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Research Article

Restoration of Natural Habitats as a Nature-based Solution for Sustaining Insect Biodiversity to Ensure Sustainable Food Production

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Abstract

The rapid loss of natural habitats and resulting loss of biodiversity in insect taxa is a serious concern that will impact future food production. Insect biodiversity decline can be mainly attributed to the intensification of agriculture with the main drivers being habitat loss, fragmentation, and use of agro-chemicals. To mitigate the pressure of agriculture on biodiversity we urgently need to prioritize the restoration of land to natural habitats within agricultural landscapes. Changes in biodiversity in agricultural landscapes as agriculture intensifies were investigated in an Afromontane biome in South Africa, using dung beetle assemblages as indicators of habitat transformation. Five localities were chosen for dung beetle monitoring in the grassland biome of the Eastern Free State, South Africa. A total of 27 dung beetle species classified in 15 genera were collected in the study area during November 2023. Land use change from natural to agricultural causes a change in the community structure of dung beetles with some species and functional groups becoming more dominant, while others disappear as agricultural intensity increases. For efficient ecosystem functioning in agricultural habitats, an integrated approach for the specific area will be necessary. The protection of large natural areas, the restoration of degraded agricultural habitats, and the promotion of livestock and crops that are adapted to the specific environment will be essential.

Introduction

In order to feed the growing human population, over the last couple of years, agriculture not only expanded to occupy most of the land area but was also intensified by increased monocultures and the use of agrochemicals. The rapid loss of natural habitats resulting in biodiversity loss in insect taxa is a serious concern that will impact food production. Monoculture renders a system unstable and can lead to total collapse of the crop since it influences the composition and abundance of the associated biota such as those of the predator complex and the soil insects and microorganisms, consequently affecting plant and soil processes. Insect biodiversity decline can be mainly attributed to the intensification of agriculture with the main drivers being habitat loss, fragmentation, and use of agro-chemicals. Brandon, et al. [1] believe that habitat conversion for agriculture is a leading cause of global biodiversity loss, with the increasing demand from a growing human population leading to increased land degradation and putting pressure on remaining habitats. Attenborough [2] states that "*The conversion of wild habitat to farmland as humankind expanded its territory throughout the Holocene has been the single greatest direct cause of biodiversity loss during our time on Earth*" Our attempts to feed the growing human population have left very little space for other species sharing the planet with us and these species cannot survive in the changing environment.

Healthy soil is crucial for the successful production of food and healthy soil for successful plant growth is a result of intricate interactions between soil, macrofauna, and microorganisms. The role of macrofauna in nutrient cycling includes fragmentation of plant residues and stimulation of microbial activity and this has a direct effect on soil structure

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by the redistribution of organic material and microorganisms while increasing soil aeration [3].

Dung beetles of the subfamily Scarabaeinae occur globally and are associated with a great variety of habitats exhibiting significant variation in spatial and temporal characteristics depending on the availability of food [4]. Dung beetles feed mainly on mammal dung in the larval and adult stages, although a few species feed on carrion, rotting fruits, fungi, and decaying plant matter [5]. The principal importance of dung beetles lies in their maintenance of pasture health by burying dung, which has the effect of removing surface wastes [6]. By burying decomposing organic matter and constructing galleries for nesting within the soil, dung beetles actively contribute to the ecological process of nutrient cycling, soil aeration, secondary seed burial, and parasite suppression [5,7-9]. The abundance and biomass of dung beetles are influenced by the physicochemical properties of the soil in agroecosystems [10]. This is important information to determine a strategy for increasing fertility and management of soil conservation in agroecosystems. Several studies indicate that dung beetle assemblages respond negatively to fragmentation and transformation of natural habitats and that larger dung beetles do not survive in these unsuitable habitats [11-13].

To mitigate the pressure of agriculture on biodiversity we urgently need to prioritize the restoration of land to natural habitats within agricultural landscapes. Well-managed protected areas are among the best strategies to stop habitat loss [1]. This paper explores the changes in biodiversity in agricultural landscapes as agriculture intensifies in an Afromontane biome in South Africa, using dung beetle assemblages as indicators of habitat transformation.

Methods

Study area

Temperate grasslands are high in biodiversity and endemism ensuring important ecosystem services. Unfortunately, these biomes are globally the least protected, with only 4.6% formally protected [14]. The Maloti-Drakensberg of South Africa and Lesotho is one of seven remaining continuous grasslands in the world and their contribution to global grassland conservation is critical [14].

Five localities were chosen for dung beetle monitoring in the grassland biome of the Eastern Free State, South Africa (Figure 1):

I. **Witsieshoek Community Conservation Area (WCCA):** The South African portion of the QwaQwa Maloti comprises the Witsieshoek Community Conservation Area (WCCA). Although included in the Maloti-Drakensberg Transfrontier Park this area is an imperiled and poorly known biome, not formally protected, and rapidly converted into settlements or degraded by alien plant invasion, bush encroachment, and livestock over-grazing [15] resulting in loss of habitat and biodiversity. Two sites, 6km apart, were selected at this locality for dung beetle monitoring. Site 1 (S28.6773E28.9019) was at an elevation of 2058m and falls in the lower subalpine (2000m-2400m). The grazing pressure in this area is moderate to high. This area is dominated by encroaching *Leucosidea sericea* and increaser *Eragrostis plana* plant species, indicating the effects of over-grazing. Site 2 (S28.7273E28.8917) was at an elevation of 2555m and falls in the higher subalpine (2400-2800m). The grazing pressure in this area is low. Because this area is less accessible it is generally protected from livestock grazing and other disturbance.

II. **Golden Gate Highlands National Park (GGHNP):** GGHNP is 30km from the WCCA. This park is the only national park in the Eastern Free State Province of South Africa, in the foothills of the Maluti Mountains, in a montane and Afro-Alpine grassland biome. An area of 4.79ha was proclaimed as a national park in 1963 and was enlarged to 11.63ha in 1988. The park was amalgamated with QwaQwa National Park in 2007, increasing the area to 33993.59 ha [16]. Residents adjacent to the park threaten natural habitats by grazing their livestock in the park or harvesting thatch grass and medicinal plants, while agricultural activities and settlement expansion of adjacent communities are worsening this situation [17]. Two sites, 6km apart, were selected at this locality for dung beetle monitoring. Site 1 (28°29'56.71"S28°42"35.78"E) was at an elevation of 1719m. This area is grazed by cattle and horses with moderate to high grazing pressure. Site 2 (28°29'42.13"S28°38'54.50"E) was at an elevation of 2100m and was grazed by Red Hartebeest and Blue Wildebeest at a low grazing pressure.

III. **De Molen Farm (DMF):** This farm covers an area of 300ha and is 10 km from the entrance to GGHNP and 40km from WCCA. The area between the farm De Molen and GGHNP is mostly a semi-natural landscape. This farm consists of 86ha of crop fields cultivated with beans and maize using conventional methods of deep ploughing combined with the use of agro-chemicals. Pastures comprise 214ha of natural and semi-natural areas grazed by Nguni cattle and sheep. Two sites, spaced 1km apart, were chosen for monitoring at this locality. Site 1 (28°31'01.89"S28°29'54.91"E) was at an elevation of 1738m with moderate grazing pressure. Site 2 (28°31'00.94"S28°29'32.45"E) was at an elevation of 1802m with a low grazing pressure.

IV. **St Ford Farm (SFF):** This farm is 24km from GGHNP and 50km from WCCA. Conservation agriculture production practices are followed on this farm. Two sites were chosen in this landscape at different elevations. Site 1 (28°33'26,45"S28°24'36,11"E) was at an elevation of 1699m and was in crop fields. The fields were planted with maize and a variety of cover crops by no-till. Agrochemicals (fertilizer, herbicides, fungicides, and insecticides) were used in this area. Livestock (cattle and sheep) grazed the area after the

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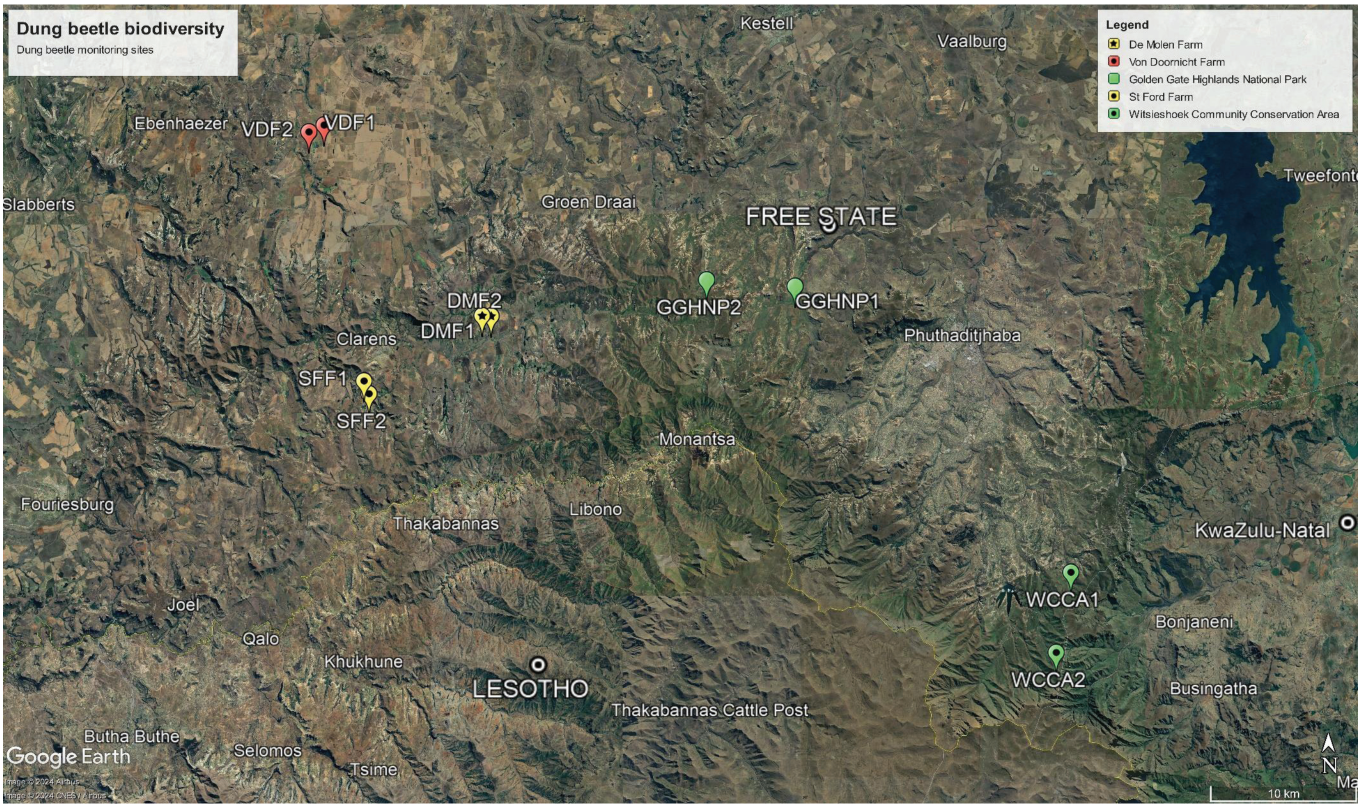

Figure 1: Monitoring sites for dung beetle biodiversity.

harvest of the maize crop at a high grazing intensity. Site 2 (28°33'55,15"S28°24'48,54"E) was 1 km from site 1 and at an elevation of 1765m. This site was in a natural pasture that was grazed by cattle at a moderate grazing intensity.

V. **Von Doornicht farm (VDF):** This farm is 25 km from GGHNP and 60km from WCCA. Conventional production practices are followed on this farm. Two sites were chosen in this landscape at different elevations. Site 1 (28°23'52,13"S28°22'58,27"E) was at an elevation of 1750m and was in crop fields. Maize and soya were planted with conventional deep tilling. Agrochemicals (fertilizer, herbicides, fungicides, and insecticides) were used in this area. Site 2 (28.402032°S 28.372308°E) was 1 km from site 1 and at an elevation of 1825m. This site was in a natural pasture that was grazed by cattle at a moderate grazing intensity.

The St Ford Farm and Von Doornicht Farm were 18km apart. Both these farms were surrounded by continuous monocrop fields managed by conventional production practices.

Monitoring

Since dung beetle activity, abundance, and diversity increase with an increase in temperature and rainfall during November, this month was chosen to conduct the dung beetle monitoring for this study. During this month most species occurring in the area will therefore be present. Dung beetles were monitored during November 2023 at the two sites in each of the 5 different localities with pitfall traps, baited with pig dung wrapped in gauze to prevent dung beetles from burrowing into the dung. In each site three plots were chosen, spaced 50m apart, in each plot we set up four pitfall traps, spaced 5m apart. The traps were left for 48 hours in the field, after which samples were collected from the traps. Since dry traps with no preservative were used 48 hours was sufficient time to attract dung beetle species in the area to the traps with the dung, while the specimens collected would still be alive. After 48 hours the dung would dry out and would no longer be attractive to dung beetles in the area. Four to six individuals of each species, including male and female, collected in the samples, were preserved in ethanol for identification and future reference purposes. Voucher specimens of this study are deposited at the National Museum, Bloemfontein, and Agricultural Research Council - Small Grain, Bethlehem.

Diversity analysis

Samples in the plots were pooled and the average diversity of the three plots per site was determined. The Shannon diversity index and Shannon Equitability index were used to determine diversity for each site:

$$H = -\sum P_i * \ln(P_i)$$

where P_i is the proportion of each species in the sample.

$$EH = H/\ln(S)$$

Where H is the Shannon Diversity Index and S is the total number of unique species.

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The Shannon diversity index takes into account the number of species (species richness in a habitat as well as their relative abundance (evenness)). The higher the value of H, the higher the diversity of species in a particular community, and the lower the value of H, the lower the diversity. A value of H=0 indicates a community that only has one species. The Shannon Equitability Index is a way to measure the evenness of species in a community. The term "evenness" simply refers to how similar the abundances of different species are in the community. The habitat's diversity increases when its evenness becomes closer to 1.

Results and discussion

Species diversity

A total of 27 dung beetle species classified in 15 genera were collected in the study area during November 2023 (Table 1). The diversity (H) in dung beetle assemblages was highest at site 2 on the De Molen farm followed by site 1 in GGHNP and site 1 in WCCA (Figure 2). The lowest diversity in dung beetle assemblages was found at the Von Doornict farm (Figure 2). The eveness (E_H) was highest in GGHNP and WCCA followed by DM, with the lowest eveness in SFF and VDF (Figure 3). The habitat's diversity increases when its evenness becomes closer to 1 indicating that a higher diversity within a dung beetle assemblage was found in habitats in the semi-natural localities where pressure from agriculture was lower (Figure 3). The diversity was also higher within an agricultural landscape on the De Molen farm than the other two localities in an agricultural landscape (Figure 2). The De Molen farm was surrounded by a semi-natural landscape which was connected to GGHNP, a larger semi-natural landscape, while the other farms were surrounded by monocrop fields in an intensive agricultural landscape. Changes in habitat probably had the principal effect on dung beetle assemblages in the study area. Shahabuddin, et al. [18] showed that dung beetle species richness, abundance as well as species composition, characterized by decreases in mean body size, changed with land-use intensity, indicating that dung type is less important than habitat type for determining the assemblage structure of dung beetles. The diversity in the dung beetle assemblages decreased as grazing pressure and agricultural intensity increased and habitats became more isolated from natural areas. Filgueiras, et al. [19] found fragmentation and isolation of the habitat to be the most significant variables for changes in dung beetle species richness.

Table 1: Dung beetle species monitored at different localities in the study area.

	Family	Subfamily	Tribe	Genus	Species	FG	SFF1	SFF2	VDF1	VDF2	DMF1	DMF2	GGHNP1	GGHNP2	WCCA1	WCCA2
1	Scarabaeidae	Scarabaeinae	Scarabaeini	*Scarabaeus*	*basuto*	*I*								1		
2	Scarabaeidae	Scarabaeinae	Cantohonini	*Epirinus*	*flagellatus*	*II*								3		3
3	Scarabaeidae	Scarabaeinae	Cantohonini	*Epirinus*	*drakomontanus*	*II*										8
4	Scarabaeidae	Scarabaeinae	Sisyphini	*Sisyphus*	*costatus*	*II*						1				
5	Scarabaeidae	Scarabaeinae	Gymnopleurini	*Gymnopleurus*	*leei*	*II*							1			
6	Scarabaeidae	Scarabaeinae	Coprini	*Xinidium*	*dentilabris*	*IV*			10	20		1			20	
7	Scarabaeidae	Scarabaeinae	Coprini	*Metacatharsius*	*troglodytes*	*IV*									1	
8	Scarabaeidae	Scarabaeinae	Onthophagini	*Onthophagus*	*cretus*	*IV*						1				
9	Scarabaeidae	Scarabaeinae	Onthophagini	*Onthophagus*	*asperulus*	*IV*	49	89	1	2	15	20	5	9	6	1
10	Scarabaeidae	Scarabaeinae	Onthophagini	*Onthophagus*	*pilosus*	*IV*		2		2		1				
11	Scarabaeidae	Scarabaeinae	Onthophagini	*Onthophagus*	*obtusicornus*	*IV*							1			
12	Scarabaeidae	Scarabaeinae	Onthophagini	*Onthophagus*	*variolosus*	*IV*		2				3				
13	Scarabaeidae	Scarabaeinae	Onthophagini	*Onthophagus*	*binodus*	*IV*				1				2		
14	Scarabaeidae	Scarabaeinae	Onthophagini	*Onthophagus*	*cribripennis*	*IV*					1	3				
15	Scarabaeidae	Scarabaeinae	Onthophagini	*Onthophagus*	*obtutus*	*IV*						1				
16	Scarabaeidae	Scarabaeinae	Oniticellini	*Euoniticellus*	*africanus*	*IV*	1			1		1				
17	Scarabaeidae	Scarabaeinae	Oniticellini	*Liatongus*	*militarus*	*IV*		1								
18	Scarabaeidae	Scarabaeinae	Oniticellini	Cyptochirus	*ambiguus*	*IV*		1				1				
19	Scarabaeidae	Scarabaeinae	Onitini	*Onitis*	*caffer*	*IV*							1			
20	Scarabaeidae	Scarabaeinae	Onthophagini	*Onthophagus*	*venustulus*	*V*	31	42			36	31	2			
21	Scarabaeidae	Scarabaeinae	Onthophagini	*Onthophagus*	*aequepugens*	*V*						5	2			
22	Scarabaeidae	Scarabaeinae	Canthonini	*Odontoloma*	*peckorum*	*VI*		2			4	1			1	
23	Scarabaeidae	Aphodiinae	Aphodiini	*Aphodius*	*pseudolividus*	*VII*	12	7	1	5	3	1			1	
24	Scarabaeidae	Aphodiinae	Aphodiini	*Aphodius*	*teter sensu lato*	*VII*	2	2		1	1	1			4	
25	Scarabaeidae	Aphodiinae	Aphodiini	*Aphodius*	*laterosetosus*	*VII*	2	1								
26	Scarabaeidae	Aphodiinae	Aphodiini	Harmogaster	*strydomi*	*VII*	1									
27	Scarabaeidae	Aphodiinae	Aphodiini	Rhysemus	*africanus*	*VII*		1								

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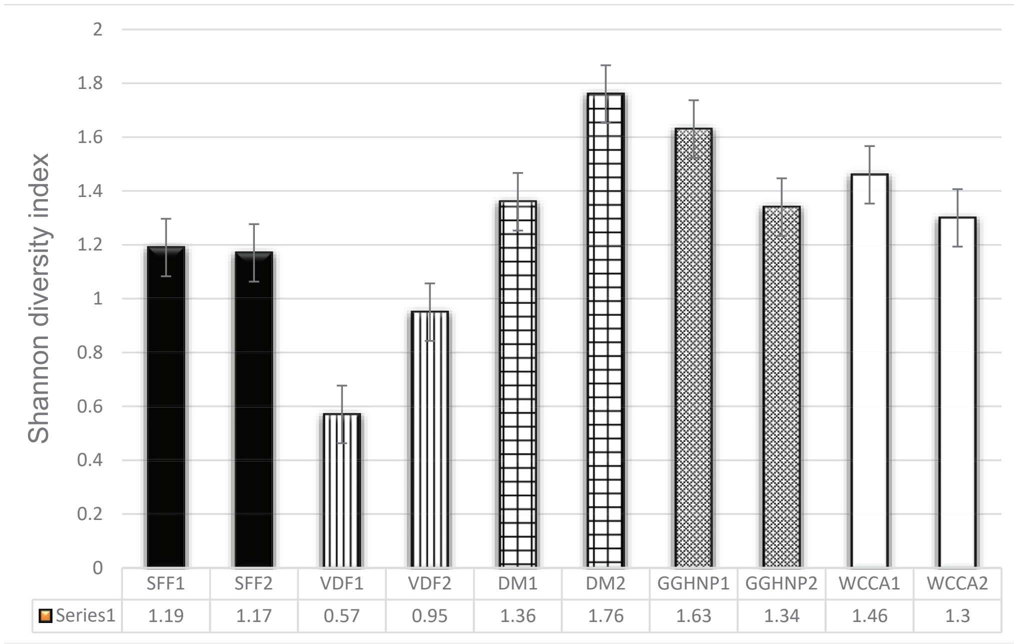

Figure 2: Shannon diversity (H) in dung beetle assemblages at different localities and sites in the study area.

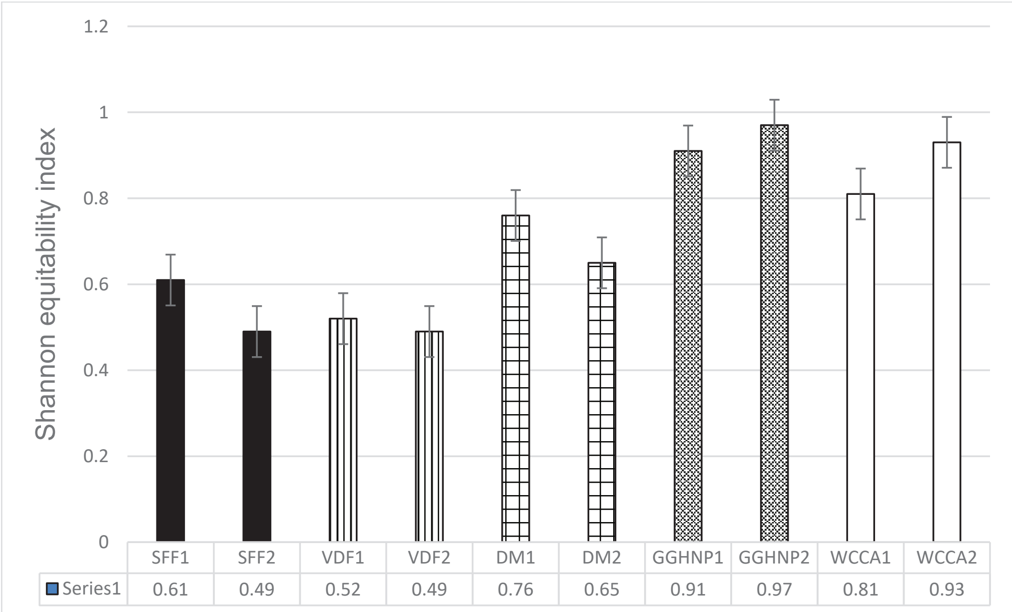

Figure 3: Shannon eveness (E_H) in dung beetle assemblages at different localities and sites in the study area.

Functional diversity

When determining the effect of habitat disturbance on biodiversity the functional diversity within a dung beetle assemblage is an important factor to consider. Regional scarabeine dung beetle assemblages in southern Africa may contain a diversity of species which range in size and live weight from 10mg to 10g [20]. These species show a variety of dung-use and reproductive strategies and this was also reflected in the dung beetle species collected in the study area. The dung beetle species were grouped into 7 functional groups (FG) based on their size and specific dung-use strategies (Table 1). Based on behavior dung beetles have been placed in four distinctive groups [21-23], telocoprids dung beetles form dung into a ball and roll it away to bury somewhere else; paracoprid dung beetles make nest chambers directly under the dung pad and transport dung from the pad by tunnelling under the dung pad; endocoprids breed inside the dung pad, and kleptocoprids use dung that has already been buried by other dung beetles. There is a clear hierarchy of functional groups in a dung beetle assemblage to compete for dung. FGI (large telocoprids) and FG III (fast-burying paracoprids) are competitively dominant, larger dung beetles that rapidly remove dung from the pad, while the smaller telocoprids (FGII) are also effective competitors [20]. FG IV and V (paracoprids)

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are smaller subordinate groups that bury dung slowly over many days, while FG VII are endocoprids that breed inside the dung pat and FGVI breed in dung buried by other beetles [20]. Ideally, dung beetles belonging to all seven functional groups should be present in a habitat for the most efficient functionality of a dung beetle assemblage.

The dominant species in the study area, which occurred at all the sites, was *Onthophagus asperulus* (Table 1). This species was dominant in the agricultural landscapes, with the highest abundance at SFF, followed by DMF, and occurred in the other localities at a lower abundance (Table 1). This species belongs to FG IV, a subordinate group that buries dung slowly over many days. This species is widespread in farmland where it is readily attracted to the dung of farm livestock and is not negatively influenced by pasture improvement [24]. Telocoprid dung beetle, *Scarabaeus basuto* (FGI) occurred only at GGHNP (site 2), while telocoprid (FGII) dung beetle species, *Epirinus flagellatus,* were only present in the semi-natural sites at a higher elevation (site 2) of GGHNP and WCCA and Telocoprid (FGII) dung beetle species *Gymnopleurus leei* occurred only at the lower elevation (site 1) of GGHNP (Table 1). Records from old crop fields suggest some resilience to habitat transformation in this species [24]. No telecoprid (FGI and II) dung beetles occurred in the agricultural landscapes with the exception of DMF where *Sisyphus costatus* was present at the higher elevation (site 2) (Table 1). This species is widespread with some tolerance of habitat transformation [24]. The functional group classification enables us to analyze the structure of different dung beetle assemblages in a way that reflects the community function [20]. The separate dung beetle communities in the different localities showed different patterns of relative abundance of species within functional groups. Dung beetles belonging to FGV and FGVII were generally more dominant in the agricultural landscapes than the semi-natural landscapes (Table 1). There was a clear difference in dung beetle species composition and ecosystem function between the semi-natural and agricultural habitats with telocoprid dung beetles only present in the semi-natural habitats and absent from the agricultural habitats (Table 1). Telecoprid dung beetles (FGI and II) are larger species and highly effective competitors for dung. They remove the dung from the surface at a fast rate and bury it at a distance, thereby spreading the nutrients in the soil efficiently. Perrin, et al. [25] found that grazing intensity was detrimental to the larger dung beetle species, while the smaller endocoprids were favoured. In the present study area, the absence of larger telocoprids in the agricultural areas may be explained by an increase in grazing intensity in these areas since these groups were also absent from pastures grazed by cattle in the agricultural landscapes (Table 1). Simba, et al. [26] found a positive effect of vegetation cover on size distribution in a dung beetle assemblage. The absence of telocoprids in the present study area may also be explained by the changes in vegetation in crop fields where both a decrease in vegetation and increased disturbance and trampling by domesticated livestock will influence the larger telocoprids negatively. Sarmiento-Garcés and Hernández [27] demonstrated that the ecosystem function of dung removal by dung beetle assemblages was strongly related to the richness and biomass of dung beetles, which in turn were influenced by tree density and air and soil temperatures. They found that areas without tree cover can lose up to 80% of the dung beetle community and up to 90% of the dung removal capacity.

Biodiversity

Biodiversity drives ecological functioning by providing ecosystem functions favored by greater functional diversity in different interacting species. It is important to recognize the links between ecological functions and biodiversity to evaluate and accurately predict the environmental consequences of human activities [8]. Disturbances in the environment will not only influence individual species, but also these interactions between species and will determine the structure of dung beetle assemblages in an area. To ensure ecological sustainability in habitats, it is necessary to also consider the ecological functions of dung beetles in addition to diversity [28-26]. Dung beetle assemblages were different in the different landscapes and sites in the study area, with FG I, FGII occurring predominantly in the semi-natural areas and FGIV, FGV, FGVI, and FGVII more dominant in the agricultural areas. FG I and II (telocoprids) are larger, competitively dominant dung beetles, which remove the dung faster, while FG IV and V (paracoprids) are smaller subordinate groups that bury dung slowly over many days. There was a decrease in the size and competitive ability of dung beetles over habitats as agricultural intensity increased in the landscape. This was accompanied by an increase in the dominance of smaller less competitive dung beetles leading to a lower even distribution of species in the habitat and consequently a lower diversity. Shahabuddin, et al. [30] found that large-bodied dung beetle species were more sensitive to habitat disturbance and the ratio of large to small-sized dung beetles declined with land-use intensity. Telecoprid dung beetles were probably absent in the agricultural areas because they are sensitive to the disturbances in these areas. The absence of telocoprid dung beetles in agricultural areas will have consequences for ecological functioning in the systems since dung beetles from a single functional group can have a major influence on ecosystem function. Noriega, et al. [31] found that dung beetle diversity and functional group richness enhanced dung removal rates and that dung removal performed by telocoprids increased with species richness of telocoprids, while Slade, et al. [32] found that the absence of large paracoprids (FGIII) reduced dung removal by 75%. The full complement of functional groups is necessary to maximize ecosystem functioning. Menéndez, et al. [33] found complementary effects between dung beetle species with different functional behavior (paracoprid and endocoprid) and that the combined effect of two dung beetle species resulted in the highest soil microbial respiration from the soil.

Dung beetle assemblages as indicators

The observations in this study area highlight the importance of the conservation of natural or semi-natural habitats to protect biodiversity as well as critical ecosystem functions. In this respect, indicators are needed to characterize natural versus transformed habitats, and environmentally destructive and environmentally acceptable agricultural

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practices. Ecological indicators have been widely accepted in conservation as useful tools for monitoring and detecting changes in the environment or habitat conditions. The dung beetle assemblages in the study area showed differences in diversity, functional diversity, as well as different assemblage structures in different habitats. There was a decrease in diversity and functional diversity and a change in assemblage structure with functional groups excluded from semi-natural habitats to agricultural habitats with an increase in agricultural intensity and disturbance. The dung beetle assemblages in the study area show the characteristics of a good indicator for habitat degradation and biodiversity decrease. Indications of a dung beetle assemblage being a good indicator of biodiversity loss and ecological deterioration include their fidelity and specificity to a particular type of habitat [30], quick response to habitat degradation, such as destruction, fragmentation, and isolation, [34], sensitivity to regional climatic and ecological conditions, as well as to local edaphic, physiognomic, trophic, and microclimatic factors [35]. Spector [36] believes that dung beetles fulfill all the criteria for an effective focal taxon for biodiversity assessment. Dung beetle assemblages can be used as indicators of effects related to local transformation from natural habitat to farmland and relative naturalness can be categorized on a scale from reserves and natural to disturbed farm habitats [6].

Effect of habitat change and fragmentation on biodiversity

Observations in the present study showed a change in community structure and function within a dung beetle assemblage, as well as a decrease in diversity, with a change in land use by agriculture. The impact of land use change, leading to habitat loss, may have serious implications for ecosystem functioning in these areas. Dung beetle communities are strongly affected by habitat loss and, in areas with agricultural practices, there is a decrease in the abundance, richness, and total biomass [3], affecting the ecosystem functions, removal and burial of organic material, and secondary seed dispersal, they provide [31,37]. The effect on dung beetle assemblages is related to the modification of natural vegetation [38,39]. In the present study, FGIV dung beetle species like *Onthophagus asperulis* were distributed throughout the study area but were more dominant in the agricultural landscapes, while FGII *Epirinus* species were limited to the higher elevations in the larger semi-natural landscapes (Table 1). Alonso, et al. [40] observed that factors acting at local and regional scales interact to produce different spatial patterns of dung beetle assemblage response to human land uses. This will have implications for the future of biodiversity and sustainable agriculture. To maximize species richness, and to maintain pasture health in a heterogeneous environment sufficiently large fragments of natural areas, that will support specialist species, are needed to conserve local biodiversity [6]. Increasing habitat disturbance in agricultural practices results in changes in species composition, with possible local extinction of some species [41]. This study showed that increased grazing pressure resulted in changes within dung beetle assemblages. The functional structure of dung beetle assemblages changed because of the exclusion of important functional groups as agricultural intensity increased. Perrin, et al. [25] showed that grazing intensity acts as an environmental filter on dung beetle assemblages, selecting species according to traits. The increasing disturbance caused by the expansion of cattle grazing is recognized as exerting one of the greatest effects on biodiversity [42] because livestock activity results in a heterogeneous distribution of defoliation, trampling, and excreta [25].

Brandon, et al. [1] found that in most places it is possible to expand the area for biodiversity conservation to protect ecosystem services vital to sustainable agricultural production and rural livelihoods. Landscapes differ and each agricultural area needs to be viewed in the particular landscape to find the best approach for protecting further species loss. This approach will not only be dependent on the specific area but also on the specific farming practice. Farm-specific management decisions seem to affect both the composition of local dung beetle assemblages and associated ecological functioning [43]. A multiscale approach is needed to understand the consequences of management decisions for a variety of ecosystem functions in agriculture [44]. Some agricultural practices seem to support dung beetle assemblages, while others severely alter patterns of dung beetle species diversity and abundance. In the study area the diversity and eveness were higher at SFF which was managed using conservation agricultural practices than at VDF which was managed by conventional agricultural practices (Figures 2,3). Hutton and Giller [45] found that dung beetle species were more abundant on organic than intensive and rough grazing farming sites and suggest that increasing the area of land under an organic or ecological farming regime (low input system encouraging diverse ecosystems) might increase regional dung beetle populations, while Nichols, et al. [8] found evidence from temperate and tropical systems indicating that local and regional-scale changes in land-use and mammal faunas can severely alter patterns of dung beetle species diversity and abundance. Although dung beetles can utilize a wide range of dung and will readily colonize cattle dung, Sands, et al. [46] emphasize the importance of conserving areas that maintain indigenous large mammal diversity and are protected from livestock incursions. Since most dung beetle species are negatively impacted when non-ruminant dung types are absent, as more land is converted to livestock agriculture, and cattle are treated with insecticides with consequent contamination of dung with toxic residues [47] management strategy in agriculture should be to maintain a variety of mammalian species and ensuring that vegetation cover is not severely reduced through grazing and trampling [26]. In the study area, DMF supports a higher dung beetle diversity and evenness than SFF and VDF (Figures 2,3). This can be explained by the fact that this farm is surrounded by a semi-natural landscape connected to GGHNP, but the specific type of cattle, the Nguni, on this farm, may also play a role. The indigenous Nguni (*Bos taurus africanus*) is a hardy, low-maintenance breed that is well adapted to the heat, disease, and environment of Africa [48]. This means that these cattle do not need supplemental feeding or chemical treatment for pests and diseases. Adapted traditional livestock breeds, managed correctly will also have the advantage of minimized trampling

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and feeding damage to the environment [49]. Kugler and Stahl [49] believe that traditional agro-ecosystems in which specifically adapted livestock and cultivated plants are used, conserve the functioning of ecological systems promote soil fertility, regulate pests and diseases, and increase pollination.

Limitations of the study and recommendations for future studies

Dung beetle assemblages are good indicators of ecological degradation in habitats because of the diversity, functional diversity, and assemblage structure within dung beetle assemblages. Dung beetle assemblages, however, differ in different geographical areas depending on the climatic conditions, vegetation, and soil type. In the present study dung beetle assemblages in only one geographical area, an Afromontane biome, were monitored. In future studies, this model should be tested in different geographical areas to determine if the same principles apply to different biomes.

Conclusion

As a result of strong competition dung beetles evolved different strategies to effectively use dung as a food source in both the adult and larval stages. A dung beetle assemblage is made up of a diversity of different species with a variety in size and dung use strategies. Not only are dung beetle assemblages important in ecosystems to maintain healthy soil, but they are also effective indicators of changes in ecosystem health as a result of agricultural pressure. Land use change from natural to agricultural causes a change in the community structure of dung beetles with some species and functional groups becoming more dominant, while others disappear as agricultural intensity increases. For efficient ecosystem functioning in agricultural habitats, an integrated approach for the specific area will be necessary. The protection of large natural areas and the restoration of degraded agricultural habitats will be essential. Any agricultural practice that limits the use of chemicals improves the soil, and increases and conserves both the plant diversity and the diversity of herbivores will improve the habitat and increase biodiversity and associated ecosystem functions. It will therefore be important to conserve as much natural habitats in and around agricultural fields and promote livestock and crops that are adapted to the specific environment.

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Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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