# South African grasslands and ploughing: Outlook for agricultural expansion in Africa

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**Significance:**

Grasslands were often viewed as successional vegetation, a precursor to a possible forest, and were thought to have low diversity. However, a growing number of research projects have shown that these ecosystems boast high biodiversity and massive carbon storing potential, and require at least a century to recover after agricultural ploughing which severely disrupts the environment and consequently lowers plant diversity and carbon stocks. Conserving natural grasslands should be prioritised, as they provide us with important ecosystem services beneficial to not only natural systems, but also the longevity of humans through food security and buffering of the effects of climate change.

## South African grasslands

Grasslands are ancient ecosystems that spread across the planet during the Miocene – approximately 8–20 million years ago.[1] They are characterised by a continuous herbaceous layer of grasses, a high species diversity of herbaceous forbs, an abundance of long-lived perennial plants, and well-developed belowground structures such as large storage organs and dense root structures.[2,3] These characteristics make grassland species resilient to endogenous disturbances, such as megafaunal herbivores and frequent fires.[4] Grasslands are globally distributed and provide a unique suite of ecosystem services, including, amongst others, water supply and its regulation, carbon storage, and forage production.[3] With extensive historical and rapid contemporary grassland transformation primarily due to agriculture and silviculture, grasslands urgently require prioritisation of their conservation and management.

A third of South Africa's land surface is covered by the Grassland Biome, with the broad vegetation units consisting of the Drakensberg grassland, and the dry- and mesic highveld grasslands.[5] A total of 34% of grasslands have been irreversibly transformed,with less than with only 2% being formally protected. The remaining 64% is mainly used for grazing by livestock and game[5] but is also subject to land use change through agricultural expansion and intensification, leading to increased fragmentation. Grasslands are permanently transformed by surface mining, intensive agriculture and silviculture, as well as infrastructure projects. These exogenous disturbances in grasslands severely disrupt soil structure, destroy belowground root and organ structures, and decrease species diversity.[3,6] Land use transformation in grasslands occurs mainly for agricultural expansion and economic growth, but with the gain of food security, other important ecosystem services are lost. Some of these ecosystem services include the loss of carbon stock and the carbon storage capabilities that are linked with soil structure, as well as faunal and floral biodiversity which plays a critical role in regulating the global biogeochemical cycles.[7,8] Moreover, as there is no penalty or consequence for ploughing intact grassland, and no current incentive in South Africa to protect these ecosystems, often these lands are abandoned after just a few years of cultivation.

Although exogenous disturbances disrupt the soil surface and ultimately lead to transformed grasslands, they are not the only drivers that degrade a grassland ecosystem. It is the combination of the removal or mismanagement of naturally occurring endogenous disturbances such as fire and/or herbivory, paired with intensive anthropogenic influence like ploughing that severely degrade grasslands.[9] Increasingly, farmers are finding woody encroachment to be a concern; species like *Seriphium plumosum, Lantana camara,* and *Campuloclinium macrocephalum* have especially increased in many South African grasslands in recent years.

Grasslands are fascinating in that their maintenance and conservation depends on complex feedbacks between soil, plants, and the herbivores and fire that consume them. After a disturbance like fire, drought or herbivory, herbaceous plants[10] can resprout from various underground storage systems such as woody or tuberous root systems, which store carbon and other resources.[11] However, when a grassland is ploughed – an exogenous disturbance – these hardy herbaceous plants with their high underground storage system diversity and large carbon storage capacity are permanently removed from the soil.[4] Ploughing severely damages the feedback loop where plant species are dependent on the soil carbon stock for growth. Removing this carbon stock consequently lowers the probability that plant communities will re-establish in that area, which negatively impacts ecosystem functionality and productivity.[12]

Grasslands are thought to be resilient in that the halting of invasive agricultural practices, such as ploughing, will allow the disturbed biodiversity to recover. Unfortunately, studies that investigated this assumption show that even when restorative measures are implemented, species recovery takes much longer than anticipated, with no guarantee of full recovery.[11] Current studies show that disturbed grasslands will take at least a century to recover to former species richness, which means that the carbon pool that is irreversibly linked to aboveground vegetation will take just as long to recover to its original storage capabilities.[4]

In South Africa, we have good knowledge of the carbon stored in our natural grasslands. We also know, from groundbreaking work in the 20th century, that there is no evidence that grass composition in the Highveld ever recovers from ploughing. Evidence gathered by Eddie Roux[11] at the Frankenwald research station was the first evidence that the ideas of succession, first put forward by Clements in 1916 and adopted by ecologists globally, were not sufficient to explain dynamics of disturbance-driven temperate and tropical ecosystems. This is supported by the identified 'purple veld' or 'climax grasslands' that never returned in the ploughed plots, even after decades of resting. However, these early researchers considered the recovery ofgrass species only, and did not document the loss or recovery of other herbaceous plants.[11] Recent demonstrations[11,12] showed that certain herbaceous functional groups were permanently lost from grasslands exposed to exogenous disturbance like silviculture, and that this impacted their belowground carbon reserves and functioning. This work raises questions about the degree to which our current legislation protects grasslands, and whether sufficient systems and efforts are in place to protect what remains, putting more effort into restoration, and planning our land use and biodiversity offsets accordingly.

## Steps for the future: Biodiversity offsets and carbon credits

The limitations involved in restoring transformed grasslands places huge importance on protecting existing old-growth grasslands. In parallel to protected area networks, two current market-based mechanisms in use for conserving old-growth ecosystems are carbon and, more recently, biodiversity credits. These credits aim to incentivise landowners to be more mindful in the way they manage their grasslands, with the goal of firstly protecting what is left, and secondly restoring previously disturbed fields.[13,14]

In response to the increasing loss of native vegetation and biodiversity, a growing number of countries have adopted 'offsetting' policies that seek to balance local habitat destruction by restoring, enhancing and/or protecting similar but separate habitats. Biodiversity offsetting from the National Biodiversity Offset Guidelines[15] refers to conservation efforts implemented to counteract the residual, harmful effects to biodiversity in an area due to activities (developmental or otherwise). The objective is to ensure that high-value ecosystem services, many of which are found in grasslands, that are being harmed in the process of development, are being compensated to maintain ecological integrity.

Not only are grasslands home to various threatened animal and plant species, but grasslands themselves are a critically threatened ecosystem.[13] Using biodiversity offsets as a conservation tactic is a feasible option as priority biodiversity areas are being taken into account as the offset option, instead of simply allocating any piece of land available as the trade-off.[13,15] Although biodiversity offsetting is recognised as a policy option published in the *NEMBA Act of 2004* to curb the decline of South Africa's biodiversity, it is yet to be officially included in South Africa's environmental law, unlike Mozambique and Madagascar that have both introduced such legislation. However, biodiversity offset legislation needs to be carefully thought out if it is to achieve its goal – there are examples that have resulted in perverse or undesirable outcomes due to the complexity of implementation – ultimately, this legislation requires that landowners and communities sacrifice some of their land with economic potential, and who sacrifices, and what is saved, may be complicated by power imbalances.[16] At its best, however, it can help farmers, developers, and communities to rethink their priorities, and come together to achieve healthier ecosystems. One example of such a collaboration is between the conservation organisation Overberg Renosterveld Conservation Trust (ORCT) and private landowners to protect what is left of the heavily fragmented Renosterveld vegetation type in the Western Cape. The ORCT approaches landowners that have Renosterveld on their property with a voluntary conservation easement contract that allows the organisation to aid in managing the natural remaining patches. These policies often have a stated aim of producing a 'net gain' or 'no net loss' in environmental benefits. It is challenging to determine the potential impacts of a policy and if, or when, it will achieve its objectives.[13,17]

Hand-in-hand with offsetting policies for biodiversity, the Paris Climate Agreement was founded in 2015 and was created as part of the movement for natural climate solutions with the goal to meet the climate goals outlined. In grasslands, carbon storage can best be achieved by avoidance of ploughing and land use change[18], but also through more sustainable grazing methods which influence both above- and below-ground soil and plant structures. Land managers can adopt more sustainable land management practices, but can also monetise from these climate change mitigation efforts. This links with the new concept of carbon credits and how the avoidance of old-growth, perennial grassland conversion mitigates climate change because of the regulating services grasslands provide in sequestering carbon in soil. Old-growth grasslands are estimated to store 20% of the global carbon, but in the case of land conversion up to 50% of that stored carbon could be lost.[15] Currently, financial mechanisms to avoid this carbon loss in grassland soils are not as sophisticated as programmes like REDD+ (Reducing Emissions from Deforestation and Forest Degradation) that focuses on incentives for reducing deforestation, i.e. there is no similar mechanism for reducing soil carbon loss in non-forest ecosystems. There are potential mechanisms through the voluntary carbon market, however, and if land managers incorporate both offsetting policies with regards to biodiversity and carbon credits for soil health, they can mitigate climate change and receive rewards for their efforts.

Although there are mechanisms by which funding for grassland conservation can be sought through the voluntary carbon market, a recent report on carbon mitigation options for Africa[18] highlights avoided land conversion of grasslands, a key carbon-mitigation activity with co-benefits for biodiversity and livelihoods. These authors call for REDD+ initiatives in grasslands.[18]

## Resilience within grasslands

Unsustainable management practices can negatively impact herbage accumulation, fodder quality, soil attributes, nutrient cycles, plant diversity and plant population density, as well as greenhouse gas emission.[7,8] Sustainable farming links to resilience, where agroecosystems are recently being exposed to external shocks like that from climate change. If ecological resilience of a system is increased, the capacity for a system to recover after disturbances also increases, which directly links to greater security for social and economic stability through food security.

Table 1 shows four of the biggest causes of land use change in grasslands and gives a brief overview of the resilience of grasslands. Resilience refers to both natural resilience and how the management of grasslands can increase this natural resilience.

## Future research for resilient grasslands

The first step to achieve Sustainable Development Goals is to quantify different aspects of grassland biodiversity and ecosystem service conservation in South Africa. For this, we identify three major research questions across African grasslands: (1) What are the rates of biodiversity and soil carbon recovery after grasslands are ploughed? (2) What is the extent of agricultural transformation across African grasslands? (3) What are the measures that could be put in place to minimise further transformation of our remaining grasslands?

**Table 1:** Managing for resilience with different land use types

| | **Land use type** | **Resilience** |
|---|---|---|
| **Ordered by severity of land use change[19]** | Overgrazed | Managing plant heterogeneity to maintain structure, composition, function, and diversity of plants. |
| | Woody-plant encroached | Adopting appropriate disturbance regimes (herbivory and fire) to maintain desired state. |
| | Intensive cropland | Mixed cropland- or plantation-livestock systems to maintain semi-natural pastures. Spatial arrangements to contribute to landscape integrity and connectivity.[19] |
| | Silviculture | Adopting appropriate disturbance regimes (herbivory and fire) in remnants to maintain desired state. |

A joint research project aims to quantify the extent of transformed grasslands in Africa, as well as the rates at which biodiversity and total carbon recover after grasslands are ploughed. The research aims to determine whether plants and soil faunacan re-establish in a ploughed grassland that has been left for a long time, coupled with how the carbon stock in previously ploughed land compares with an old-growth grassland which still contains the perennials with dense root systems that have carbon storage capabilities. By investigating the effects of exogenous disturbances (specifically ploughing) on both the floristic diversity and carbon stock, a holistic view begins to form as we look at, not only the visible effects above-ground, but the unseen below-ground impacts too.

There is currently conflicting information on both the historical and current extent of old-growth grasslands. Because grasslands often occur interspersed with forests (such as in the Drakensberg or the Miombo ecoregion), they can be hidden in global maps. Moreover, maps of potential vegetation used for restoration projects will often indicate that ancient old-growth grasslands are degraded forests because the environmental conditions can support forests.[20] Without a clear understanding of where grasslands occur, we cannot meaningfully conserve them. Fortunately, novel methods in vegetation mapping, that make use of high-performance computing as well as global biodiversity databases, provide new options for grassland mapping in Africa. We aim to (1) review and refine current grassland maps for Africa using comparative approaches to produce up-to-date, biologically meaningful vegetation maps. This will allow the identification of both core and transitional regions between grasslands and other vegetation types. Importantly, once core grassland regions are identified, we aim to (2) monitor the extent of land use conversion in African grasslands. With constantly improving access to remote-sensing imagery, we are now able to track land use change both historically and in near-real time. We will focus on developing open-access tools to monitor agricultural expansion into grasslands to conserve their ecosystem services and biodiversity.

The tools that can identify grasslands and near-real time land use change can be used in identifying priority restoration sites of important grassland fragments to improve landscape integrity and connectivity, and are essential for effectively implementing the legislation and financing mechanisms to promote conservation and restoration of grasslands.

## Outlook

Aldo Leopold stated in his novel, *A Sand County Almanac*:

> *We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect.*

The global extent and value of grasslands for human livelihoods strongly support the sustainable management and restoration of biodiversity and ecosystem services provided by old-growth grasslands. Improved evidence of biodiversity and soil carbon recovery rates and the extent of current grassland transformation will inform the selection of areas to be targeted for ecological restoration, and increase public support for grassland conservation.

Conservation is not meant to only be a follow-up action to be taken when an ecosystem is disturbed, but rather a series of proactive interventions to ensure ecosystem resilience. Conservation means protecting what is there, following best management practice that has been through trial and error, fostering biodiversity between croplands and ensuring that there is sufficient ecological feedback between components in an ecosystem. Grassland conservation acknowledges food security through advocating effective management and the reuse of previously ploughed land and adding ancient, old-growth grasslands on the conservation agenda to prevent further losses to agricultural expansion and to combat ill-thought out tree planting initiatives. Despite evidence of large-scale transformation, it is not too late to join hands with landowners and the government. The quantification of carbon stocks and rates of biodiversity change under different land uses will be used to justify and inform biodiversity offset legislation and help fund restoration through the voluntary carbon market. Moreover, with lessons learned here in South Africa, coupled with novel mapping techniques produced by this programme, it can be used to contribute to land use planning activities in parts of Africa where agricultural expansion in grasslands is occurring rapidly, sometimes with limited recognition of the long-term consequences.

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## Competing interests

We have no competing interests to declare.

## References

1. Edwards E, Osborne CP, Strömberg CAE, Smith SA, C4 Grasses Consortium, Bond WJ, et al. The origins of C4 grasslands: Integrating evolutionary and ecosystem science. Science. 2010;328(5978):587–591. https://doi.org/10.1126/science.1177216
2. Nerlekar AN, Veldman JW. High plant diversity and slow assembly of old-growth grasslands. Proc Natl Acad Sci USA. 2020;117(31):18550–18556. https://doi.org/10.1073/pnas.1922266117
3. Sanford W, Wangari E. Tropical grasslands: Dynamics and utilization. Nat Resour J. 1985;21(3):12–27.
4. Buisson E, Archibald S, Fidelis A, Suding KN. Ancient grasslands guide ambitious goals in grassland restoration. Science. 2022;377(6606):594–598. https://doi.org/10.1126/science.abo4605
5. Carbutt C, Tau M, Stephens A, Escott B. The conservation status of temperate grasslands in southern Africa. Grassroots. 2011;11(1):17–23. Available from: https://grassland.org.za/publications/grassroots/issues/february-2011/5%20201102%20Carbutt.pdf
6. Yellajosula G, Cihacek L, Faller T, Schauer C. Soil carbon change due to land conversion to grassland in a semi-arid environment. Soil Syst. 2020;4(3):43. https://doi.org/10.3390/soilsystems4030043
7. Bardgett RD, Bullock JM, Lavorel S, Manning P, Schaffner U, Ostle N, et al. Combatting global grassland degradation. Nat Rev Earth Environ. 2021;2(10):720–735. https://doi.org/10.1038/s43017-021-00207-2
8. O'Mara FP. The role of grasslands in food security and climate change. Ann Bot. 2012;110(6):1263–1270. https://doi.org/10.1093/aob/mcs209
9. Muller M, Siebert SJ, Ntloko BR, Siebert F. A floristic assessment of grassland diversity loss in South Africa. Bothalia. 2021;51(1):Art. #a11. https://doi.org/10.38201/btha.abc.v51.i1.11
10. Siebert F, Dreber N. Forb ecology research in dry African savannas: Knowledge, gaps, and future perspectives. Ecol Evol. 2019;9(13):7875–7891. https://doi.org/10.1002/ece3.5307
11. Roux E, Roux WM. Grass: A story of Frankenwald. Cape Town: Oxford University Press; 1969. https://doi.org/10.2307/3896812
12. Zaloumis NP, Bond WJ. Grassland restoration after afforestation: No direction home? Austral Ecol. 2011;36(4):357–366. https://doi.org/10.1111/j.1442-9993.2010.02158.x
13. Prinsloo H, Reilly B, Myburgh W. Identifying potential protected areas in the Grassland Biome of South Africa. S Afr J Sci. 2021;117(3/4):Art. #7507. https://dx.doi.org/10.17159/sajs.2021/7507
14. Dean C, Kirkpatrick JB, Harper RJ, Eldridge DJ. Optimising carbon sequestration in arid and semiarid rangelands. Ecol Eng. 2015;74:148–163. https://doi.org/10.1016/j.ecoleng.2014.09.125
15. National Biodiversity Offset Guideline. Section 24J of the National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA). South Africa; 2022.
16. Bidaud C, Schreckenberg K, Jones JP. The local costs of biodiversity offsets: Comparing standards, policy and practice. Land Use Policy. 2018;77:43–50.

17. Brownlie S, Von Hase A, Botha M, Manuel J, Balmforth Z, Jenner N. Biodiversity offsets in South Africa – challenges and potential solutions. Impact Assess Proj Apprais. 2017;35(3):248–256. https://doi.org/10.1080/14615517.2017.1322810

18. Armani M, Asefa M, Zakari S, Agyekum EO. Enhancing climate change adaptation and mitigation actions on land in Africa. In: Archibald SA, Pereira LM, Coetzer KL, editors. Future ecosystems for Africa (FEFA). Johannesburg: University of the Witwatersrand; 2022. p. 92.

19. O'connor TG, Kuyler P. Impact of land use on the biodiversity integrity of the moist sub-biome of the grassland biome, South Africa. J Environ Manage. 2009;90(1):384–395. https://doi.org/10.1016/j.jenvman.2007.10.012

20. Bastin JF, Finegold Y, Mollicone D, Rezende M, Routh D, Zohner CM, et al. The global tree restoration potential. Science. 2019;365(6448):76–79. https://doi.org/10.1126/science.aax0848