.	Ba, Le, Ro	Constipation, Stomach ache, Labour pains, Headache
Annonaceae	<i>Annona senegalensis</i> Pers	Le, Ro, Ba	Sore throat, Conjunctivitis, Tooth ache, Snake bites, Schistosomiasis, Scabies
Apocynaceae	<i>Calotropis procera</i> (Aiton) Dryand	Ba, Le, Ro, St	Tuberculosis, Gastritis, Impotence, Snake Bites, Small Pox, diabetes, Whitlow, tooth ache, Stomach Ache
Apocynaceae	<i>Strophanthus hispidus</i> DC.	Ro, Ba, Le Wp	Leprosy, Elephantiasis, Constipation, Tooth Ache, Eye inflammation, Snake bites
Arecaceae	<i>Borassus aethiopicum</i> Mart.	Ro	Malaria, Dysentery, Gonorrhoea, Constipation, Eye inflammation, Headache, Skin Diseases, Syphilis
Asteraceae	<i>Ageratum conyzoides</i> (L.) L.	Wp, Le, St	Sore Throat, Asthma
Asteraceae	<i>Tridax procumbens</i> L.	Wp	Fresh Wounds, Headache, Diarrhoea, Convulsion, Eye inflammation, Female Infertility
Asteraceae	<i>Vernonia guineensis</i> Benth.	Wp	Malaria
Balanitaceae	<i>Balanites aegyptiaca</i> (L.) Delile	Ba, Le, Ro, Fr	Malaria, General Weakness, Headache
Bignoniaceae	<i>Crescentia cujete</i> L.	Ba	Syphilis, Stomach ache, Yellow Fever, Worms, Epilepsy, Malaria, Snake bite, Schistosomiasis
Bignoniaceae	<i>Stereospermum kunthianum</i> Cham.	Ba, Le	Wounds
Bignoniaceae	<i>Kigelia africana</i> (Lam.) Benth.	Ba	Coughs, Pneumonia
Bombacaceae	<i>Adansonia digitata</i> (L.)	Ba, Fr, Le, Ro	Sores, Body Pains, Fever, Amenorrhoea, Anaemia
Bombacaceae	<i>Bombax costatum</i> Pellegr. & Vuillet	Ba, Ro	Stomach ache, Asthma, Malaria
Bombacaceae	<i>Ceiba pentandra</i> (L.) Gaertn.	Ba, Ro, Ba, Le	Skin Diseases, Yellow Fever, Headaches
Burseraceae	<i>Boswellia dalzielii</i> Hutch.	Ba	Lactation
Celastraceae	<i>Maytenus senegalensis</i> (Lam.) Exell.	Ro	Oedema, Diarrhoea, Hypertension, Sexual weakness, Mental disorders
Combretaceae	<i>Anogeissus leiocarpus</i> (Araújo et al.) Guill. & Perr.	Le, Ba, Ro Se	Tooth decay
Combretaceae	<i>Combretum glutinosum</i> Perr. Ex DC	Ba, Ro	Wounds
Combretaceae	<i>Combretum molle</i> R.Br. ex G.Don	Ro, Ba	Jaundice, Yellow Fever, Tooth Ache, Chest Pain, Cough, Wounds, Snake bite, Hepatitis, Aphrodisiac, Worm Infestation
Combretaceae	<i>Terminalia avicinioides</i> Guill. & Perr.	Le, Ro	Boils, Eczema, Wounds, Sexual weakness
Combretaceae	<i>Terminalia macrocarpa</i> Guill. & Perr.	Le, Ba, Ro	Fever, Headache, Stomach Ache, Poisoning
Combretaceae	<i>Pteleopsis suberosa</i> Engl. & Diels	Ro	Rheumatism, Anaemia, Burns, Wounds, lactation, witchcraft
Convulvulaceae	<i>Evolvulus alsinoides</i> (L.) L.	Wp, Le, St	Constipation, Anaemia, Fever, Sexual Weakness
Ebenaceae	<i>Diospyros mespiliformis</i> Hochst. ex. A. DC	Ba, Le, Ro	Stomach ache, Skin diseases, Headache, epilepsy, cough, Tooth ache, Filariasis, jaundice, haemorrhoids
Euphorbiaceae	<i>Bridelia ferruginea</i> Benth.	Ba, Ro	Gonorrhoea, Sores, Sexual weakness, Snake bite
Euphorbiaceae	<i>Euphorbia balsamifera</i> Aiton	Le, Ro	Stomach Ache, Antidote to Poison, Wounds, Evil spirits
Euphorbiaceae	<i>Securinega virosa</i> (Roxb. ex Willd.) Baill.	Ba, Ro	Diarrhoea, Intestinal Worms, Poor Urination
Lamiaceae	<i>Hoslundia opposita</i> Vahl	Ro, Le	Antihelminthes, Dental Carries
Leguminosae	<i>Acacia dudgeoni</i> Holland	Ro	Tooth decay, Chest Pain, Pneumonia, Malaria, Hernia, Anaemia, Insomnia
Leguminosae	<i>Acacia hockii</i> De Wild.	Ba, Ro	Aphrodisiac, wounds
Leguminosae	<i>Acacia macrostachya</i> DC.	Le	Malaria, Haemorrhoids, Stomach Ache
Leguminosae	<i>Acacia nilotica</i> (L.) Delile	Ba, Le, Ro	Dysentery, Tooth Ache, Leprosy
Leguminosae	<i>Acacia Senegal</i> (L.) Willd.	Ba, Le	Tooth decay, Snake bite
Leguminosae	<i>Azafia africana</i> Sm.	Ba, Le	Dysentery, Mental disorder, Sexual impotence
Leguminosae	<i>Albizzia lebeck</i> (L.) Benth.	Le, Ro, Ra, Ba	Malaria
Leguminosae	<i>Burkea africana</i> Hook	Ba, Ro, Le	Constipation, Aphrodisiac, High blood pressure, Haemorrhage, Lumbago, Leprosy, wounds, Stomach ache
Leguminosae	<i>Cassia sieberiana</i> DC.	Ro, Ba, Le	Back Pain, Oedema, Gonorrhoea, Anti-poison, Hernia, Trypanosomiasis, Stomach problems, Oedema, Epilepsy, Haemorrhoids
Leguminosae	<i>Daniellia oliveri</i> (Rolfe) Hutch. & Dalz.	Ba, Le	Fever, Wounds, Stomach Ache, Headache, Sexual Impotence
Leguminosae	<i>Detarium microcarpum</i> Guill. & Perr.	Le, Se, Ro, Ba	Haemorrhoids, Stomach problems, Gonorrhoea, Malaria, Schistosomiasis, Painful Urination, Sexual weakness
Leguminosae	<i>Detarium microcarpum</i> Guill. & Perr.	Le, Se, Ro, Ba	Headache
Leguminosae	<i>Detarium microcarpum</i> Guill. & Perr.	Le, Se, Ro, Ba	Convulsion, Skin Diseases, Wounds, Paralysis, Sexual weakness

(Continued)

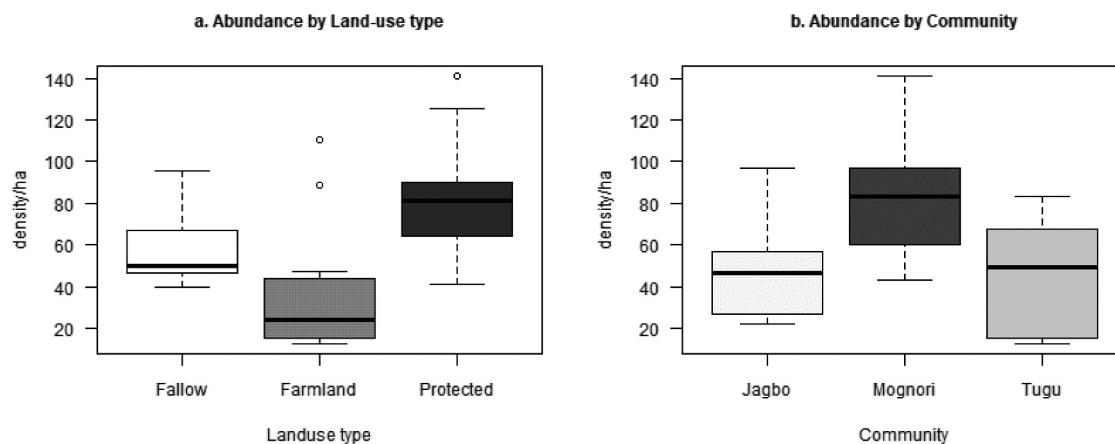
Table 1. (Continued).

Family	Species	Part(s) used	Ailment(s) treated
Leguminosae	<i>Dichrostachys cinerea</i> (L.) Wight & Arn.	Le, Ba	Epilepsy, snake bites and scorpion
Leguminosae	<i>Entada africana</i> Guill. & Perr.	Le	Wounds
Leguminosae	<i>Erythrina senegalensis</i> DC.	Ro, Ba, Le, Wp	Tooth Ache, Female Infertility, Impotence, Leprosy
Leguminosae	<i>Faidherbia albida</i> (Delile) A. Chev.	Ba, Ro, Le	Malaria, Convulsion, Wounds
Leguminosae	<i>Isoblerina doka</i> Craib & Stapf	Le, Ba, Ro	Jaundice, Yellow Fever, Malaria
Leguminosae	<i>Parkia biglobosa</i> (Jacq.) G.Don	Ba, Se, Le	Hypertension, Tooth Ache, Sexual weakness, Wounds, Leprosy, Snake bite, Pneumonia, Haemorrhoids
Leguminosae	<i>Pericopsis laxiflora</i> (Benth.) Meeuwen	Ba, Ro	Yellow Fever, Haemorrhoids
Leguminosae	<i>Piliostigma thonningii</i> (Schum.) Miln-Redh	Le, Ro	Chicken Pox, Haemorrhoids, Mental disorder
Leguminosae	<i>Prosopis africana</i> (Guill. & Perr.) Taub.	Ba	Malaria
Leguminosae	<i>Pterocarpus erinaceus</i> Poir.	Ba, Le, Ro	Diarrhoea, Haemorrhoids, Anaemia, Tooth decay, dysmenoria, Fever, Mental illness, Typhoid fever
Leguminosae	<i>Pterocarpus santalinoides</i> DC.	Ba, Le, Ro	Stomach ache, fever
Leguminosae	<i>Senna alata</i> (L.) Roxb.	Le	Intestinal Worms, Gonorrhoea
Leguminosae	<i>Senna occidentalis</i> (L.) Link	Se, Le, Fl	Hypertension, Helminthiasis, Intestinal Worms, Malaria
Leguminosae	<i>Senna siamea</i> (Lam.)	Ro, Le	Jaundice, Yellow Fever
Leguminosae	<i>Sesbania Sesban</i> (L.) Merr.	Ro	Scorpion Bite
Leguminosae	<i>Tamarindus indica</i> L.	Le, Ba, Ro	Circumcision Wound, Chest Pain, Malaria
Hymenocardiaceae	<i>Hymenocardia acida</i> Tul.	Le, Ba	Diarrhoea, Wounds
Icacinaeae	<i>Icacina senegalensis</i> Juss.	Le	Malaria
Loganiaceae	<i>Strychnos innocua</i> Delile	Ro	Gonorrhoea, Snake Bites
Loganiaceae	<i>Strychnos spinosa</i> Lam.	Le, Ro	Skin Diseases, Mental disorder, Haemorrhoids, witchcraft
Malvaceae	<i>Sida acuta</i> Burm.f.	Le	Abdominal Pain
Meliaceae	<i>Azadiracta indica</i> A. Juss.	Ba, Se, Le, Ro	Intestinal Worms, Sore Throat, Cough, Back Pain, Skin Diseases, Malaria, Haemorrhoids
Meliaceae	<i>Khaya senegalensis</i> (Desv.) A. Juss.	Ba, Ro, Le	Fever, Intestinal Worms, Malaria, Anaemia, Jaundice, Sexual Weakness, Syphilis, Constipation, Male infertility, Scorpion bites, Haemorrhoids
Meliaceae	<i>Pseudocedrela kotschy</i> (Schweinf.) Harms	Le, Ba, Ro	Tooth decay, Asthma, Sexual weakness, Scorpion bite, Malaria, Mental disorder, Haemorrhoids
Moraceae	<i>Ficus exasperata</i> Vahl	Ro, Ba, Le	Gonorrhoea, Asthma, Tuberculosis, Haemorrhoids, Stomach Ache, Cough
Moraceae	<i>Ficus sur</i> Forssk.	Ba, Le	Fever, Cough, Wounds, Sickle cell
Moraceae	<i>Ficus thonningii</i> Blume	Ba, Ro	Wounds, lactation, Sore throat, Haemorrhoids
Moringaceae	<i>Moringa oleifera</i> Lam.	Ba, Le, Ro, Se	Diarrhoea, Malaria, Snake bite, aphrodisiac
Myrtaceae	<i>Psidium guajava</i> L.	Le, Fr	Constipation, Diarrhoea, Constipation, Tooth Ache, Cough, Measles, Painful Urination
Olacaceae	<i>Ximena Americana</i> Linn.	Ro	Diarrhoea
Piperaceae	<i>Piper guineense</i> Schumach. & Thonn.	Fr	Body Pains
Phyllanthaceae	<i>Phyllanthus fraternus</i> G.L. Webster	Wp, St	Malaria, Jaundice
Polygalaceae	<i>Securidaca longipedunculata</i> Fresen.	Ro	Gonorrhoea, Rheumatism, Syphilis, Sexual Impotence, Snake bite
Rhamnaceae	<i>Ziziphus mauritiana</i> Lam.	Ro	Mental disorder, Witchcraft, Fever, wounds
Rubiaceae	<i>Feretia apodanthera</i> Delile	Ro	Gonorrhoea, Syphilis, Snake bite
Rubiaceae	<i>Gardenia ternifolia</i> Schumach. & Thonn.	Ro, Le	Rheumatism, Syphilis, Leprosy
Rubiaceae	<i>Mitragyna inermis</i> (Willd.) Kuntze	Ba, Le, Ro	Stomach Problems, Mental disorder, Fever
Rubiaceae	<i>Nauclea latifolia</i> Sm.	Ro, Le	Stomach Problems, Poor Urination, Hepatitis
Rutaceae	<i>Zanthoxylum zanthoxyloides</i> (Lam.) Zepern. & Timler	Ra, Se, Ro	Cancer, malaria, Snake bites, haemorrhoids, Sore throat, Whooping cough
Sapindaceae	<i>Blighia sapida</i> K.D.Koenig	Ba, Ro	Diarrhoea, Snake bite, Sickle cell,
Sapotaceae	<i>Vitellaria paradoxa</i> C.F.Gaertn.	Ba, Ro, Fr	Pneumonia, Hepatitis, Jaundice, diarrhoea, Stomach ache, dysentery, Nasal congestion, Haemorrhoids
Sterculiaceae	<i>Sterculia setigera</i> Delile	Ba, Le	Diarrhoea, Tuberculosis, Mental disorder
Verbanaceae	<i>Vitex doniana</i> Sweet	Ba, Le	Abdominal Pain, Diarrhoea, Wounds
Vitaceae	<i>Cissus populnea</i> Guill. & Perr.	Ro, Ba	Impotence, Syphilis

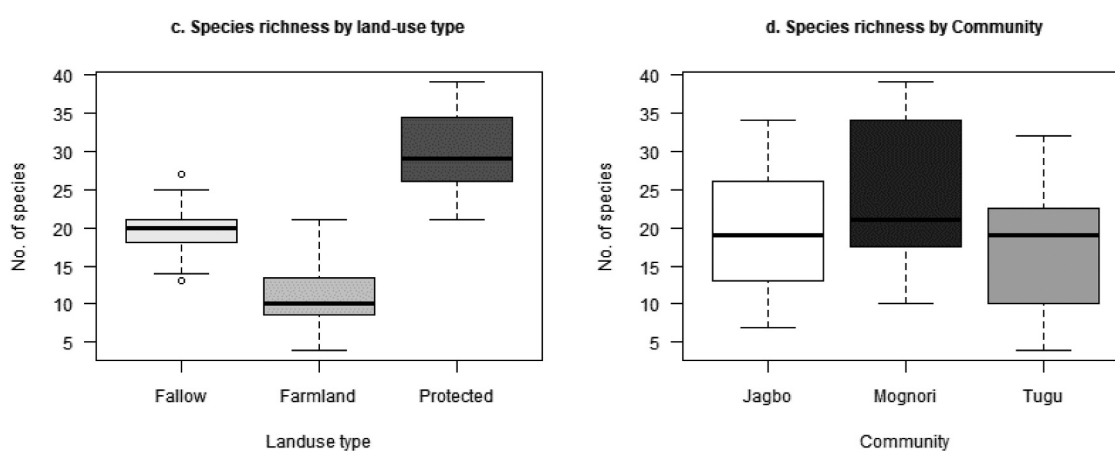
Ro = Roots, Ba = Bark, Le = Leaves, Fr = Fruit, WP = Whole plant, Se = Seed, St = Stem, Fl = Flowers

components that were extracted (Table 2). The first two components accounted for 72.1% of the total variance in the original data set. On PC<sub>1</sub> (principal component one), 12 out of the 16 variables with positive values loaded heavily on it. These consisted of abundance per hectare

of medicinal plants (0.8092), species richness (0.9168), pH (0.8874), TN (0.9312), P<sub>av</sub> (0.7748), SOC (0.9353), exchangeable Ca (0.6682), exchangeable Mg (0.6901), exchangeable K (0.6148), exchangeable Na (0.7345), ECEC (0.7789) and %BS (0.6685; Table 2).



**Figure 2.** Effects of land-use type (a) and community (b) on the abundance ( $\text{ha}^{-1}$ ) of medicinal plants in the Guinea Savanna zone of Northern Ghana.



**Figure 3.** Effects of land-use type (c) and community (d) on species richness (per plot) of medicinal plants in the Savanna zone of Northern Ghana.

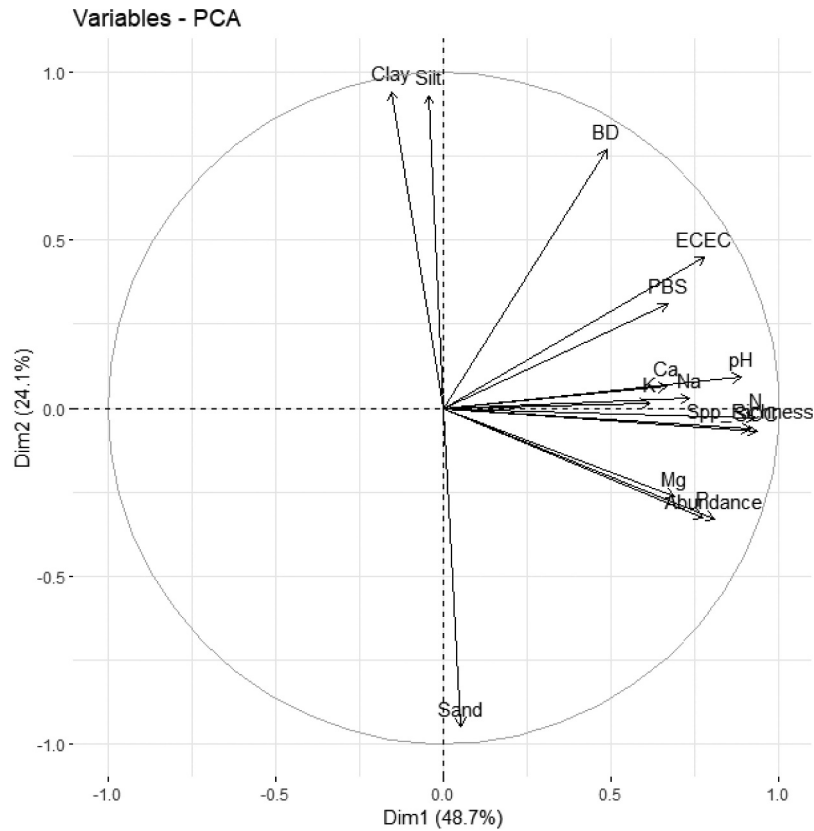
**Table 2.** PCA results for the variables extracted from the abundance and species richness of medicinal plants and 14 soil physicochemical properties in the land-use types and the communities in the Guinea Savanna zone of Northern Ghana.

Variable	Principal Components				
	PC <sub>1</sub>	PC <sub>2</sub>	PC <sub>3</sub>	PC <sub>4</sub>	PC <sub>5</sub>
Abundance	0.8092	-0.3327	-0.0062	0.2227	-0.0086
Species richness	0.9168	-0.0621	-0.0146	-0.0361	-0.0098
pH	0.8874	0.0917	-0.0868	0.0449	-0.0045
N	0.9312	-0.0292	-0.0579	-0.0844	-0.2004
P <sub>av</sub>	0.7748	-0.3252	-0.2244	0.2611	-0.0398
SOC	0.9353	-0.0695	-0.0109	-0.1950	-0.1363
Ca	0.6682	0.0649	0.2754	0.5278	0.3449
Mg	0.6901	-0.2632	-0.4974	0.1050	-0.1579
K	0.6148	0.0156	-0.3187	-0.3915	0.5937
Na	0.7345	0.0286	0.2222	-0.5044	-0.1138
ECEC	0.7789	0.4493	0.2968	-0.0073	0.0976
PBS	0.6685	0.3096	0.4895	-0.0007	-0.0338
Sand	0.0533	-0.9493	0.2568	-0.0543	-0.0067
Silt	-0.0419	0.9304	-0.2975	0.0566	0.0273
Clay	-0.1547	0.9430	0.0913	-0.0498	-0.0207
BD	0.4877	0.7693	-0.0924	0.1259	-0.1909
Eigen value	7.7850	3.8545	1.0349	0.8879	0.6182
Variance (%)	48.6565	24.0905	6.4684	5.5497	3.8639
Cumulative variance (%)	48.6565	72.7471	79.2155	84.7651	88.6291

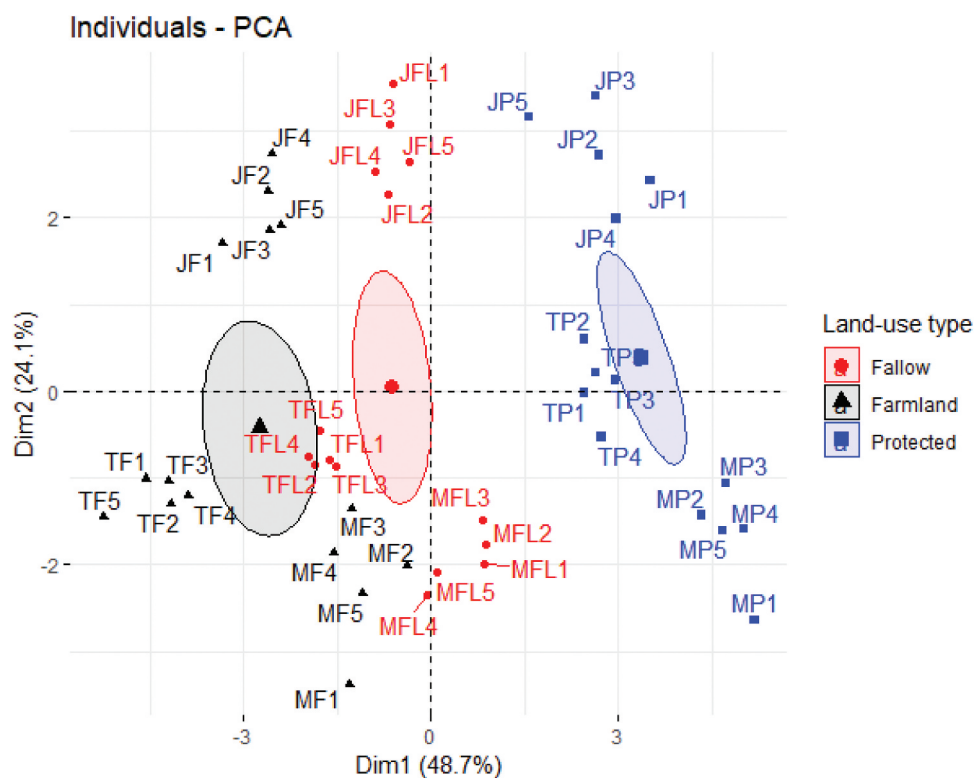
The PC<sub>1</sub> accounted for 48.7% of the variance in the linear combination of abundance, species richness of medicinal plants and soil chemical properties (Figure 4 and 5). The PC<sub>2</sub> had four soil properties that loaded heavily on it, namely, sand (-0.9493) which was negative while silt (0.9304), clay (0.9430) and bulk density (0.7693) were positive. The PC<sub>2</sub> represented the soil physical properties which accounted for 24.1% of the variance in the soil properties (Figures 4 and 5).

### 3.4. Plant parts used for herbal remedies

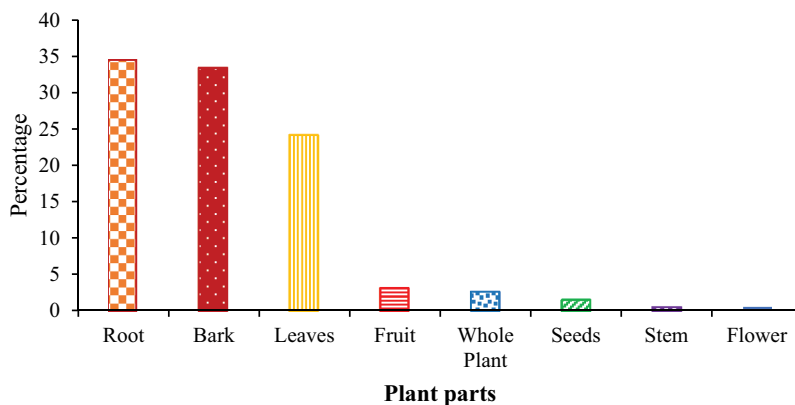
The results of the interviews revealed that the most commonly harvested part used for herbal medicines were roots (34.4%), followed by bark (33.3%), while the flowers (0.5%) were the least used (Figure 6). For instance, the roots and stripped bark of *Balanites aegyptiaca* and *Pteleopsis suberosa*, respectively, were most used while the leaves of *Piliostigma thonningii* and fruits of *Parkia biglobosa* were the most utilised parts (Figure 7).



**Figure 4.** Correlation circle showing the covariates in a two-dimensional plot (Dim 1  $\times$  Dim 2) in the Savanna Zone of Northern Ghana. SOC = SOC (%), N = TN (%), P = available phosphorus, Ca = calcium, K = potassium, Na = sodium, ECEC = effective cation exchange capacity, PBS = percentage base saturation, BD = bulk density, Sand = sand (%), Silt = Silt (%), Clay = clay (%).



**Figure 5.** Visualisation of abundance and species richness of medicinal plants and the physicochemical properties of soils in a two-dimensional plot (Dim 1  $\times$  Dim 2) in the Savanna Zone of Northern Ghana. MP = Mognori protected area (PA); MFL = Mognori fallow land, MF = Mognori farmland, JP = Jagbo PA; JFL = Jagbo fallow land, JF = Jagbo farmland, TP = Tugu PA; TFL = Tugu fallow land, TF = Tugu farmland.



**Figure 6.** Percentage herbal healers/traders using different plant parts for medicines in Northern Ghana.



**Figure 7.** Examples of plant parts used for herbal medicine (a) roots of *Balanites aegyptiaca*, (b) stripped bark of *Pteleopsis suberosa*, (c) leaves of *Piliostigma thonningii*, and fruits (d) of *Parkia biglobosa*.

#### 4. Discussion

Land-use change in sub-Saharan countries is still on the increase (Abdullahi, 2021), and this has implication on loss of important biodiversity including medicinal plants which form an important component of health-care provision to rural people in Ghana. Generally, land quality and soil fertility affect plant species productivity and richness (Ahmed et al., 2016; Bakhshandeh et al., 2019).

Our result showed that different land-use types influenced the abundance and richness of medicinal plants (Figure 5). The PAs had higher abundance and diverse medicinal plants than both the fallow lands (FL) and FA. Such observation can be attributed to the fact that in the PAs, the medicinal plants are naturally grown and protected without human exploitation while in the FA, farmers are selective in the choice of species retained in their field based on how useful the

trees are to their crops and other needs. For instance, farmers may not even know the medicinal importance of the tree species they remove and this could contribute to the decrease in tree species richness and abundance. In a comparative study by Boakye et al. (2017), E.K et al. (2018), and Asinwa et al. (2018), lands which had less disturbance in the Guinea Savanna of Northern Ghana generally had higher number of multi-purpose trees with diverse species than lands with more anthropogenic activity.

Interestingly, a previous meta-analysis by Darkoh (2003) found that agriculture in the African drylands had lower species richness and abundance than natural environments, contrary to the findings of García-Vega and Newbold (2020).

In addition, we found that the study areas, especially FA, had many medicinal trees (e.g. *Faidherbia albida*, *Parkia biglobosa*, *Cassia sieberiana*, *Tamarindus*

*indica*, *Azelia africana*, etc) being either leguminous (putative N<sub>2</sub>-fixing) or produce high amount of green biomass (Table 1). The possible extra benefits of these trees to improve the soil fertility could contribute to farmers retaining them on their farms, since Atakora et al. (2019) and Ochire-Boadu et al. (2020) reported that poor soil fertility is a major factor inhibiting crops yield in the Guinea Savanna zone of Northern Ghana.

In addition, leguminous/Fabaceae family have speedy regeneration potential and are known to be resilient species and thrive in extreme weather/dryland conditions (Ilstedt et al., 2016; Ouedraogo et al., 2017; Oyebamiji et al., 2017). This align with our result since our study area (Figure 1) is considered as a dry region of Ghana, with unimodal rainfall pattern characterised by long period of drought (Atakora et al., 2019; Ochire-Boadu et al., 2020). Therefore, it is not surprising that the leguminous/Fabaceae family species were the most abundant and diverse (Table 1).

The results of the PCA (Table 2 and Figure 5) showed that the abundance and richness of medicinal plants were influenced by variation in the physico-chemical properties of the soil in the three land-use types. The PC<sub>1</sub> represented the abundance and richness of medicinal plants and the chemical properties of the soil across the different land-use types. The soil chemical properties, namely, pH, organic matter, TN, P<sub>av</sub>, exchangeable calcium, CEC and percentage base saturation showed positive loadings on the PC<sub>1</sub>, which implied that they increased across the different land-use types from FA to FL and then to PA.

Thus, the highest soil nutrients recorded in the PA corresponded with the high abundance and diverse medicinal plants whilst the low soil nutrients in the FA also had a relatively lower abundance and diverse medicinal plants. This clearly showed the impact of management practices on the abundance and richness of the medicinal plants, as tillage practices and chemical weed control in FA is expected to reduce soil organic matter, which is crucial for soil quality and species richness (Ferrero et al., 2017; Triantafyllidis et al., 2020). Our result further confirms the findings of Siebert et al. (2021) and Gaglio et al. (2017) who reported that PAs function to counter species loss as they are designed to maintain habitat integrity and species richness. In addition, an earlier report by Rodrigues et al. (2018); De Deyn & Kooistra, (2021) and Bartelheimer et al. (2016) indicated that soil properties and plant species diversity/richness differ between forested, fallowed (abandoned) and cultivated lands, indicating that different management practices and soil nutrients are an important edaphic factor that play a role in plant species establishment. A typical case study is in the Mediterranean basin where Balzan et al. (2020) and Plieninger et al. (2014) reported that different land-use types, especially agricultural intensification in arable systems, were

associated with reduced plant species and functional diversity/ richness. Our findings prove that changes in land-use practices are the major cause of medicinal plants losses and this should be of grave concern to Africa, especially, since African savannas provide essential ecosystem goods and services to indigenous livelihoods (Inkoom et al., 2017; Siebert et al., 2021). However, our results contradict the findings of Peña-Claros et al. (2012) and Nadeau and Sullivan (2015) who indicated that higher tree richness tends to occur on poor soils with low fertility and tree species diversity/richness was not related to any soil variables (K, Ca, Mg, P, Fe, Cu, Zn, Mn, CEC, total N, organic C) as fertility index.

The PC<sub>2</sub> that represented the soil physical properties had the clay and silt percentages loading positively while sand loaded negatively on it. This indicated that silt and clay percentages increased across the land-use types from FA to PA while sand content decreased across the land-use types from FA to PA. This might be because during land preparation and tillage, the soil particles are broken down making them loosely held. Further, in a continuous farming with low/poor inputs and little or no intermittent fallow periods, the organic matter content is depleted making the particles further loose.

These are characteristics of our study area (Atakora et al., 2019; Ochire-Boadu et al., 2020) where farmers rarely practice fallow, and slash and burn method with the use of heavy equipment is widely used during land preparation.

## 5. Conclusion

Medicinal plants are an important biodiversity in Africa and provide essential ecosystem goods and services to indigenous livelihoods. Unfortunately, change in land use affects the conservation of these medicinal plants. We studied abundance, richness and use of medicinal plants under different land uses in the Guinea Savanna Zone of Northern Ghana and how those plants are influenced by soil characteristics. We established that different land-use types influenced the abundance and richness of medicinal plants. The PA had higher abundance and diverse medicinal plants, followed by the FL while the FA had the least. However, FA had many medicinal trees being either leguminous (putative N<sub>2</sub>-fixing) or producing high amount of green biomass. In addition, the abundance and richness of medicinal plants were influenced by variation in the physiochemical properties of the soil in the three land-use types. The pH, organic matter, TN, P<sub>av</sub>, exchangeable calcium, CEC and percentage base saturation increased from FA to FL and then to PA. However, silt and clay percentages increased from FA to PA while sand content showed a reverse pattern. We further established that significant number of people in the study areas

use different parts of the medicinal plants for the treatment of various ailments and it also serves as source of income, health and livelihood.

Our findings suggest that the PA provided a favourable environment for rehabilitation and natural regeneration of soil fertility, growth and richness of medicinal plants. Therefore, it would be necessary to put in place the measures to lessen the effect of the ever-increasing human pressure on the reserves of the savanna ecosystem to avoid a further decline in medicinal plants, loss of biodiversity and soil fertility. In addition, farmers in the FA could consider integrating the medical plants into their crops in an Agroforestry system as alternative to improve the growth and abundance of medicinal plants. Finally, our findings have implications for the attainment of the United Nations Sustainable Development Goals (SDGs), particularly SDG 3 (good health and well-being), SDG 13 (climate action) and SDG 15 (Life on land).

## Highlights

Integrating medical plants into crops as Agroforestry system can improve their abundance and richness in cropland use systems.

Conversion of forest land to Agriculture land-use type has negative implications for the attainment of the SDGs 3 (good health and well-being), 13 (climate action) and 15 (Life on land).

Land-use change in sub-Saharan countries is still on the increase and this has implication on loss of important biodiversity including medicinal plants which form an important component of health care provision to rural people.

## Disclosure statement

No potential conflict of interest was reported by the author(s).

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## Data Availability

Data related to the manuscript can be found using the link [10.6084/m9.figshare.20334402](https://doi.org/10.6084/m9.figshare.20334402)

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