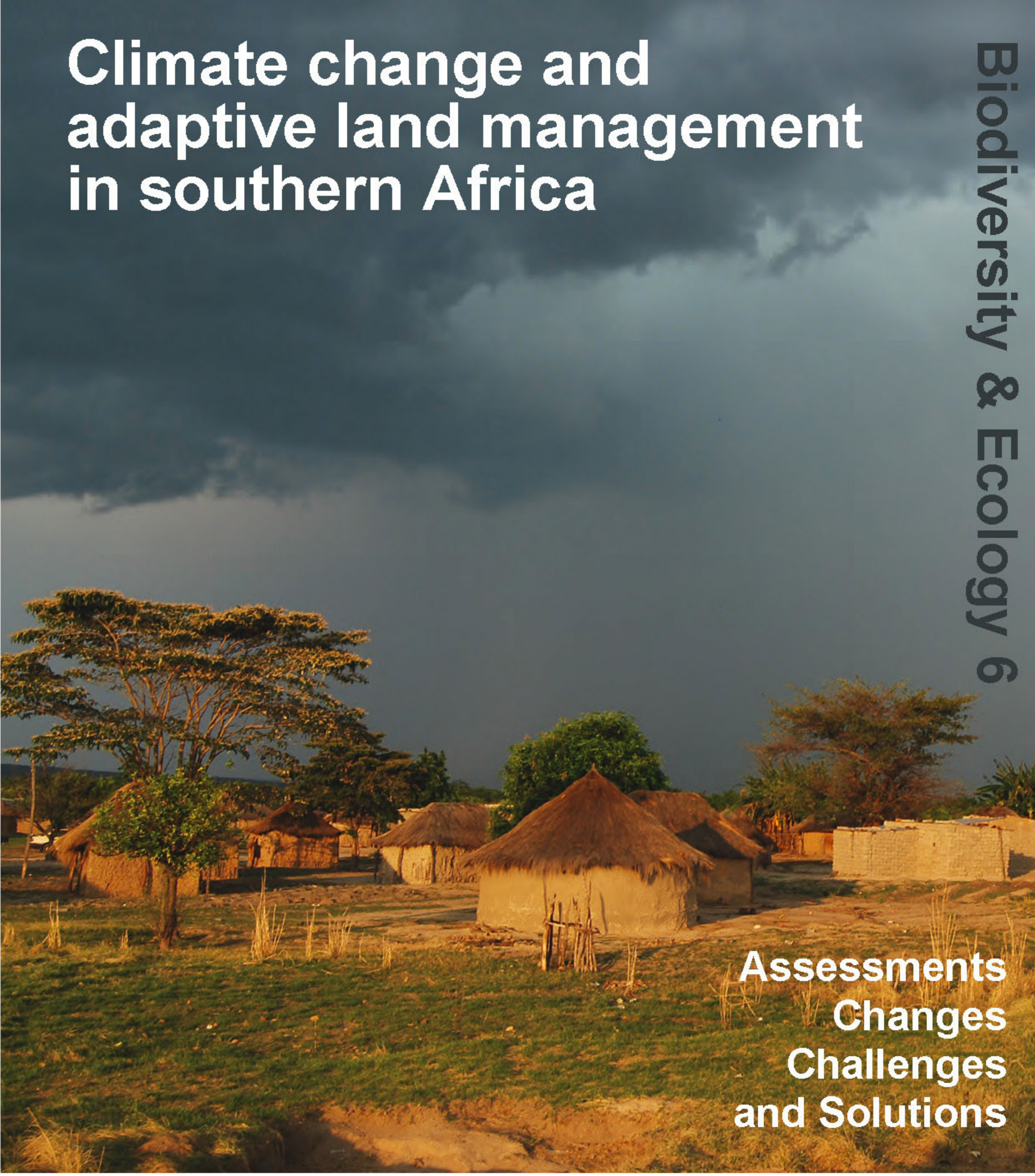
# Climate change and adaptive land management in southern Africa

Biodiversity & Ecology 6



## Assessments
## Changes
## Challenges
## and Solutions

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# Climate change and adaptive land management in southern Africa

## Assessments, changes, challenges, and solutions

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Biodiversity

# Diversity patterns of woody vegetation of Kgatleng District, Botswana

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**Abstract:** Vegetation assessments have intensified around the globe to document plant diversity in the wake of climatic shifts and local environmental changes. Botswana also recognises the value of documenting plant diversity, and in this study we present the results of a vegetation survey of Kgatleng District. Between November 2013 and December 2016 we assessed tree species abundance on 77 plots sized 20 m × 50 m. Vegetation classification resulted in the identification of five woody plant communities: Terminalia sericea–Maytenus tenuispina, Dichrostachys cinerea–Combretum apiculatum, Combretum zeyheri–Vachellia tortilis, Senegalia erubescens–Senegalia mellifera, and Grewia flava–Rhigozium brevispinosum. One-way analysis of variance indicated that species richness was not different among the five plant communities, nor was tree density. We furthermore provide a vegetation map of the district based on supervised classification of Landsat 8 imagery.

**Resumo:** Estudos de vegetação intensificaram em todo o mundo, de modo a documentar a diversidade de plantas na sequência das alterações climáticas e de mudanças ambientais locais. O Botswana também reconhece o valor de documentar a diversidade de plantas e, neste estudo, apresentamos os resultados do levantamento da vegetação do Districto de Kgatleng. Entre Novembro de 2013 e Dezembro de 2016, avaliámos a abundância de espécies de árvores em 77 parcelas de 20 m × 50 m. A classificação da vegetação resultou na identificação de cinco comunidades de plantas lenhosas: *Terminalia sericea–Maytenus tenuispina, Dichrostachys cinerea–Combretum apiculatum, Combretum zeyheri–Vachellia tortilis, Senegalia erubescens–Senegalia mellifera*, *e Grewia flava–Rhigozium brevispinosum.* A análise da variância a um factor indicou que nem a riqueza específica, nem a densidade de árvores, eram diferentes entre as cinco comunidades de plantas. Fornecemos ainda um mapa da vegetação do districto baseado na classificação supervisionada de imagens de Landsat 8.

## Introduction

Botswana, like most southern African countries, comprises expansive areas of savanna woodlands. Kgatleng District lies within the woodland and thorn bush savanna ecosystems. These ecosystems provide browse for domestic and wild animals, habitat cover for wild animals, wood products, and traditional medicines, among other uses. The diversity of ecosystems is integral to rural livelihoods, as they use veld products to sustain themselves. As such, effective management of savannas requires proper knowledge and documentation of vegetation types and species composition (Moore & Attwell, 1999).

Bush encroachment threatens the ecological integrity of savanna ecosystems and is of concern in southern Africa (Trollope, 1980; Skarpe 1990; Ward, 2005; Britz & Ward, 2007) and Botswana (Rhode et al., 2006), as it reduces diversity of vegetation. A number of causal drivers to changes in vegetation composition have been proposed, ranging from low rainfall to support grass growth, overgrazing, reduced fire frequency favouring woody plant establishment (Kgosikoma et al., 2012) and climatic shifts (O'Connor et al., 2014). To that end, environmentally friendly and sustainable methods of farming observing correct rangeland stocking rates have been advocated for in Botswana (Kgosikoma et al., 2012).

Species such as *Dichrostachys cinerea* can affect the development of other woody vegetation (Mudzengi et al., 2013), thus reducing species diversity and richness. A study by Mudzengi et al. (2013) observed significant differences between invaded and uninvaded sites in abundance, density, and richness of woody species.

Environmental variables such as soil and topography influence the occurrence of plant species and as such govern

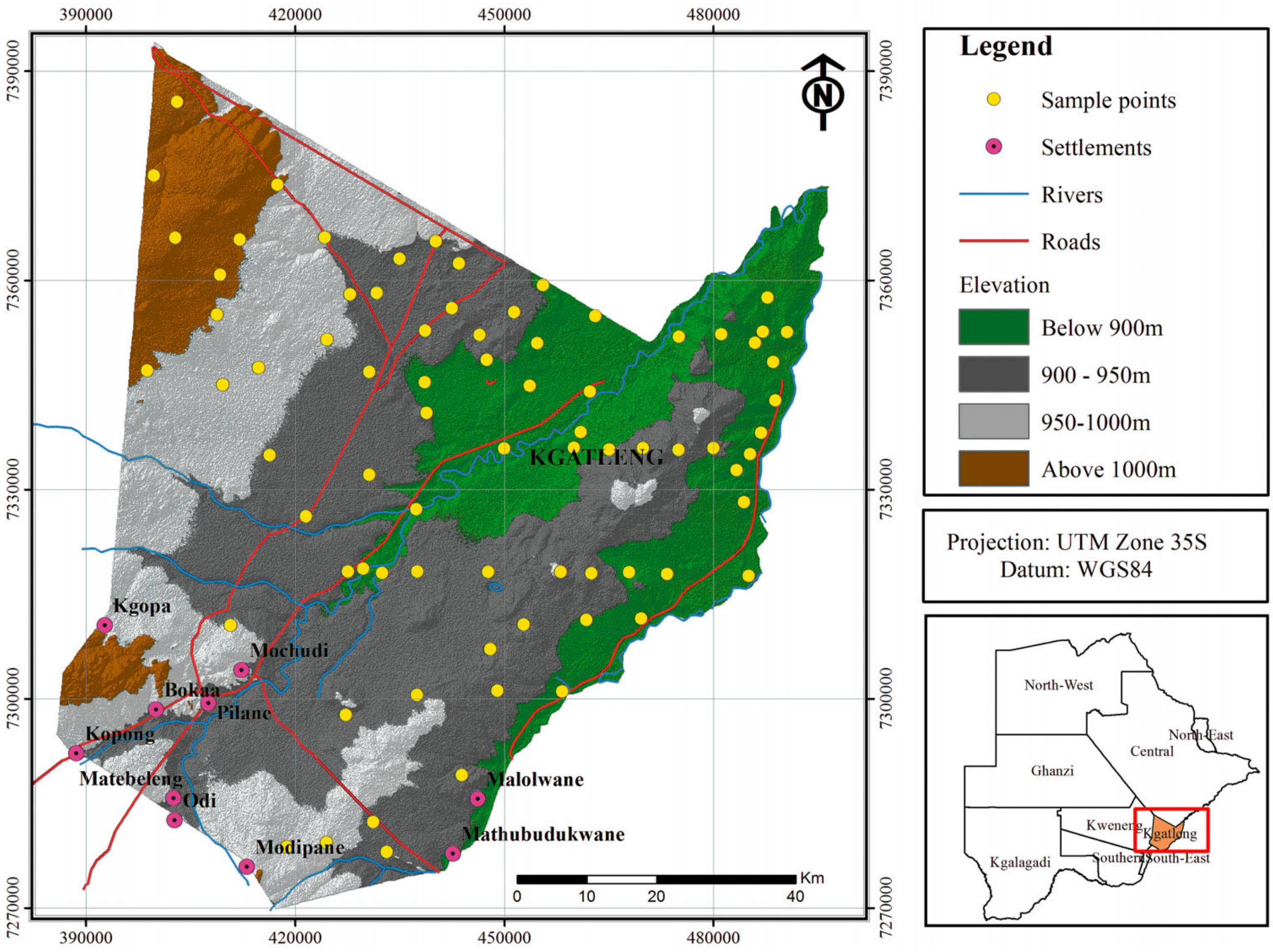


Figure 1: Location map for Kgatleng District, Botswana. Map on the bottom right shows the location of Kgatleng District in Botswana.

species composition and the diversity of the vegetation (Miyamoto et al., 2003). A study by Dahlberg (2000) in north-eastern Botswana observed that woody species richness was higher on red soil than on white soil, but species richness did not differ between ranching and communal grazing land. The study also found significantly ($P < 0.01$) more shrubs on communal land than on ranch land, probably because of less competition with the herbaceous plants, resulting in shrub seedling establishment. In Dahlberg's (2000) study conducted in the north-east district of Botswana, *Senegalia nigrescens*, *Combretum apiculatum,* and *Grewia* spp. were observed to prefer red soil whereas *Colophospermum mopane* preferred white soil. Other environmental variables such as elevation have also been noted to affect species and community diversity of vascular plants (Khan et al., 2011).

Kgatleng District, with a land area of 7960 km$^2$, is relatively small and is under immense pressure from different land uses. Like most communal parts of Botswana, the district is exposed to both arable farming and open-access communal livestock grazing. For sustainable management of vegetation resources, documentation of plant communities and species richness in these areas is of pivotal importance. Meanwhile, literature is lacking as far as plant diversity and richness in these areas are concerned. Thus, defining plant communities in these systems in an era of climate-change effects on vegetation is critical to serve as reference points for vegetation changes. Therefore, the objectives of the study were to (1) determine the abundance of woody (trees and shrubs) species, (2) to identify tree communities and their ecological drivers, (3) to produce a vegetation map based on Landsat imagery and the results of the phytosociological classification, and (4) to determine the species richness of the tree communities.

## Methods

### Study area

The study was conducted between November 2013 and December 2016. The study area covered the Kgatleng District of Botswana, located between latitude 23.88°S–24.51°S and longitude 25.89°E–26.82°E (Fig. 1). The district covers an area of 7,960 km$^2$ and is characterized by vegetation dominated by *Vachellia* spp., *Senegalia* spp., and *Grewia* spp., among others. Annual rainfall for the district ranges between 450 mm and 550 mm. The temperatures range between 6°C and 20°C in winter and 22°C and 30°C in summer (Bhalotra, 1987). Soils are predominantly arenosols and luvisols (Moganane,

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Table 1. Abundance (individuals/ha) and indicator species for the woody plant communities identifed in Kgatleng District, Botswana.

| Family | Species | Abundance ± SE (individuals/ha) | Indicator Value (IV) | Mean ± SD | p * |
|---|---|---|---|---|---|
| **Unit 1 *Terminalia sericea–Maytenus tenuispina* community** | | | | | |
| Combretaceae | *Terminalia sericea* | 96.1 ± 28.14 | 70.2 | 17.1 ± 4.25 | 0.0002 |
| Celastraceae | *Maytenus tenuispina* | 34.6 ± 20.01 | 20.2 | 11.7 ± 5.26 | 0.0732 |
| Caesalpiniaceae | *Bauhinia petersiana* | 20.0 ± 8.01 | 18.6 | 9.3 ± 4.73 | 0.0506 |
| Celastraceae | *Maytenussenegalensis* | 12.8 ± 7.44 | 7.4 | 10.6 ± 5.12 | 0.7051 |
| **Unit 2 *Dichrostachys cinerea–Combretum apiculatum* community** | | | | | |
| Mimosaceae | *Dichrostachys cinerea* | 147.4 ± 22.95 | 57.1 | 23.1 ± 3.94 | 0.0002 |
| Combretaceae | *Combretum apiculatum* | 35.5 ± 8.11 | 54.3 | 14.7 ± 4.66 | 0.0002 |
| Tiliaceae | *Grewia bicolor* | 33.8 ± 6.96 | 51.9 | 18.5 ± 5.52 | 0.0006 |
| Mimosaceae | *Senegalia nigrescens* | 2.0 ± 1.03 | 28 | 9.3 ± 5.01 | 0.0056 |
| Anacardiaceae | *Sclerocary abirrea* | 0.7 ± 0.35 | 20 | 7.6 ± 4.31 | 0.0204 |
| Capparaceae | *Bosciafoetida* | 0.3 ± 0.22 | 12 | 6.7 ± 4.02 | 0.166 |
| Euphorbiaceae | *Croton gratissimus* | 8.5 ± 6.10 | 6.9 | 8.9 ± 4.66 | 0.6159 |
| Combretaceae | *Combretumimberbe* | 0.2 ± 0.25 | 4 | 6.5 ± 1.81 | 1 |
| Euphorbiaceae | *Spirostachysafricana* | 0.2 ± 0.25 | 4 | 6.5 ± 1.80 | 1 |
| Rubiaceae | *Vangueriainfausta* | 0.1 ± 0.12 | 4 | 6.5 ± 1.80 | 1 |
| Olacaceae | *Ximeniaamericana* | 0.5 ± 0.51 | 4 | 6.5 ± 1.81 | 1 |
| **Unit 3 *Combretum zeyheri–Vachellia tortilis* community** | | | | | |
| Combretaceae | *Combretum zeyheri* | 5.3 ± 2.64 | 29.4 | 8.8 ± 4.74 | 0.0028 |
| Mimosaceae | *Vachellia tortilis* | 40.6 ± 12.25 | 29 | 18.1 ± 5.33 | 0.0418 |
| Tiliaceae | *Grewia retinervis* | 28.9 ± 6.39 | 28.5 | 17.4 ± 5.63 | 0.0506 |
| Anacardiaceae | *Rhus tenuinervis* | 2.8 ± 1.09 | 19.5 | 10.3 ± 5.05 | 0.0532 |
| Caesalpiniaceae | *Peltophorum africanum* | 1.9 ± 0.76 | 17.7 | 9.9 ± 4.98 | 0.0742 |
| Ochnaceae | *Ochna pulchra* | 20.7 ± 11.40 | 12.4 | 12.9 ± 6.19 | 0.4311 |
| Ebenaceae | *Diospyros lycioides* | 16.2 ± 10.42 | 10.8 | 8.0 ± 4.36 | 0.2478 |
| Caesalpiniaceae | *Burkea africana* | 0.2 ± 0.25 | 8.3 | 6.5 ± 1.81 | 0.3149 |
| Mimosaceae | *Vachellia erioloba* | 3.1 ± 1.75 | 8.1 | 8.7 ± 4.53 | 0.4345 |
| Mimosaceae | *Vachellia karroo* | 6.4 ± 6.23 | 5.8 | 6.5 ± 3.44 | 0.4219 |
| **Unit 4 *Senegalia erubescens–Senegalia mellifera* community** | | | | | |
| Mimosaceae | *Senegalia erubescens* | 36.1 ± 9.42 | 55 | 17.9 ± 5.02 | 0.0002 |
| Mimosaceae | *Senegalia mellifera* | 31.4 ± 12.17 | 37.1 | 13.1 ± 4.74 | 0.0014 |
| Capparaceae | *Boscia albitrunca* | 10.1 ± 2.01 | 18.5 | 17.1 ± 4.69 | 0.3117 |
| Combretaceae | *Combretum hereroense* | 2.2 ± 0.83 | 12.4 | 10.2 ± 4.80 | 0.247 |
| Ebenaceae | *Euclea undulata* | 18.9 ± 5.78 | 10.8 | 13.9 ± 5.41 | 0.6847 |
| Rhamnaceae | *Ziziphus mucronata* | 2.4 ± 1.15 | 8.1 | 9.0 ± 4.49 | 0.4609 |
| Mimosaceae | *Vachellia nilotica* | 0.3 ± 0.28 | 6.9 | 7.4 ± 3.25 | 0.5999 |
| **Unit 5 *Grewia flava–Rhigozum brevispinosum* community** | | | | | |
| Tiliaceae | *Grewia flava* | 103.7 ± 14.54 | 56.2 | 23.0 ± 3.92 | 0.0002 |
| Bignoniaceae | *Rhigozum brevispinosum* | 24.8 ± 8.87 | 33.5 | 14.2 ± 5.72 | 0.01 |
| Burseraceae | *Commiphora africana* | 43.2 ± 8.86 | 33.3 | 21.9 ± 5.92 | 0.0486 |
| Tiliaceae | *Grewia flavescens* | 7.6 ± 3.09 | 24.5 | 12.9 ± 5.87 | 0.0504 |
| Mimosaceae | *Senegalia fleckii* | 8.1 ± 3.96 | 16.5 | 10.3 ± 5.20 | 0.1252 |
| Celastraceae | *Maytenus buxifolia* | 1.5 ± 1.15 | 6.5 | 6.6 ± 3.38 | 0.4657 |
| Olacaceae | *Ximenia caffra* | 0.2 ± 0.18 | 4.7 | 6.2 ± 3.26 | 0.6863 |

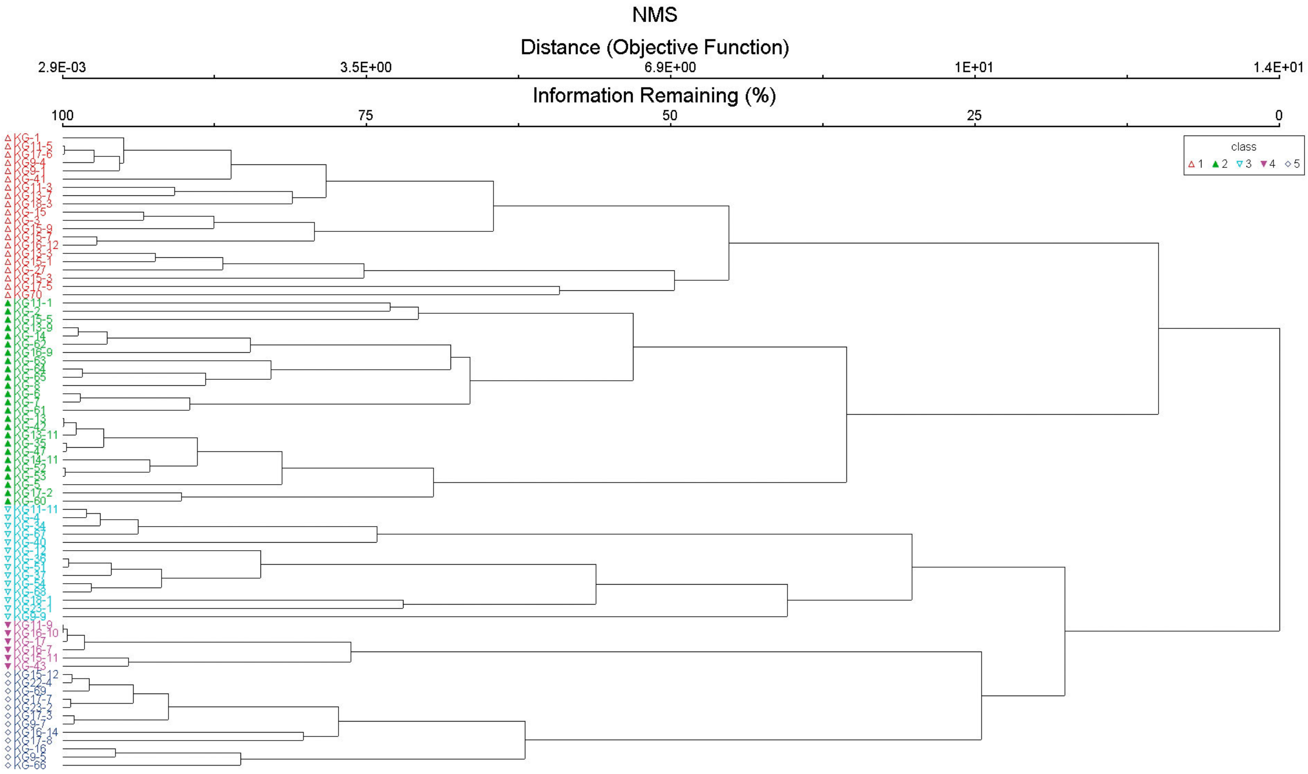


Figure 2: Cluster analysis showing the five plant communities identified in Kgatleng District, Botswana. *Terminalia sericea–Maytenus tenuispina* (1), *Dichrostachys cinerea–Combretum apiculatum* (2), *Combretum zeyheri–Vachellia tortilis* (3), *Senegalia erubescens–Senegalia mellifera* (4) and *Grewia flava–Rhigozium brevispinosum* (5).

1990). The eastern part of the district falls in the hardveld whereas the north-western part falls partly in the sandveld ecological zone (Nsinamwa et al., 2005).

### Vegetation and soil sampling

Vegetation sampling involved the use of transects cutting across different vegetation types using a geographical positioning system (GPS) receiver. Before field work, satellite imagery from Google Earth was used to identify different vegetation types by contrasting colours along systematically placed transects running in a south-north direction through the entire length of the district. At each sampling point a survey pin was thrown over the shoulder, and where it landed it formed the centre point of a vegetation plot. Sampling points were established along transects at distances ranging from 5 km to 10 km apart depending on the differences in the vegetation and land use (e.g., fenced fields). The homogeneity or heterogeneity of the vegetation determined the spacing of the transects, and distances between transects were increased when the vegetation was homogenous. At each sampling point along the transects, a 50 m × 20 m quadrat, the standard plot size agreed upon for SASSCAL vegetation monitoring and mapping activities, was established. In each vegetation plot, all woody (tree and shrub) species rooted in the rectangle were counted and recorded by species. Furthermore, the percent cover of each species was estimated visually as described in Bonham (1989). A total of 77 plots were sampled (Fig. 1). Abundance data for woody species was then expressed as individuals/ha. Nomenclature for scientific names follows van Wyk & van Wyk (1997) and Kyalangalilwa et al. (2013). At each sampling plot, soil samples were also collected at a depth of 10–15 cm in the middle of each plot. Soil samples were then analysed for particle size, soil pH, and electrical conductivity (EC) following standard laboratory procedures.

## Data analysis

### Vegetation classification and statistical analyses

Cover data (%) of species for all 77 vegetation plots were standardised using relativisation by maximum. The data were then subjected to hierarchical cluster analysis (β linkage, β = –0.25, Sorensen distance) (McCune et al., 2002) based on 39 species distributed in the 77 plots. Indicator species analysis (Dufrene & Legendre, 1997) was used to define meaningful vegetation communities. Indicator values (IVS) were assessed for statistical significance using the Monte Carlo technique. Sorensen distance measure was used to examine differences between vegetation communities using a multi-response permutation procedure (McCune et al., 2002). Vegetation communities were plotted in ordination space using non-metric multidimensional scaling (NMDS). And the environmental variables (sand particles [%], clay particles [%], silt [%], pH, EC, inclination, and exposition) were fitted post hoc. All of these statistical analyses were performed in PCORD 6 (McCune et al., 2002).

Species richness was calculated as the mean number of species occurring in the plots of each community. To test whether species richness differs among communities, the data were analysed with one-way analysis of variance using SPSS 16.0.

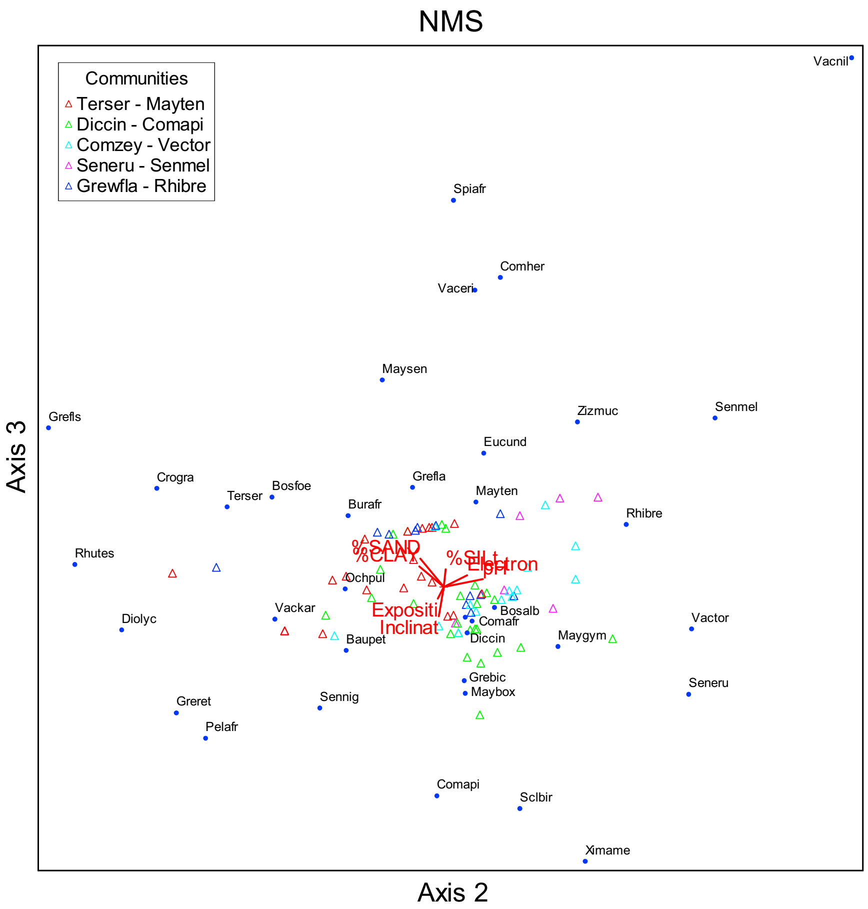


Figure 3: Non-metric multidimensional scaling (NMDS) of the vegetation data, showing the species (abbreviations show the first three letters of the genus and the epithet), the plots coloured according to the five identified communities and the environmental variables. Bauhinia petersiana – Bahpet; Boscia albitrunca – Bosalb; Boscia foetida – Bosfoe; Burkea africana – Burafr; Combretum apiculatum – Comapi; Combretum hereroense – Comher; Combretum imberbe – Comimb; Combretum zeyheri –Comzey; Commiphora africana – Comafr; Croton gratissimus – Crograt; Dichrostachys cinerea – Diccin; Diospyros lycioides –Diolyc; Euclea undulata – Eucund; Grewia bicolor –Grebic; Grewia flava – Grefla; Grewia flavescens – Grefla; Grewia retinervis – Greret; Maytenus buxifolia – Maybux; Maytenus senegalensis – Maysen; Maytenus tenuispina – Mayten; Ochna pulchra – Ochpul; Peltophorum africanum – Pelafr; Rhigozum brevispinosum – Rhibre; Rhus tenuinervis – Rhuten; Sclerocarya birrea – Sclbir; Senegalia erubescens – Seneru; Senegalia fleckii – Senfle; Senegalia mellifera – Senmil; Senegalia nigrescens – Sennig; Spirostachys Africana – Spiafr; Terminalia sericea – Terser; Vachellia erioloba – Vaceri; Vachellia karroo – Vackar; Vachellia nilotica – Vacnil; Vachellia tortilis – Vactor; Vangueria infausta – Vaninf; Ximenia Americana – Ximame; Ximenia caffra – Ximcaf; Ziziphus mucronata – Zizmuc; *Terser-Mayten: Terminalia sericea–Maytenus tenuispina, Diccin-Comapi: Dichrostachys cinerea-Combretum apiculatum, Comzey-Vactor: Combretum zeyheri-Vachellia tortilis, Seneru-Senmel: Senegalia erubescens-Senegalia mellifera and Grefla-Rhibre: Grewia flava-Rhigozium brevispinosum*.

Means were considered significantly different at $P < 0.05$. Species richness was reported as number of species per 1000 $m^2$. Box plots of species richness were generated from the data using SPSS 16.0.

### Vegetation mapping

A vegetation map was developed to show the spatial distribution of plant communities. Four wet season scenes of Landsat 8 Operational Land Imager of 2016 were freely downloaded from USGS GloVis (Global Visualization Viewer) at a resolution of 30 m. The wet season scenes were used because during that season the vegetation is mature and the images show the vegetation in full development. However, our sampling on the ground covered both the dry and wet seasons. The scenes were atmospherically corrected using FLAASH and mosaicked using seamless mosaic in ENVI 5.1. Supervised classification was performed on the Landsat images using maximum likelihood classifier. Five vegetation communities were mapped using ENVI 5.1, and the classification results were imported into ArcMap 10.3 for finalization of the map.

## Results

### Diversity and abundance of woody species

A total of 15 families, 23 genera, and 39 species were observed in the district (Tab. 1). Fabaceae was the most species-rich family in the study area, and there were more species of the subfamily Mimosaceae than of the subfamily Caesalpiniaceae. The Combretaceae family had 2 genera with a total of 5 species. Only 1 species was observed for each of Bignoniaceae, Burseraceae, Ochnaceae, Rhamnaceae, and Rubiaceae families in the district.

The most abundant species in their respective communities were *Dichrostachys cinerea* with 147 individuals/ha followed by *Grewia flava* (103.7 ± 14.54 indiv./ha) and *Terminalia sericea* (96 ± 28.1 indiv./ha). Overall, abundance of the genera *Vachellia* and *Senegalia* was 50.4 and 77.6 individuals/ha, respectively (Tab. 1).

### Vegetation classification and mapping

The cluster analysis identified five communities (Fig. 2). They were named based on the two species with the highest indicator values: Community 1, *Terminalia sericea–Maytenus tenuispina*; Community 2, *Dichrostachys cinerea–Combretum apiculatum*; Community 3: *Combretum zeyheri–Vachellia tortilis*; Community 4, *Senegalia erubescens–Senegalia mellifera*; and Community 5, *Grewia flava–Rhigozium brevispinosum.* The indicator species for each community are presented in Table 1. NMDS also confirmed that there were 5 distinct communities (Fig. 3). Though most of the species were clustered, the dominant indicator species for each community were clearly showing. For example, *Ximenia americana, Boscia foetida, Combretum apiculatum,* and *Dichrostachys cinerea* occurred together, characterizing the *Dichrostachys cinerea–Combretum apiculatum* community (Fig. 3). *Terminalia serecea–Maytenus tenuispina* community occurrence

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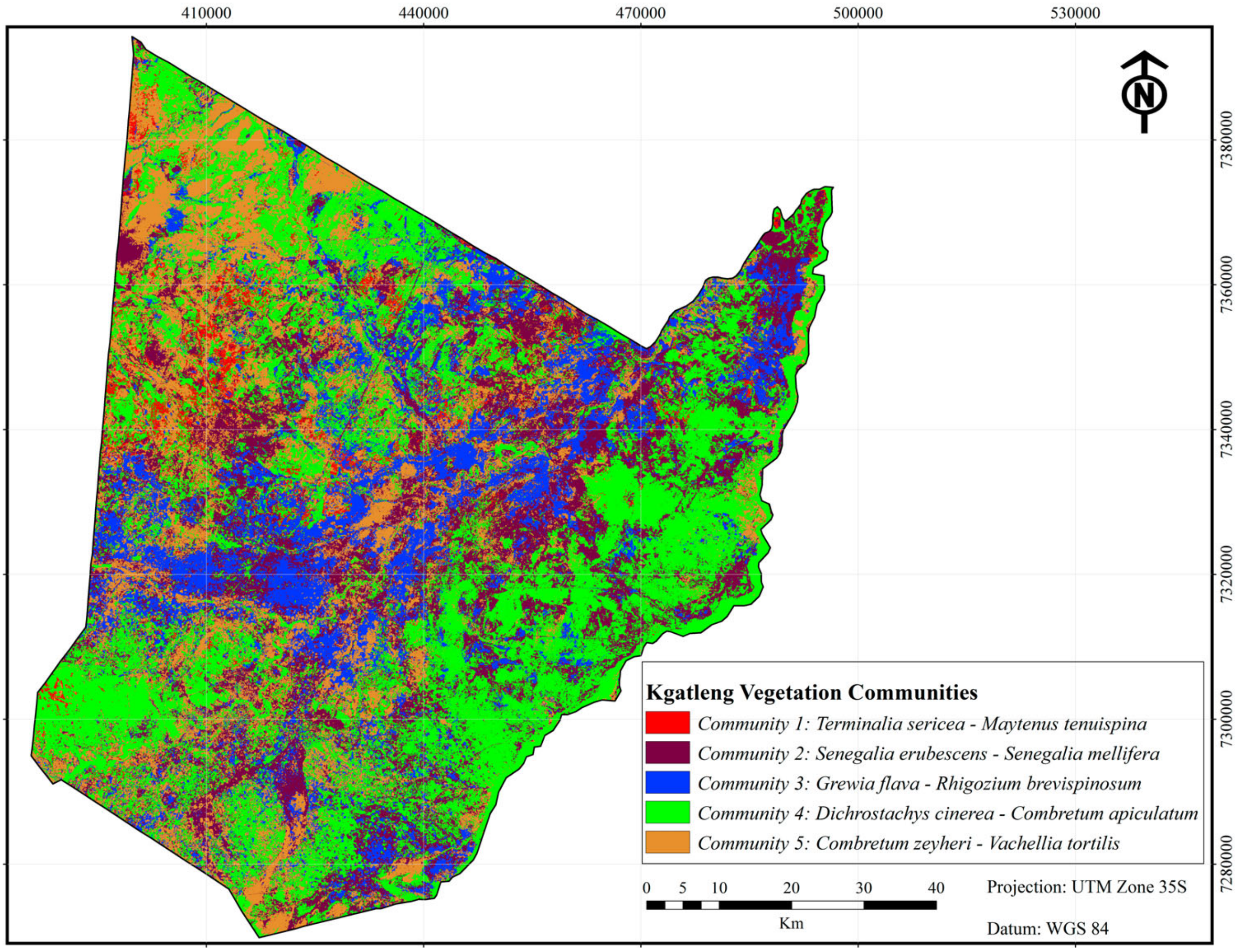


Figure 4: Vegetation map based on supervised classification of Landsat 8 scenes, showing the five communities identified in Kgatleng District, Botswana.

was influenced by the percentages of clay and sand, whereas inclination and soil pH influenced the occurrence of *Combretum zeyheri–Vachellia tortilis* communities (Fig. 3).

Upon mapping the communities, it was observed that the *Senegalia erubescens–Senegalia mellifera* community was dominant and occurred over most parts of the district, followed by the *Dichrostachys cinerea–Combretum apiculatum* community (Fig. 4). The *Terminalia sericea–Maytenus tenuispina* community covered the least area and occurred mostly towards the northern parts of the district in the sandveld.

## Species richness

Species richness ranged, on average per community, between 6.4 and 7.9 species, and no significant differences were

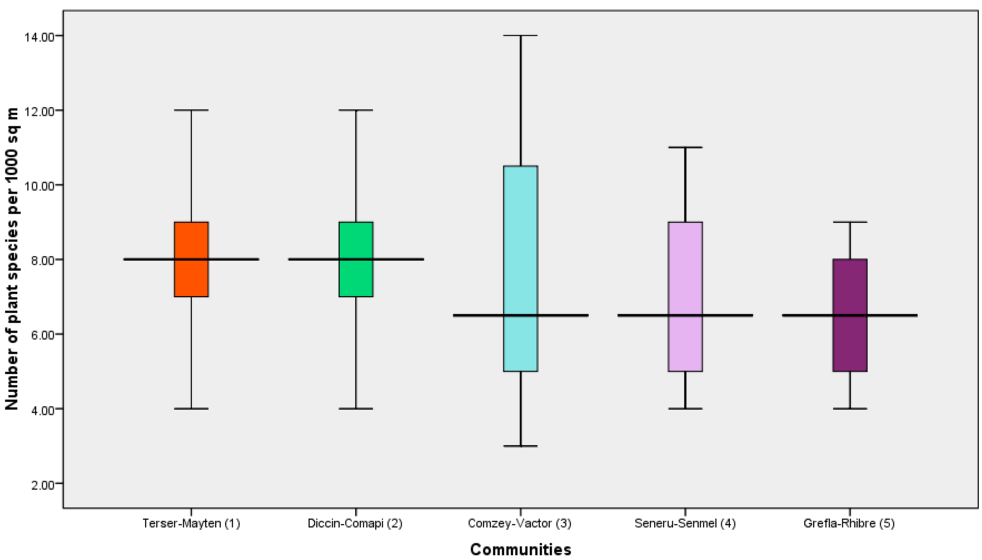


Figure 5: Box plots of the species richness of the five communities in Kgatleng District, Botswana. The abbreviations are as explained: Terser-Mayten: Terminalia sericea–Maytenus tenuispina, Diccin-Comapi: Dichrostachys cinerea-Combretum apiculatum, Comzey-Vactor: Combretum zeyheri-Vachellia tortilis, Seneru-Senmel: Senegalia erubescens-Senegalia mellifera and Grefla-Rhibre: Grewia flava-Rhigozium brevispinosum

detected among the five communities (ANOVA: $F_{4,72} = 1.87, P = 0.125$) (Fig. 5). Interestingly, the *Senegalia erubescens–Senegalia mellifera* community that dominated the district (Fig. 4) was among the communities that had low species richness (Fig. 5), even if it was not significantly different from other communities. Species richness varied widely between plots for the *Combretum zeyheri–Vachellia tortilis* community (Fig. 5).

Densities of individuals per hectare were 1022, 748, 896, 696, and 787 for the five communities, respectively. Densities of plants did not differ significantly among communities (ANOVA: $F_{4,72}$ = 1.73, P = 0.15).

## Discussion

### Vegetation classification and mapping

The *Terminalia sericea–Maytenus tenuispina* community typically occurs on the sandveld north-western parts of the district, which is characterized by deep, sandy soils. Typically, *Terminalia sericea* is deep rooted and occurs on well-drained soils (van Wyk & van Wyk, 1997). According to Moore & Attwell (1999), coarse-grained soils are associated with the occurrence of tree savannas. The *Dichrostachys cinerea–Combretum apiculatum* community dominated on the eastern side of the district and occurs on the hardveld. This area is typical of bush savanna, consisting of characteristic *Dichrostachys cinerea* thickets mixed with *Grewia* species and *Combretum apiculatum* (Aganga & Omphile, 2000). In the centre of the district, the *Senegalia erubescens–Senegalia mellifera* and *Grewia flava–Rhigozium* communities were dominant. These communities comprise species such as *S. erubescens, S. mellifera,* and *G. flava*. Moleele (1998) identified these as encroaching on grazing areas in the district. Increases in these species may interfere with the predominant land use of cattle grazing as grasses are outcompeted.

### Species richness

Studies have observed that plant species diversity and richness increase with an increase in plant density (Belay et al., 2013). In our study we observed high woody-plant density in the north of the district, suggesting lessened anthropogenic impact farther away from major villages in the south. However, species richness was similar across all communities. As species richness focused only on woody vegetation, it would probably have been different if all life forms were considered.

Indications of relatively high numbers of individuals from the genera *Vachellia* and *Senegalia* may be supported by earlier observations by other researchers (e.g., Moleele, 1998), who observed encroacher species such as *Senegalia mellifera* to be dominant in the north-eastern part of the district. The eastern part of the district, where bush encroachment has been identified, comprises fertile soils that support the growth of vegetation (Moganane, 1990). In the southern district of Botswana, Mosweu (2008) also observed *Vachellia* spp. encroacher species to be more in areas that were highly utilized by livestock. Because the current study covered a large area, average plant abundance was fairly low as a result of many plots sampled with variable abundances across the district, unlike Moleele's (1998) study, which was localized in a high-abundance area for the encroacher species at Oliphants Drift. Earlier studies have indicated that an area is encroached if it has ≥ 2,500 individuals/ha (e.g., Richter et al., 2001). Thus, in the current study, bush encroachment was not a concern. In contrast, in these ecosystems, *Vachellia* and *Senegalia* genera are important sources for browse and firewood. Of relevance for the local communities are also the species of the families Tiliaceae and Combretaceae, as these provide edible berries and fencing materials, respectively.

## Conclusion

Woody vegetation for Kgatleng District was composed of 15 families, 23 genera, and 39 species. The five communities identified were *Terminalia sericea–Maytenus tenuispina, Dichrostachys cinerea–Combretum apiculatum, Combretum zeyheri–Vachellia tortilis, Senegalia erubescens–Senegalia mellifera,* and *Grewia flava–Rhigozium brevispinosum.* Woody species richness was not significantly different between the communities. The study provided a map of the spatial distribution of the communities in the district. The findings of this study will serve as baseline information that can be used for determining land suitability for different sectors of agriculture. The information also serves as baseline information that can be used in future to determine whether encroachment is increasing.

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