Towards an integrated ecological restoration approach for abandoned agricultural fields in renosterveld, South Africa

AUTHOR:
Sheunesu Ruwanza[1]

AFFILIATION:
[1]Department of Ecology and Resource Management, School of Environmental Science, University of Venda, Thohoyandou, South Africa

CORRESPONDENCE TO:
Sheunesu Ruwanza

EMAIL:
ruwanza@yahoo.com

KEYWORDS:
biodiversity; conservation; Fynbos Biome; land abandonment; ecological recovery; succession

HOW TO CITE:
Ruwanza S. Towards an integrated ecological restoration approach for abandoned agricultural fields in renosterveld, South Africa. S Afr J Sci. 2017;113(9/10), Art. #a0228, 4 pages. http://dx.doi.org/10.17159/sajs.2017/a0228

The importance of intact renosterveld vegetation to the maintenance of ecosystem health and services has been increasingly highlighted in the literature.[1-3] Similarly, acknowledgement of heavy transformation (over 80%) and fragmentation (approximately 5% intact remnant patches remain) of renosterveld vegetation has been well documented.[4,5] Renosterveld – a shrubby vegetation type dominated by *Elytropappys rhinocerotis* (L.f.) Less – has been heavily transformed and replaced by agriculture, mostly vine, olive and wheat cultivation.[6] The fragmented renosterveld remnants remain under threat of being cleared for new agricultural lands or being subjected to disturbances like overgrazing, fire and invasion by alien plants.[5] There is, therefore, the need for conservation of renosterveld through securing the existing remnants, linking fragments through ecological restoration and spreading awareness about good management practices.

Ecological restoration of abandoned agricultural fields using either the successional or alternative state models creates an opportunity to increase renosterveld size and restore ecosystem function and structure. Ecological restoration is dependent on the type, size, disturbance history and survival of introduced species (where active restoration is initiated). The key questions linked to ecological restoration pertain to when and how to implement ecological restoration intervention. The answers to these questions vary given the many angles and components of the questions, e.g. have biotic and abiotic ecological thresholds been passed or have ecological, social and economic concerns been considered?[7,8]

There have been a few articles over the past 10 years that have addressed ecological restoration in renosterveld. These articles are a product of a few field-based research experiments that have been conducted on a small scale and their aim is to find an appropriate restoration technique that is cost effective. This commentary presents an evaluation of field-based research experiments on ecological restoration in renosterveld abandoned agricultural fields. Using 11 articles published between 2005 and 2016, three important ecological restoration themes were identified that justify some discussion. These themes are related to (1) factors hindering ecological restoration in renosterveld abandoned agricultural fields, (2) evaluating ecological restoration success in renosterveld abandoned agricultural fields and (3) moving towards an integrated ecological restoration approach for abandoned agricultural fields in renosterveld. The last theme is an outcome of the evaluation process aimed at developing a new ecological restoration approach that can be used to achieve restoration success in abandoned agricultural fields of renosterveld.

Factors hindering ecological restoration

Previous field-based research experiments have identified several factors that impede ecological restoration in renosterveld abandoned agricultural fields. The factors can be grouped into three broader groups: vegetation factors, soil and environmental conditions (Table 1). Vegetative factors, such as seed sources, competition from invasive alien grasses and predation of recruiting native plants by animals have been identified as some of the factors that hinder ecological restoration in renosterveld. Previous studies on soil-stored seed bank in renosterveld abandoned agricultural fields have reported a lack of native species in soil-stored seed banks.[9,10] The lack of soil-stored seed banks in renosterveld abandoned agricultural fields is a result of previous cultivation that has depleted the soil seed bank. An examination of seed dispersal has shown that dispersal of native species into abandoned agricultural fields does occur, but seeds struggle to germinate on arrival.[11,12] In areas where grazing is allowed, the few native species that manage to recruit are grazed by animals whilst they are still young.[6] If not grazed, environmental factors, e.g. the hot summer temperatures accompanied with the lack of rainfall, seem to affect seedling establishment.

Table 1: Summary of factors that hinder ecological restoration success, based on the 11 reviewed field-based ecological restoration experiments conducted in abandoned agricultural fields of renosterveld

Vegetation	Soil	Environmental
Seed source	Elevated soil nutrients	Climatic patterns
Predatory	Competition	
Invasive alien grasses		

The proliferation of invasive alien grasses, which is linked to high soil nutrients in abandoned agricultural fields of renosterveld, has also been identified to hinder ecological restoration.[13,14] Past fertilisation has been identified as one of the drivers of the observed high soil nutrients. Studies on recovery following alien grass removal have concluded that most alien grass control options (e.g. herbicide application) produce successful results, but they negatively affect native species recovery.[13,14] Also, a study on soil nutrient manipulation has reported that the technique is an ineffective ecological restoration method.[14] Both invasive alien grasses and the high soil nutrients create positive and negative feedback mechanisms that hinder plant and soil recovery.[15,16] For example, nutrient-rich soils found in abandoned agricultural fields tend to facilitate the growth of fast-growing invasive alien grasses, which when dead contribute to high soil nutrient content. This positive and negative feedback mechanism tends

to contribute to the maintenance of a degraded abandoned agricultural field.[16] Competition for resources (e.g. water and soil nutrients) has been highlighted as a factor hindering ecological restoration in renosterveld.[6,10] Competition is linked to the proliferation of fast-growing invasive grasses that are known to utilise nutrient resources faster than native species.[14] Most environmental factors that hinder ecological restoration have not yet been studied in renosterveld, but have been observed during some experiments. For example, the mortality rate for most introduced native species was high in summer because of a lack of water and high temperatures associated with summer in the Western Cape Province.[14]

Evaluation of ecological restoration success

Assessing the success of any ecological restoration project is important so as to justify restoration as a management intervention that improves the provision of ecosystem services.[17] Evaluating ecological restoration is not straightforward given the debate around how best to measure success.[17] If ecological restoration is defined as 'the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed', then restoration success should be guided by three outcomes: recovery of vegetation structure, species diversity and abundance and ecological processes.[17,18] This implies that recovery of abandoned agricultural fields in renosterveld should entail the recovery of diverse native species and ecological processes, e.g. physical (soil structure), chemical (soil nutrients) and biological (soil bacteria) processes.

Based on previous field-based research experiments in renosterveld, three conclusions can be made with regard to restoration success. Firstly, studies in which native species were introduced in abandoned agricultural fields of renosterveld have concluded that the introduction of native species produces little ecological restoration success (Table 2).[6,14] However, a recent study has shown that seeding has the potential to yield positive ecological restoration results if combined with other grass

Table 2: Summary of research aims, results and outcomes of ecological restoration successes, based on the 11 reviewed field-based ecological restoration experiments conducted in abandoned agricultural fields of renosterveld

Broader restoration aims	Restoration results	Restoration outcomes	Reference
Influence of competition and herbivory on old field restoration	Introduced native plants competed with alien grasses for resources. Competition negatively affected germination and seedling survival and growth.	Competition from grasses and herbivory need to be reduced for restoration to be successful.	Midoko-Iponga et al.[6]
Effective alien grass control linked to old field restoration success	Controlling alien grasses by burning is cheaper but affected native species seed banks. It also promoted alien grass infestations. The light burn of invasive grasses stimulated plant recovery. Mowing was cheaper but triggered little species recovery. Hand pulling and herbicide application are expensive methods. Herbicide application inhibited native species recovery.	Integrated control methods are necessary to effectively control and restore native species.	Musil et al.[13]
Restoration implication of seed dispersal in the dung of herbivores	Alien grasses dominated seedlings from herbivore dung. Only one shrub species was identified in herbivore dung.	The presence of large herbivores in old fields could retard recovery because they disperse seeds of alien grasses.	Shiponeni and Milton[12]
Hydrological and soil retention services are benefits of restored renosterveld	Infiltration was higher in renosterveld than in transformed renosterveld. Intact renosterveld reduced wind speed and aeolian loads compared to transformed renosterveld.	Restoring renosterveld old fields has some ecological benefits.	O'Farrell et al.[20]
Vegetation recovery in abandoned renosterveld croplands	Therophyte and chamaephyte species increased with an increase in abandonment years. Species richness increased with age since cropland abandonment.	Vegetation recovery in abandoned croplands is occurring naturally but the recovery rate differs amongst the life forms.	Van der Merwe and van Rooyen[19]
Introducing pioneer species and bush clumps for restoration purposes	Introduced plants had high germination rates in the greenhouse but low germination and establish rates under field conditions. Bush clumps increased seed dispersal but germination and established rates following seed dispersal was low.	Restoration using early succession species and natural dispersal vectors does not trigger native vegetation recovery.	Heelemann et al.[11]
Effects of soil manipulation using sucrose on plant and soil recovery	Sucrose addition negatively affected the growth of both native and alien grasses. Sucrose addition had little effect on bacterial activity.	Soil manipulation by adding sucrose is ineffective as a restoration option because it negatively affects the growth of both native and alien species.	Ruwanza et al.[14]
Seed bank of remnant and degraded renosterveld	Old fields were dominated by alien grasses, nutrient-rich soils and depleted indigenous soil seed banks. Seed smoking did not influence seedling recruitment.	Abandoned agricultural fields have low restoration potential because of the lack of an indigenous soil seed bank.	Heelemann et al.[9]
Carbon sequestration and restoration through fallowing	Ecosystem carbon stocks in fallow fields were equal to those in intact renosterveld. Fallowing had the potential to sequestrate carbon.	Carbon financing could be used to promote restoration of old fields.	Mills et al.[21]
Impacts of herbivores and fire on renosterveld vegetation	Herbivory, fire and their interaction negatively affected vegetation composition in old fields. Burning and grazing caused the growth of unpalatable species, whilst grazing restrictions caused the growth of palatable species.	Herbivory removal can cause recovery of palatable species. Burning combined with restricted grazing in old fields causes proliferation of alien grasses.	Radloff et al.[4]
Seeding recruitment under multifactorial restoration treatments	Seeding alone was ineffective, and needed to be combined with another method, e.g. herbicide application to remove grasses, burning to enhance seed germination, tillage for soil preparation and grass removal, or rodent exclusion.	Seeding does improve native species presence in old fields but needs to be combined with other restoration methods.	Waller et al.[10]

removal techniques.[10] Secondly, a study on natural recovery concluded that vegetation recovery is occurring naturally in mountain renosterveld (Table 2).[4,19] Lastly, studies on restoration benefits have confirmed that restoring abandoned agricultural fields improves hydrological and soil retention services.[20,21] The above three outcomes are an indication that ecological restoration initiatives in renosterveld are yielding mixed results. The slow recovery reported in some studies could be a result of the previously identified factors that hinder ecological restoration. Indeed, abandoned agricultural fields whose restoration is constrained by the identified factors represent old fields that are in a persistent degraded state. In such state, both biotic and abiotic factors have been strongly altered by the previous cultivation.[16]

The applicability of natural succession as an ecological restoration initiative in lowland renosterveld might be difficult and may take several years, although it is yielding positive ecological restoration results in mountain renosterveld.[19] Firstly, there exists a possibility that natural succession in lowland renosterveld may trigger bush encroachment. This is possible where grazing and browsing animals are allowed to utilise palatable species, leaving unpalatable species to dominate abandoned agricultural fields.[4] Besides, grazing has also been reported to disperse seeds of invasive alien grasses rather than those of native shrubs.[12] Secondly, natural succession will only be successful where remnants of renosterveld are close to the abandoned agricultural fields so as to allow seed dispersal to take place. Seed dispersal is reported to be taking place, but is unfortunately spreading invasive alien grasses.[11,12]

Towards an integrated ecological restoration approach

Restoration attempts in abandoned agricultural fields of renosterveld should move towards an integrated ecological restoration approach (Figure 1). The integrated ecological restoration approach should seek to combine several restoration techniques aimed at restoring abandoned agricultural fields. The advantage of adopting an integrated ecological restoration approach is that it will allow several methods to be implemented consecutively or combined. Integrating several ecological restoration methods has yielded positive results in old fields in Virginia (USA), where herbicide application combined with soil nutrient manipulation and seeding facilitated native grass recovery.[22] However, the integrated restoration approach has its own challenges. Firstly, the selection of an appropriate ecological restoration technique may be difficult and require several trials. Secondly, different restoration approaches may yield different results that may positively or negatively affect other approaches. For example, alien grass mowing might result in cut grass biomass blocking sunlight penetration and reducing seed-to-soil contact resulting in reduced native species germination. Lastly, integrating different ecological restoration approaches requires constant monitoring and evaluation, which is likely to be time consuming and costly.

A successfully integrated restoration approach for renosterveld must include four phases: control of invasive grasses, recovery of soil properties, recovery of vegetation and monitoring and evaluation (Figure 1). The control of invasive grasses can be achieved by using different techniques aimed at grass removal, e.g. fire, herbicide application, hand pulling or mowing.[13] Measures to restore soil properties – e.g. soil nutrient manipulation, top soil removal and tillage – should aim to recover soil physico-chemical properties. Measures to recover native species (e.g. seed sowing, seedling transplanting and perching) should aim to restore vegetation diversity, structure and function. The monitoring and evaluation process should concentrate on both soil and plant recovery (Figure 1). In order for the suggested integrated ecological restoration approach to be cost-effective, soil transfer which aims for both soil and plant recovery simultaneously can be tried. After implementing grass control measures, soil transfer from renosterveld remnant areas to abandoned agricultural fields has the advantages of improving soil physico-chemical and microbial properties and processes.[22,23] It also introduces intended natural species that are present in soil flora transferred from renosterveld remnant areas. However, soil transfer has its own negative impacts, e.g. the transfer of unwanted species, movement of large quantities of soil[23], it is costly and the soil is disturbed.[24] Besides these challenges, several studies have reported that soil transfer provides good restoration results.[23-25]

In conclusion, previous studies have shown that ecological restoration in abandoned agricultural fields of renosterveld is producing mixed results.

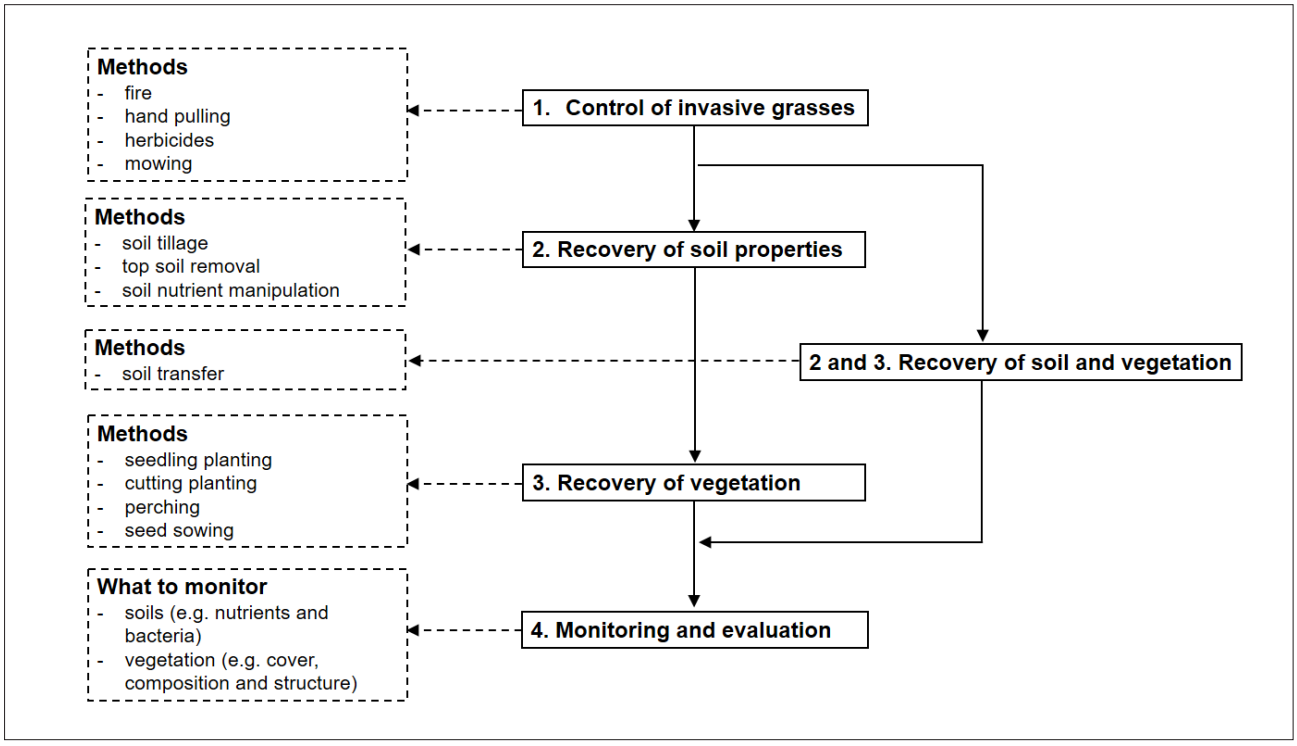

Figure 1: The conceptual framework of the suggested integrated ecological restoration approach for renosterveld.

One can generally conclude that it is on a slow recovery trajectory. Factors inhibiting ecological restoration are multiple and seem to interact in a way that maintains the degraded state. An integrated ecological restoration approach in which multiple ecological restoration methods are implemented should be adopted for ecological restoration success to be realised in renosterveld. For the integrated ecological restoration approach to be economical, soil transfer from intact renosterveld areas to abandoned agricultural fields can be adopted following implementation of invasive alien grass control techniques.

References

1. Cowling RM, Pierce SM, Moll EJ. Conservation and utilisation of South Coast renosterveld, an endangered South African vegetation type. Biol Conserv. 1986;37:363–377. http://dx.doi.org/10.1016/0006-3207(86)90078-9
2. Rebelo T. Renosterveld: Conservation and research. In: Low AB, Jones FE, editors. The sustainable use and management of renosterveld remnants in the Cape Floristic Region. Proceedings of a Symposium. FCC Report 1995/4. Cape Town: Flora Conservation Committee, Botanical Society of South Africa; 1995. p. 32–42.
3. Bergh NG, Verboom GA, Rouget M, Cowling RM. Vegetation types of the Greater Cape Floristic Region. In: Allsopp N, Colville JF, Verboom GA, editors. Fynbos: Ecology, evolution, and conservation of a megadiverse region. Oxford: Oxford University Press; 2014. p. 26–46. http://dx.doi.org/10.1093/acprof:oso/9780199679584.003.0001
4. Radloff FGT, Mucina L, Snyman D. The impact of native large herbivores and fire on the vegetation dynamics in the Cape renosterveld shrublands of South Africa: Insights from a six-yr field experiment. Appl Veg Sci. 2014;17:456–469. http://dx.doi.org/10.1111/avsc.12086
5. Kemper J, Cowling RM, Richardson DM. Fragmentation of South African renosterveld shrublands: Effects on plant community structure and conservation implications. Biol Conserv. 1999;90:103–111. http://dx.doi.org/org/10.1016/S0006-3207(99)00021-X
6. Midoko-Iponga D, Krug CB, Milton SJ. Competition and herbivory influence growth and survival of shrubs on old fields: Implications for restoration of renosterveld shrubland. J Veg Sci. 2005;16:658–692. http://dx.doi.org/10.1111/j.1654-1103.2005.tb02411.x
7. Esler KJ, Holmes PM, Richardson DM, Witkowski ETF. Riparian vegetation management in landscapes invaded by alien plants: Insights from South Africa. S Afr J Bot. 2008;74:401–552. http://dx.doi.org/org/10.1016/j.sajb.2008.01.168
8. Aronson J, Milton SJ, Blignaut JN. Restoring natural capital: Science, business, and practice. Washington: Island Press; 2007.
9. Heelemann S, Krug CB, Esler KJ, Reisch C, Poschlod P. Soil seed banks of remnant and degraded Swartland Shale Renosterveld. Appl Veg Sci. 2013;16:585–597. http://dx.doi.org/10.1111/avsc.12026
10. Waller PA, Anderson PML, Holmes PM, Allsopp N. Seedling recruitment responses to interventions in seed-based ecological restoration of Peninsula Shale Renosterveld, Cape Town. S Afr J Bot. 2016;103:193–209. http://dx.doi.org/org/10.1016/j.sajb.2015.09.009
11. Heelemann S, Krug CB, Esler KJ, Reisch C, Poschlod P. Pioneers and perches-promising restoration methods for degraded renosterveld habitats? Restor Ecol. 2012;20(1):18–23. http://dx.doi.org/10.1111/j.1526-100X.2011.00842.x
12. Shiponeni NN, Milton SJ. Seed dispersal in the dung of large herbivores: Implications for restoration of Renosterveld shrubland old fields. Biodivers Conserv. 2006;15:3161–3175. http://dx.doi.org/10.1007/s10531-005-6317-5
13. Musil CF, Milton SJ, Davis GW. The threat of alien invasive grasses to lowland Cape floral diversity: An empirical appraisal of the effectiveness of practical control strategies. S Afr J Sci. 2005;101:337–344.
14. Ruwanza S, Musil CF, Esler KJ. Sucrose application is ineffectual as a restoration aid in a transformed southern African lowland fynbos ecosystem. S Afr J Bot. 2012;80:1–8. http://dx.doi.org/org/10.1016/j.sajb.2012.01.009
15. Suding KN, Gross KL, Houseman GR. Alternative states and positive feedbacks in restoration ecology. Trends Ecol Evol. 2004;19:46–53. http://dx.doi.org/org/10.1016/j.tree.2003.10.005
16. Cramer VA, Hobbs RJ, Standish RJ. What's new about old fields? Land abandonment and ecosystem assembly. Trends Ecol Evol. 2008;23(2):104–112. http://dx.doi.org/org/10.1016/j.tree.2007.10.005
17. Wortley L, Hero J-M, Howes M. Evaluating ecological restoration success: A review of the literature. Restor Ecol. 2013;21(5):537–543. http://dx.doi.org/10.1111/rec.12028
18. Society for Ecological Restoration (SER). Society for Ecological Restoration international's primer of ecological restoration [homepage on the Internet]. c2004 [cited 2017 Apr 04]. Available from: http://www.ser.org/resources/resources-detail-view/ser-internationalprimer-on-ecological-restoration
19. Van der Merwe H, Van Rooyen MW. Life form and species diversity on abandoned croplands, Roggeveld, South Africa. Afr J Range For Sci. 2011;28(2):99–110. http://dx.doi.org/10.2989/10220119.2011.642097
20. O'Farrell PJ, Donaldson JS, Hoffman MT. Local benefits of retaining natural vegetation for soil retention and hydrological services. S Afr J Bot. 2009;75:573–583. http://dx.doi.org/org/10.1016/j.sajb.2009.06.008
21. Mills AJ, Birch S-JC, Stanway R, Huyser O, Chisholm RA, Sirami C, et al. Sequestering carbon and restoring renosterveld through fallowing: A practical conservation approach for the Overberg, Cape Floristic Region, South Africa. Conserv Lett. 2013;6:255–263. http://dx.doi.org/10.1111/conl.12003
22. Priest A, Epstein H. Native grass restoration in Virginia old fields. Castanea. 2011;76(2):149–156. https://doi.org/10.2179/09-056.1
23. Hölzel N, Otte A. Restoration of a species-rich flood meadow by topsoil removal and diaspore transfer with plant material. Appl Veg Sci. 2003;6:131–140. http://dx.doi.org/10.1111/j.1654-109X.2003.tb00573.x
24. Bulot A, Potard K, Bureau F, Bérard A, Dutoit T. Ecological restoration by soil transfer: Impacts on restored soil profiles and topsoil functions. Restor Ecol. 2017;25:354–366. http://dx.doi.org/10.1111/rec.12424.
25. Muller I, Buisson E, Mouronval J-B, Mesléard F. Temporary wetland restoration after rice cultivation: Is soil transfer required for aquatic plant colonization? Knowl Manag Aquat Ecosyst. 2013;411(3):1–17. https://doi.org/10.1051/kmae/2013067