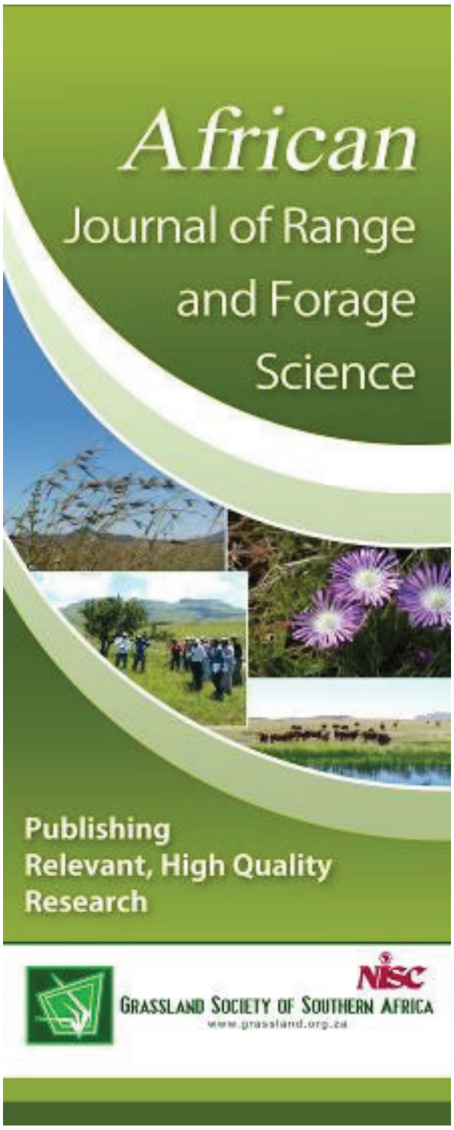

Grassroots

Newsletter of the Grassland Society of Southern Africa

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Contents

Editor's Note

Welcome to this issue of Grassroots! Congress 50 is just around the corner and we are looking forward to the half centenary celebrations of the GSSA in Pietermaritzburg. You will find more information and important dates on this exciting event on the back page of this issue.

Our grassland scientists play an integral role in conserving wetlands, amongst other ecosystems. As we are always trying to keep you up-to-date with relevant news on a wide variety of grassland-relevant topics, we have included two news articles on wetland management and conservation within this issue. Furthermore, we bring you three feature articles. *Parthenium hysterophorus* is a problem plant which is invading grazing, cultivated, fallow and protected areas for the conservation of biodiversity. It has very bad health implications on both animals and people and is definitely a plant to look out for so as to prevent the spread of it into further areas. In a feature article by Lorraine Strathie, challenges with this weed are identified, and successful biocontrol management of this plant is discussed.

In the second feature article, the impact of soil moisture balance on bush encroachment is debated. This argues that soil moisture balance is the most significant edaphic feature controlling landscape change, which could have important consequences for research to control shrub invasion of grasslands. Please feel free to send us your comments to debate these aspects further.

Finally, the strategic over-sowing of temperate grasses and legumes has been found to be an economical forage-based way to improve the dry matter production, forage quality and milk production potential of kikuyu based pasture systems. Research results from Outeniqua Research Farm near George, provides the latest information on establishing grass-legume mixtures into kikuyu using various mechanical and herbicidal methods.

Pieter Swanepoel

Citizens Needed to Help with Data Collection

Alan Short
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Members of the public have the chance to contribute to scientific research by taking photographs of landscapes that were photographed decades ago.

For years, Timm Hoffman and his team at the University of Cape Town's Plant Conservation Unit have been collecting thousands of old landscape photographs from South Africa and Namibia, some dating back to the mid-nineteenth century. They have managed to relocate and rephotograph a small percentage of the photos, giving us some fascinating insights into how landscapes have changed over the past decades, and allowing us to better understand how fire, grazing, human activities and climate change affect vegetation. The task is enormous and now they are enlisting the help of the public through a citizen science initiative called rePhotoSA http://rephotosa.adu.org.za/

Anyone can join and contribute to improving our understanding of how the vegetation in our beautiful country changes over time. Some of the comparisons are eye-opening. What you might consider to be natural today looked completely different fifty or a hundred years ago. Timm and other scientists can use your photos to understand why. The rePhotoSA website gives clear guidelines on how you can participate, and how to use your knowledge of an area as well as Google Earth to track down the locations of decades-old photos.

Cropping Africa's Wet Savannas Would Bring High Environmental Costs

Ticiana Jardim Marini
Princeton University, Woodrow Wilson School of Public and International Affairs

With the global population rising, analysts and policy-makers have targeted Africa's vast wet savannas as a place to produce staple foods and bioenergy groups at low environmental costs. But a new report finds that converting Africa's wet savannas into farmland would come at a high environmental cost and, in some cases, fail to meet existing standards for renewable fuels.

With the global population rising, analysts and policymakers have targeted Africa's vast wet savannas as a place to produce staple foods and bioenergy groups at low environmental costs. But a new report published in the journal *Nature Climate Change* finds that converting Africa's wet savannas into farmland would come at a high environmental cost and, in some cases, fail to meet existing standards for renewable fuels.

Led by researchers from Princeton University's Woodrow Wilson School of Public and International Affairs and Department of Ecology and Evolutionary Biology, the study finds that only a small percentage of Africa's wet savannas (2-11 percent) have the potential to produce staple crops while emitting significantly less carbon dioxide than the world's aveage cropland. In addition, taking land conversion into account, less than 1 percent of these lands would produce biofuels that meet European standards for greenhouse-gas reductions. "Many papers and policymakers have simply assumed that Africa's wetter savannas are expendable from an environmental standpoint because they aren't forests," said co-lead author Tim Searchinger, a research scholar at Princeton's Program in Science, Technology and Environmental Policy (STEP), which is based at the Woodrow Wilson School. "Governments have used this assumption to justify large leases of such lands to produce food for the outside world and large global targets for bioenergy. But when you actually analyze the realistic potential to produce food or bioenergy relative to the losses of carbon and animal biodiversity, the lands turn out not to be low cost."

Even if these lands are converted for agricultural use, the only way Africa could become an exporter of crops is by depriving its own people of food, the researchers report. Farming a large expansion of Africa's savannas - nearly half of the world's remaining savannas - would also have negative impacts on the rich and diverse population of tropical birds and mammals.

The results highlight the need for policies that influence where and to what extent cropland expansion occurs. Likewise, any new cropland that is created for growing staple foods should be prioritized to meet Africa's growing food demands, the researchers report. “Our paper does not merely analyze the climate costs of different lands, but does so relative to their potential food benefits," said co-lead author Lyndon Estes, associate research scholar at Princeton's Wilson School and STEP. "Because of Africa's rapidly increasing needs for more food, and the high environmental costs of agriculture, it is important to perform this analysis on a more detailed level in each country to determine which lands would produce the most crops for the least environmental cost."

Studying the Guinea Savanna

Using a map from the World Bank, the researchers examined the "Guinea Savanna," a region in Africa that includes a wide range of savannas, shrublands and woodlands. Given the area's relatively high rainfall, the region has good potential for growing crops, especially maize and soybeans, which the World Bank cites as the optimal staple crops to grow in sub-Saharan Africa.

The researchers examined the potential environmental impacts versus the benefits of growing maize and soybeans. Using a variety of existing global datasets and simulation methods, they found that, on average, current global maize croplands emitted 20 tons of carbon for each ton of crop grown annually. For soybeans, it's 44 tons for each ton grown. This means that only 2 percent of lands in the Guinea Savanna could be considered high-benefit/low-carbon-cost maize farmland, while between 9.5 and 11 percent would qualify for soybeans.

According to past studies, the Guinea Savanna could also serve as a large potential source of land for low-carbon biofuels. But those studies don't take into account the costs of carbon released by land conversion, what the researchers call "carbon payback time." This is the number of years it takes for greenhouse gas savings to justify the initial cost of releasing carbon through land conversion. Factoring in this land-use change, the researchers find that it would take more than 50 years to recover from converting half of the Guinea Savanna's wet savannas into cropland. This doesn't meet the European Union 2017 standard -- that biofuels must produce 50 percent less greenhouse gas than gasoline over 20 years. They also find that less than 1 percent of the land would be recovered in less than 10 years.

Even if Africa's wet savannas could provide some staple crops at low environmental costs, sub-Saharan Africa can only become an exporter of crops by stripping its own people of food.

Africa's population is expected to double by 2050 and so, for sub-Saharan Africa to become self-sufficient in food production, the amount of crop calories would need to grow 4.7 times the 2007 levels, the researchers report. This means that Africa would need to expand its cropland by 345 million acres (140 million hectares), releasing 33 billion tons of carbon dioxide. This is the same amount released globally in 2013.

"Because of Africa's rapidly increasing needs for more food, and the high environmental costs of agriculture, it is important to perform this analysis on a more detailed level in each country to determine which lands would produce the most crops for the least environmental cost," Estes said. In terms of biodiversity, agricultural conversion nearly always has large impacts. In the Guinea Savanna, there is a high diversity of animals that are distinct compared to other continents. In addition to this richness, the Guinea Savanna supports some of the last large mammal migrations and provides key habitat and freshwater flows to critical biodiversity areas such as the Okavango Delta, which is located outside of the region. Because many of the factors related to the biodiversity costs of agricultural conversion are unknown, researchers did not make a calculation.

"What we show is that for a few key taxa - birds and mammals in particular the Guinea Savanna is almost as biodiverse as the world's wet tropical forests, and has a species richness as great as all of Africa's protected areas outside the Guinea Savanna," said Dan Rubenstein, a professor in the Department of Ecology and Evolutionary Biology and director of the Program in African Studies. "Transforming this habitat into cultivated landscapes not only will release high levels of previously stored carbon, it will also engender high costs in terms of lost species, some of which are seriously endangered and unique to the Guinea Savanna."

Considerations for Expanding Cropland

Overall, the findings seem to suggest that it is important to limit cropland expansion, but that is not what the researchers stress. Instead, they point toward creating policies that influence where cropland expansion occurs. With such a rapidly growing global population, particularly in Africa, where agriculture is the primary livelihood, creating additional farmland is inevitable and necessary. But undertaking more finely-tuned analyses - with even more precise data than what these researchers used here - can help to better target specific regions ripe for less environmentally costly conversion.

"One basic lesson is that Africa's wet savannas deserve more environmental respect than they get," said Phil Thornton, a co-author and senior researcher with the CGIAR Research Program on Climate Change, Agriculture and Food Security.

Great Gains for Conservation of SA's Grasslands and Wetlands

WWF South Africa

A major milestone for the conservation of South Africa's grasslands and wetlands was reached on 22 January 2014 when the MEC for Economic Development, Environent and Tourism, Ms Pinky Phosa, declared five new protected areas in Mpumalanga. South Africa's grasslands are poorly represented in formal protected areas and this declaration will now add over 73 000 hectares of important grassland habitat to the network of protected areas within the province. The new protected areas are:

- The Chrissiesmeer Protected Environment (60203 hectares);
- The Kwamandlangampisi Protected Environment, near Wakkerstroom which is extended by 3 094 hectares;
- The Mabola Protected Environment (8772 hectares), also near Wakkerstroom; the Tafelkop Nature Reserve (1 208 hectares);
- The first community-owned protected environment in Mpumalanga, known as the Mndawe Trust Protected Environment (826 hectares), near Lydenburg.

Our grasslands are of vital cultural and natural importance. Read about them at wwf.org.za/grasslands

Supporting Future Earth with Global Geo-information

Jun Chen
ISPRS President

Future Earth is a newly launched 10 -year research program by the International Council of Science (ICSU). The major goal of the Future Earth program is to deliver, at global and regional scales, the knowledge that societies need to effectively address global change while meeting economic and social goals, by answering the most pressing questions in the context of securing human development in an era of rapidly escalating global environmental risks. *The Dynamic Planet*, *Global Development* and *Transformations towards Sustainability* are the three key research themes of Future Earth. Since its official launch in 2012, Future Earth has received strong support from international communities and is becoming a global research platform.

The implementation and success of the Future Earth program depends critically on the availability and utilization of geo-information at multiple scales. Nowadays, people are producing/generating more and more geo-data sets at both local and global scales with earth observation, web-sensors, crowd-sourcing and other technologies. Landsat data is the most well-known image data which has been widely used by international communities. GlobeLand30 is the first open access 30m global land cover dataset with 10 classes for the years 2000 and 2010 (www.globeland30.org) However, a better understanding and sustainable development of our planet has asked us to provide more detailed and up-date geo-information about the Earth and its environment and other physical objects and processes. For examples, GEO (Group on Earth Observation) has identified a group of critical variables to be derived for the nine Societal Benefit Areas (SBAs). The bio-diversity people have also defined a set of Essential Biodiversity Variables (EBVs) and some of them can only be obtained with the help of remote sensing and GIS technology. It is becoming a huge challenge for us to provide the right geo-information, in the right place, at the right time, and the right people for making appropriate decisions at both local and global scale.

With the dramatic increasing of the geo-data volumes, we are entering a data-intensive world or an era of so-called big data. People wish to share all data resources distributed across regions or have an easy access to the massive quantities of data. This can be facilitated by setting up a web-based spatial information platform for easier access to diverse and distributed data. Effective analysis tools are requested to derive meaningful knowledge from these large data sets. With the recent development of Model Web, it would be possible to find

The desired algorithms and models from the internet catalogues, and re-use them using a combination of complex workflows and an execution over a distributed architecture. In addition, advanced visualization, animation and interaction tools are also needed to enhance the understanding of the massive and dynamic datasets. Supporting Future Earth with reliable global geo-information provides our geo-spatial professionals a good opportunity for advancing photogrammetry, remote sensing and geo-spatial sciences, for promoting spatially enabled government and societies, and facilitating easier access to geo-spatial education. However, a number of key issues remain to be examined, such as the user requirements, the major challenges and key gaps, and cross-boundary collaboration. ISPRS plans to organize an international workshop on this subject (http://ngcc.sbsm.gov.cn/article/en/GLC2015/) from 9-10 June, 2015, in Beijing, jointly with other sister organizations. This workshop will present the latest development of global spatial data production and sharing, exchange successful application experiences of global geo-information, examine up-to-date user requirements and key gaps, and identify major challenges. It aims at promoting the multi-disciplinary collaboration towards providing reliable global geo-information to support Future Earth. A special issue has also been planned in International Journal of Digital Earth (IJDE) and will be published at the beginning of 2016 as the output of this workshop. You are welcome to join us and to support Future Earth!

"It is becoming a huge challenge for us to provide the right geo-information, in the right place, at the right time, and the right people for making appropriate decisions at both local and global scale."

National Veld Forest Fire Amendment Draft Bill, 2015

Agriculture, Forestry and Fisheries

The Department of Agriculture, Forestry and Fisheries invites you to comment on the National Veld Forest Fire Amendment Draft Bill.

agriculture, forestry & fisheries

Department: Agriculture, Forestry and Fisheries
REPUBLIC OF SOUTH AFRICA

The Bill seeks to amend the National Veld and Forest Fire Act, 1998, so as to:

- Amend and insert certain definitions;
- Provide for the facilitation of the formation of fire protection associations by a municipality or a traditional council;
- Compel a municipality, state owned enterprise, public entity or other organ of state which owns land to join the fire protection associations;
- Empower the Minister to develop a framework for monitoring, evaluation, assessment and reporting in respect of veld and forest fire management;
- Amend the title of the Act to National Veldfire Act;
- Amend the short title and substitute the long title.

More information of the gazette is available online at www.gpwonline.co.za

Launch of the Green Technologies in South Africa Report

ASSAF

The report on The State of Green Technologies in South Africa was formally launched and handed over to the Department of Science and Technology (DST) on 28 January 2015 at the Hyatt Regency in Rosebank, Johannesburg.

Prof Eugene Cloete from Stellenbosch University and chairman of the panel that conducted the study presented on the findings and recommendations of the study. The event was attended by stakeholders in the private and public sectors, amongst whom were Dr Thomas Auf der Hyde and Mr Imraan Patel, both Deputy Directors-General of the Department of Science and Technology (DST) who commissioned the study.

Subsequent to the launch, the DST and ASSAf have embarked on a plan to ensure broad-scale dissemination and exposure of the report, with the goal to impact the highest levels of policymaking.

The study presents the following recommendations:

- Ensure that policies are enabling and regularly review policies to allow for learning
- Prioritise niche areas for local develop ment of green technologies based on existing innovation capacity
- Government should look to shaping the market
- Strengthen the NSI to ensure coherency between role players and skills development
- Target communication strategies to promote uptake of green technologies by the public and plan for the export market, particularly within Africa
- The country's development needs should inform and direct but not prescribe green technology investments
- Conduct a follow-up study to identify a set of indicators for the M&E framework for green technology uptake in South Africa
- Sub-national considerations at developing green technologies hubs
- Systematic reviews of projects, particularly failed or discontinued projects, so that learning can be enhanced.

2016 IRC
Second Announcement

You are invited to attend the X^th^ International Rangeland Congress in Saskatoon, Saskatchewan, Canada July 17-22, 2016

The Future Management of Grazing and Wild Lands in a High Tech World

CALL FOR PAPERS

We invite you to present a paper - oral or poster presentation - featuring your research on range/grassland related to one of the topics listed below. If you are a rancher, grass farmer, extension agrologist, range manager, land reclamation specialist, parks or wild lands supervisor, modeller, remote sensing specialist or a person interested in the management of the world's grazing and wild lands you are also invited to make an oral or poster presentation involving your work or operation. Below is a list of the topic categories that you can present in.

1. State of Global and Canadian Rangeland and Pasture Resources

Eco site descriptions, Historical developments, Conservation, Grazing management, Genetic resources and forage development.

2. Ecological Goods and Services of Rangeland and Pasturelands

Nutritional links from soil to plant to livestock to people, Carbon sequestration, Water supply and quality, Wildlife habitat , Aesthetic and spiritual value of wild lands.

3. The People of the Grasslands

Changes to pastoral systems, Private and leased, Urban and sub-urban grassland societies, Professional extension and technology-transfer, Social justice issues in rangelands.

4. Multiple use of the Rangelands Resource Extraction Impacts in Asia and North America

Energy development and reclamation, Fire management and restoration, Revegetation with perennial forages, Invasive species impacts, Wild land conflicts in tourism.

5. Range and Forage of High Latitudes and Altitudes including Arctic and Sub Arctic North America and Europe, Ande An/Patagonian or Tibetan Plaeau

4. Climate Change in Rangeland

Climate change impact on Plant, Livestock and grazing system, Water supply and quality, Historic & cultural response, Modeling future human and climate change response.

7. Grazing Land Assessment and Management in a High-tech World

New Technology in: Remote sensing for land resource data acquisition and modeling, Social and psychological data, Animal movement data, Education and extension, new developments in fencing, water supply, and livestock health.

Rancher/Stockman/Cattlemen/ Herdsmen Forum

Management of grazing lands has changed over time as knowledge of grassland systems increase and new challenges, opportunities, innovations, and technologies emerge. This Forum will include presentations from ranchers and grassland farmers on the Canadian prairies as well as from ranchers, stockmen, and grass farmers in other regions of the world.

Tours

There will be two 4 day pre-congress tours in Saskatchewan visiting rangeland projects, ranches and farms. The 7 day pre-congress tour will visit the rangelands and ranches of southern Saskatchewan and Alberta in Western Canada including the Rocky Mountains. In addition, several local full day tours, mid-week (Wednesday) during the Congress will visit research facilities, farms, cattle ranches, historical and cultural sites. There will also be programs for accompanying persons.

For detailed information and if you would like to continue to receive email updates about IRC 2016, please go to our website: **www.irc2016canada.ca** and sign up.

We hope to see you in Saskatoon in July 2016!

Lowveld Protected Areas: To Manage or Not to Manage

Mike Peel
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As we are all aware, the Lowveld has experienced average to above average rainfall over the past six years. During these 'years of plenty', with the veld looking great, we are often numbed into a false sense of security and as game numbers increase, we try to create a sense of 'anticipatory awareness' - the dry times will return and we cannot predict when, how long and what the severity of the dry period will be when it comes. In fact it appears that with increased variability in climatic conditions, prediction may become more and more difficult.

The Rangeland Ecology group of the Agricultural Research Council has, over many years, presented potential animal trend scenarios to a large number of land users based on current veld condition and animal numbers (both based on up to 25 years of historical data) under varying rainfall conditions and with the predicted response of the grass layer to these variables. The bottom line is that we do not want unpleasant surprises and we need to be proactive rather than reactive when taking management decisions relating to animal numbers. In the following discussion I share some thoughts relating to animal management under fluctuating environmental conditions.

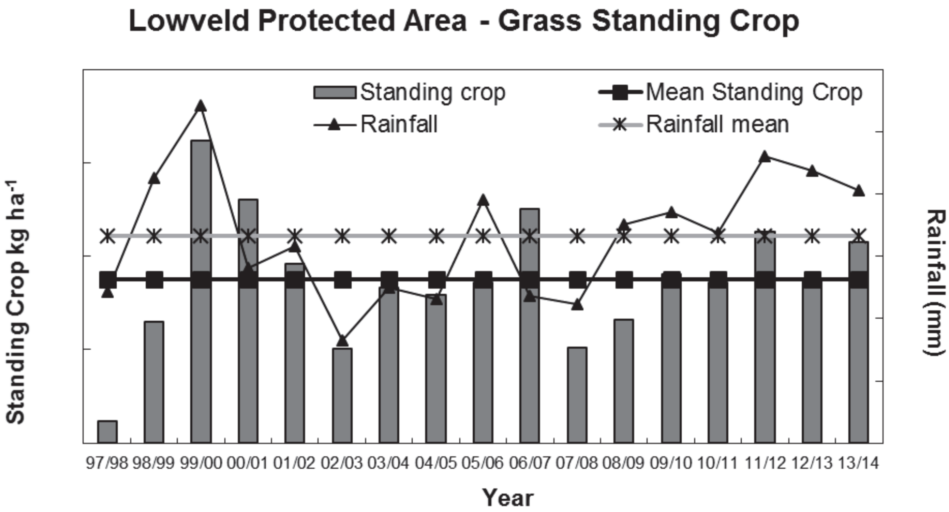
The fact that, due to land fragmentation there is no longer movement to the higher rainfall areas and forage resources in the west near the Drakensberg range, means that there will be animal losses in drought years. Population declines especially in larger grazer species such as buffalo, zebra and wildebeest would vary from minimal through steep as evidenced by the 1982-83 drought for example where some grazers were reduced to between 10 and 20% of their pre-drought numbers following large scale perennial grass mortality. Mortality amongst these grazing herbivores may be viewed as part of a longer term cycle and droughts are also times when predators, in particular lions, feast on weakened animals.

The question is whether or not we are prepared to allow drought related mortality to occur and whether the cost to the veld would be acceptable if numbers are allowed to increase unchecked? Management decisions are also linked to whether the protected area is fenced (no movement to favourable grazing areas possible) or not.

The relationship between grass production and standing crop is highlighted with recent favourable rainfall seasons in the eastern Lowveld (mean or above rainfall since 2008/09 in the example given below) resulting in an increase in grass standing crop (the portion of production that remains after utilisation) (Figure 1). The latter is due to a favourable perennial composition and cover and improved soil moisture conditions that promote grass growth (Figure 1). This has in turn resulted in a steady increase in herbivore numbers in Lowveld Protected Areas (Figure 2) which largely reflects these favourable grazing conditions.

Figure 1 illustrating the favourable relationship between annual rainfall and grass standing crop (note mean or above mean rainfall since 2008/09 and above or above average grass standing crop since 2009/10 – note lag of one rainfall season before the grass response becomes clearly evident.

Figure 2 illustrating trends in three grazing species in the protected areas of the eastern Lowveld. Note the increases in these important grazers in response to the data shown in Figure 1 (increased rainfall and increased grass standing crop from around 2008/09 and linked increases in grazing animals).



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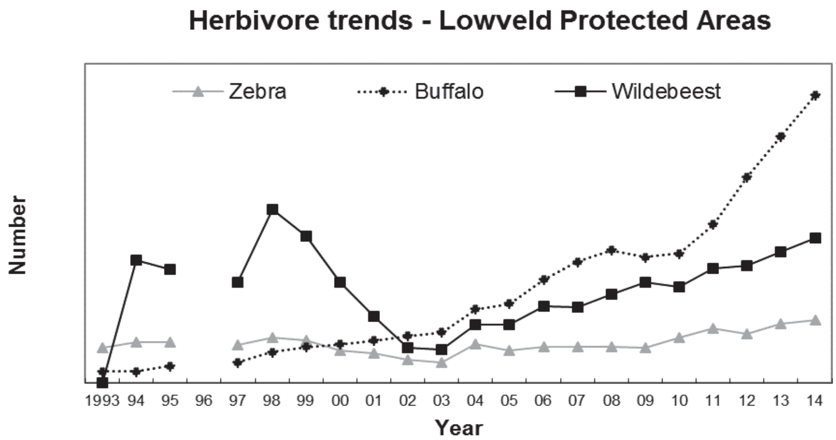

Figure 2 illustrating trends in three grazing species in the protected areas of the eastern Lowveld. Note the increases in these important grazers in response to the data shown in Figure 1 (increased rainfall and increased grass standing crop from around 2008/09 and linked increases in grazing animals)

Over the past few years we can see that the grass layer has not been limiting for grazers in general (Figure 1). Further I think that given the fact that grazers, like buffalo, move in large herds over extensive areas and are not sedentary around a single water point, that they have a generally beneficial effect on the vegetation for, among others, the following reasons. High densities of large hooved animals:

- Break soil crusts by their hoof action allowing for a good soil surface to seed contact;
- Reduce the height of moribund grass, thus allowing sunlight to penetrate the shorter vigorous grass tufts while reducing the temperature of the soil and making it more suitable for rai fall infiltration; and
- Deposit concentrated amounts of dung and urine

All of the above promotes seedling establishment, particularly in bare areas and promotes a healthy productive perennial sward of grasses. Closer plant spacing (increased density) with a better litter layer (organic matter) and stable soils results in less evaporation and more effective rainfall (infiltration) with lower soil temperatures, less rainfall runoff, silting up of streams etc. The presence of predators, in particular lions, causes buffalo herds to bunch when chased thus intensifying the positive impacts outlined above.

The fact that these large herds are mobile also means that they seldom 'camp' on a patch for a long period of time but are continually moving through different landscapes. This means that unlike selective water dependent grazers, buffalo will utilise an area and then move on thus reducing the chance of overgrazing (a function of time and not necessarily number – veld needs rest). For example excessive artificially supplied surface water results in high densities of sedentary water dependent species (e.g. impala). So where and when do we exercise animal control? Even on unfenced areas animal control may need to be considered where water point provision has resulted in increased animal numbers due to their increased distribution resulting in insufficient forage for animals during dry periods (obviously more critical in fenced situations). The alternative is that the population is allowed to fluctuate with the prevailing resource conditions, i.e. a die-off in drought (weaker animals). This may be acceptable in unfenced, 'open' situations but is it appropriate in fenced areas where animals are unable to migrate? The tricky issue if the 'laisser-faire' option is pursued, is the long term effect on the resources resulting from overgrazing.

A hypothetical example from a fenced area – to manage or not to manage

We examine the effect of resource use by grazers by inserting the resource requirements for grazing species and determine whether the grazing population is able to maintain themselves under varying environmental and attendant resource conditions.

For this exercise the model is based on a fenced protected area using real data (main grazers rounded off: buffalo 1 000; wildebeest 550; zebra 250; impala 3 100), year 1 grass standing crop (≈ 1 700kg ha^{-1} which provides some residual for the year 2 season's standing crop) and as a worst case scenario a projected a grass standing crop for year 2 season which yields only 600kg ha^{-1} (approximately the lowest standing crop on the PA in question for some 18 years). The results indicate that there would have been insufficient forage for the grazing animals present on the PA. This information is critical for managers to take early animal management decisions and depending on the amount of risk they are willing to take. Any animal management would be aimed at preventing:

- Excessive animal die-off; and
- Veld degradation.

This situation obviously brings into question the species that we should consider managing. We need to be wary about reducing prey species such as wildebeest and zebra which, in this case are showing encouraging increases (Figure 2). The reason for this caution is that the lion population has the ability to relatively quickly push these and other more sensitive species (e.g. waterbuck) into a predator pit (as happened under high predator levels for wildebeest and zebra between 1997 and 2002 (Figure 2). The latter situation required predator, in particular lion, management – a discussion for another day!). Consideration could be given to the removal of species such as impala but caution is again advised as impala are an important buffer to other prey populations that may be under pressure. All the while the grazing resource would be stressed. To address this situation the removal of around 20 buffalo would have ensured that there was just sufficient food to satisfy the needs of the grazing population (this is obviously an oversimplification but is used here purely for illustrative purposes).

The reality is that we had a good year 2 season so the stressed grazing situation never materialised. If we feed the year 2 standing crop in (≈ 2 100kgha^{-1}) and project an increase in animal numbers minus predation (actual data obtained from the protected area concerned) and remembering that populations close to 'ecological carrying capacity' do not generally increase at rates attained when a population is increasing with surplus resources (on the fast part – logarithmic part of the growth curve) then anything less than 680kgha^{-1} would result in a shortage of grazing. Note: The point at which grazing stress becomes an issue increases from 600kgha^{-1} to 680kgha^{-1} (assuming reduced animal increment levels for the reasons given above resulting in more grass but still a stressed grazing resource to 'break-even). At 600kgha^{-1} it would be difficult to reduce the number of buffalo alone (in one exercise) to get to the 'break even' point as this number would be projected at around 1 150 to reduce to around 900 (a 10% increase in buffalo from 1 000 is 100! Plus the other species would also increase in number). Is this logistically practical? We need to look at other species as well. In addition, for example, 700 impala could be removed to stabilize the situation. As stated above however we need to be wary to reduce prey species such as wildebeest and zebra (which are both increasing), as well as waterbuck due to their susceptibility to heavy predation.

BUT the above assumes a drought situation and we are coming off a run of good seasons. The good news is there was sufficient grazing and offtakes should be aimed at maintaining this situation depending on rainfall. A staggered offtake is logistically preferable but what I aim to illustrate in this discussion is how quickly 'things can get away'. On fenced areas where the animals cannot move, the situation is even more critical!!

An active adaptive management approach means that in the worst case scenario:

- We suffer a drought
- We lose animals;
- Pressure is taken off the veld;
- Feeding is considered in some cases;
- We recoup something from offtakes.

The best case scenario would be that;

- We do not suffer a drought
- We lose animals through natural attrition
- Pressure is taken off the veld;

- The veld remains in a favourable condition;
- We recoup something from offtakes

In unfenced protected areas there is obviously another option in terms of management, that of a laisser faire or hands-off approach. However, populations cannot increase at consistent rates under stressed conditions so one would expect a drop off in natural increments. So we use adaptive management where opportunities are grasped (allow numbers to climb) and hazards are avoided (large scale die-offs related to veld degradation).

In many Lowveld protected areas the stocking rates are such that it would require a relatively large management effort to reduce the numbers to adapt to any decline in veld condition. As the grazing resource is generally limiting, grazer species in particular require constant monitoring (removal, feeding or no action). These 'managed' animals would be animals not removed by predation but considered necessary for removal for ecological reasons while at the same time being careful not to push prey species into a 'predator pit' and all the while striving to achieve the ecological and economic objectives of the protected area in question.

"Populations cannot increase at consistent rates under stressed conditions"

Managing the Invasive Alien Plant *Parthenium hysterophorus* in South Africa

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Parthenium hysterophorus is an annual plant of the Asteraceae family, originating from Central and South America. It has invaded southern and eastern Africa, Asia and Australia, causing substantial economic losses in many countries. In South Africa, this invasive alien plant is commonly referred to as parthenium, Demoina weed, Maria-Maria and more recently named 'famine weed' and 'Umbulalazwe', due to the damaging impacts that accompany its rampant spread. Infestations of parthenium can severely impact on agricultural production, by reducing available grazing and crop yields (e.g. yield losses of between 40% and 90% reported in crops such as sorghum), as well as affecting biodiversity conservation in protected areas. Human and animal health is affected as regular exposure to parthenium causes severe respiratory (asthma and hayfever) and skin (contact dermatitis) allergic reactions in many individuals. The meat and milk of animals that ingest parthenium, is tainted.

In South Africa, parthenium has invaded particularly KwaZulu-Natal and Mpumalanga, as well as North-West and Limpopo provinces, and continues to spread. Dense and extensive infestations occur along roadsides and watercourses, and in grazing, cultivated, fallow and conservation land, and protected areas for the conservation of biodiversity. . Some rural homesteads are entirely surrounded by parthenium, with associated health risks through frequent exposure and contact with the plant. Seed dispersal occurs by means of water, vehicles, machinery (agricultural, road construction and maintenance), animals, seed lots, and stock feed.

Up to 25 000 seeds per plant have been recorded, mostly viable, and if buried a few centimetres below the soil surface can survive for at least six years. Local studies revealed considerable annual variability within the parthenium seed bank in the soil, with up to 95 000 parthenium seeds per m^2 recorded on occasion at some sites. Parthenium has also widely invaded Swaziland, as well as parts of Mozambique, Zimbabwe, Tanzania, Kenya, Uganda, Eritrea, Egypt and particularly Ethiopia, where it is a severe problem and impacts on the livelihood of millions of people by reducing grazing and arable land. Predictive modelling has shown that most of sub-Saharan Africa is climatically suitable for the growth of parthenium and at risk of invasion by this plant.

Poor land management practices such as incorrect stocking densities, leading to overgrazing, exacerbate the spread of parthenium, as it readily invades bare, disturbed soil. The production of allelochemicals assist parthenium to outcompete native vegetation, resulting in the formation of monospecific stands. Certain grass species such as *Panicum maximum* can outcompete parthenium when grazers are excluded. Reducing animal stocking densities to improve grass cover can prevent or alleviate parthenium infestations, and such management methods have been effectively used in Australia. However, the modification of stocking densities in systems in Africa where high cultural value is placed on cattle and where unfenced, communal grazing is commonly practiced, is challenging.

Several effective herbicides are registered for the control of parthenium, but chemical control requires repeated follow up treatments which may be beyond the economic means of some landowners or may be impractical in regions where infestations are very extensive. Hand-weeding, a widely used weed management practice in Africa, carries associated serious health risks through regular exposure and contact with parthenium, and is often not conducted sufficiently early, prior to seed set, to be effective. Biological control, using selected natural enemies (insects, mites and/or pathogens) introduced from the plant's native range, is a cost-effective, long-term, sustainable management option. It aims to reduce (not eradicate) parthenium to levels at which it becomes less problematic in the environment, to the extent where, ideally, either other control measures are not required, or where they are required at lower levels. After selection of the most suitable natural enemies in the native range, and importation of the candidate biological control agents into quarantine facilities in the introduced country, rigorous research assesses their host range to ensure that they are host specific and will only have an impact on the target invasive alien plant, and will not have a detrimental effect on any indigenous and economically important plant species. Biological control of invasive plants has been practiced for more than 100 years in South Africa, with some outstanding successes where no other control options have been required, and other species with significant success but where other control options are still required although to a lesser degree. The track-record throughout this period is clean, with no unpredicted shifts of agents onto any other unintended plant species.

In Australia, the extent and density of parthenium has been considerably decreased since the 1980's, using a combination of natural enemies (seven insect agents and two rust fungi) imported from the native range of parthenium in the Americas. Farmers in Queensland State nowadays consider parthenium far less of a problem than previously. A suite of natural enemies, affecting different parts of the plant, is required to adequately suppress parthenium under the various conditions that it invades. In 2003, a research programme on the biological control of parthenium in South Africa was initiated by the ARC-PPRI, funded by the Working for Water Programme.

Larval feeding by *Listronotus setosipennis* inside *Parthenium hysterophorus* stems

The summer rust fungus *Puccinia xanthii var. parthenii-hysterophorae*

The results of the Australian biocontrol programme were relied upon during the selection of potentially suitable biocontrol agents for importation and assessment for their suitability for local conditions. The winter rust fungus *P. abrupta* var. *partheniicola* (Pucciniales: Pucciniaceae), was already present in South Africa and was probably introduced with the plant at an earlier stage. To date, the summer rust fungus *Puccinia xanthii* var. *parthenii-hysterophorae* (Pucciniales: Pucciniaceae), the leaf-feeding beetle *Zygogramma bicolorata* (Coleoptera: Chrysomelidae), the seed-feeding weevil (*Smicronyx lutulentus* (Coleoptera: Curculionidae), all originating from Mexico but imported from Australia at various times, and the stem-boring weevil *Listronotus setosipennis* (Coleoptera: Curculionidae) from Argentina, were assessed in the ARC-PPRI quarantine facilities (Cedara and Stellenbosch). Applications for permission to release them in South Africa were approved by the Department of Agriculture, Forestry and Fisheries at various stages since 2010 onwards.

The biocontrol agents target different parts of parthenium: *Z. bicolorata* feed on leaves and under suitable conditions can completely defoliate plants; *L. setosipennis* larvae tunnel inside parthenium stems, structurally damaging the plant; severe infection levels of *P. xanthii* stunt plants; and *S. lutulentus* larvae feed within seeds, reducing the plant's reproductive vigour. Biocontrol agents are mass-reared by ARC-PPRI and released in conjunction with the Department of Environmental Affairs Natural Resrouces Management Programme's biological control implementation in each province, into selected sites within the invaded range in South Africa, particularly in northern KZN and eastern Mpumalanga where parthenium is most extensive. Large numbers of the leaf -feeding beetle, stem-boring weevil and summer rust fungus have been released at about 200 sites and continue to be released, with establishment confirmed at some sites, to varying degrees. Agent performance is variable; they establish and are effective under different conditions. Recent drought conditions in parts of the country appear to be hampering agent establishment.

Additional challenges include the need for secure sites, where mechanical and chemical clearing efforts will not be undertaken for some years, to enable the biocontrol agents to establish, build up population numbers and spread. Efforts are underway to increase the production of agents for release by establishing additional mass-rearing facilities, particularly in the regions that are severely invaded by parthenium. Additional agents are also under consideration; the stem-galling moth *Epiblema strenuana* (Lepidoptera: Tortricidae) has also been investigated, with further research required to elucidate its field host range, and most recently, the sesiid moth *Carmenta Ithaca* (Lepidoptera: Sesiidae) with larvae that tunnel in the root crown of parthenium, from Mexico, was imported from Australia and is currently under assessment in ARC-PPRI quarantine facilities for its suitability for release in South Africa.

Parthenium infestation in the Ndumo Game Reserve

The stem-boring weevil *Listronotus setosipennis* in its mature state

Few invasive plants can boast such broad-reaching detrimental impacts on agriculture, biodiversity conservation, as well as human and animal health, as parthenium, and increased concern due its rapid, recent spread resulted in a call for national, coordinated management interventions. To this end, a national strategy and national implementation plan were compiled for the Department of Environmental Affairs' Natural Resources Management Programme in 2014, for the management of parthenium in South Africa. Using differential zoning of affected and unaffected areas of the country, the strategy and plan outline various goals, recommend structures, and identify stakeholder responsibilities for management efforts including chemical and biological control methods, to increase awareness, facilitate the use of best management practices, and coordinate management activities.

Efforts to facilitate the biological control of parthenium further north in Africa (Ethiopia and Tanzania) have been undertaken in collaboration with international partners (the USAID-funded Integrated Pest Management Innovation Lab and CABI Africa). ARC-PPRI provided advice on quarantine facility establishment and biological control research, and starter cultures of parthenium agents. Wider management efforts on the continent are required to halt the spread of parthenium, which, if left unchecked, will continue to have a devastating impact on the livelihoods of subsistence farmers in particular. Biological control has been demonstrated to play a crucial role in the long-term, cost-effective integrated management of parthenium weed in Australia, and expectations are that it should prove to be equally effective to assist in managing the invasion of this weed in South Africa and, where implemented, further north on the continent.

Financial support, particularly by the Department of Environmental Affairs Natural Resources Management Programme, is gratefully acknowledged. Staff of the ARC-PPRI are thanked for their research and technical inputs.

Defoliation of *Parthenium hysterophorus* by *Zygogramma bicolorata*

The adult leaf-feeding beetle, *Zygogramma bicolorata*

Production Potential and Evaluation of Establishment Methods to Over-sow Kikuyu with Grass and Legume Species

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Introduction

Kikuyu is a pasture species that is well adapted to the main milk producing areas in the Western Cape Province of South Africa (Botha 2003). The strategic incorporation of various temperate grasses and legume species, over-sown during autumn, has been found to be an economical forage-based way to improve the seasonal dry matter (DM) production, forage quality and milk production potential of kikuyu based pasture systems (Botha 2003, Fulkerson et al. 1993a, Van der Colf 2011). The species that have thus far been evaluated by over-sowing them into kikuyu include westerwolds ryegrass, Italian ryegrass, perennial ryegrass, red- and white clover mixtures, perennial ryegrass-clover mixtures, rescue grass (*Bromus catharticus*) and tall fescue (Betteridge 1985, Hill 1985a, Betteridge and Haynes 1986, Harris and Bartholomew 1991, Davison et al. 1997a, Botha et al. 2008a, Botha et al. 2008b, Van der Colf et al. 2011). The preferred species to include in a kikuyu based system will be based on factors such as fertiliser costs, milk price, ease of management and the availability of natural resources, especially water (Botha et al. 2008a).

To date, kikuyu-ryegrass pastures have been favoured over kikuyu-clover pastures in the main milk producing areas of the Western Cape due to the fact that these systems are easy to manage, requires fewer field operations to establish and has a high seasonal DM production potential (Davison et al. 1997a, Botha et al. 2008a). Such kikuyu-ryegrass systems can maintain pasture production rates of between 15 and 18 t DM ha^{-1} $annum^{-1}$ (DM intake basis) and achieve milk production rates of approximately 30 000 kg FCM ha^{-1} (Van der Colf 2011). However, due to the high fertilisation rate (500 kg N ha^{-1} $annum^{-1}$) and irrigation requirements of kikuyu-ryegrass pastures, the sustainability of such systems in the future is questionable. The inclusion of legumes and perennial grasses is the most likely way to streamline pasture systems so as to increase long-term survival and sustainability (Cransberg and McFarlane 1994). Perennial legumes such as white clover hold the potential to fix atmospheric nitrogen, provide high quality feed for livestock (Brock and Hay 2001) and decrease the reliance on expensive nitrogen fertilisation (Graham and Vance 2003, Neal et al. 2009).

The direct challenge in the development of systems based on over-sowing kikuyu with adapted perennial grasses in mixtures with perennial clovers is the successful establishment and long-term persistence of these species in order to improve the production potential of the system as a whole. The objective in the establishment of such pastures will be to maintain perennial pasture with optimum seasonal production, and to maintain the clover content above 30% of the botanical composition during winter and up to 50% during spring (Botha et al. 2008a) (Kemp et al. 2000). The aim of this study was to evaluate various methods to establish tall fescue and cocksfoot in mixtures with white and red clover into existing kikuyu-based pastures.

Materials and methods

The study was carried out on existing kikuyu pasture under permanent irrigation on the Outeniqua Research Farm (altitude 210 m, 33°58'38" S and 22°25'16"E) in the Western Cape Province of South Africa. The area is characterised by an Estcourt soil type (Soil Classification Work group 1991). The study consisted of a randomized block design with three blocks that acted as replicates and to which treatments were randomly allocated. The pasture treatments are described in terms of abbreviation, common name, scientific name and seeding rate in Table1

Table 1: Treatment abbreviation, common name, scientific name and seeding rate of pasture treatments.

Abbreviation	Common name	Scientific name	Seeding rate (kg ha^{-1})
Cocksfoot mixture	Kikuyu	*Pennisetum clandestinum*	Existing pasture
	Cocksfoot	*Dactylis glomerata*	10
	White clover	*Trifolium repens*	4
	Red clover	*Trifolium pratense*	4
Tall fescue mixture	Kikuyu	*Pennisetum clandestinum*	Existing pasture
	Tall fescue	*Festuca arundinacea*	10
	White clover	*Trifolium repens*	4
	Red clover	*Trifolium pratense*	4

Table 2: Treatment abbreviation, herbicide treatment, cultivation and description of establishment method to be used during the trial

Treatment	Treatment abbreviation	Herbicide treatment	Cultivation	Establishment method
1	Mulch	Nil herbicide	Mulcher	Graze to 50 mm Broadcast seed Mulch to ground level Roll with teff roller
2	Planter		Planter	Graze to 50 mm Mulch to ground level Plant with Aitchison seeder Roll with teff roller
3	Rotavate		Rotavate	Graze to 50 mm Mulch to ground level Rotavate to 120 mm Roll with teff roller Broadcast seed Roll with teff roller
4	Gly+Mulch	Glyphosate	Mulcher	Graze to 50 mm Spray with glyphosate (5 L ha^{-1}) Broadcast seed Mulch to ground level Roll with teff roller
5	Gly+Plant		Planter	Graze to 50 mm Spray with glyphosate (5 L ha^{-1}) Mulch to ground level Plant with Aitchison seeder Roll with teff roller
6	Gly+Rot		Rotavate	Graze to 50 mm Mulch to ground level Spray with glyphosate (5 L ha^{-1}) Rotavate to 120 mm Roll with teff roller Broadcast seed Roll with teff roller
7	Par+Mulch	Paraquat	Mulcher	Graze to 50 mm Spray with paraquat (5 L ha^{-1}) Broadcast seed Mulch to ground level Roll with teff roller
8	Par+Planter		Planter	Graze to 50 mm Spray with paraquat (5 L ha^{-1}) Mulch to ground level Plant with Aitchison seeder Roll with teff roller
9	Par+Rotavate		Rotavate	Graze to 50 mm Mulch to ground level Spray with paraquat (5 L ha^{-1}) Rotavate to 120 mm Roll with teff roller Broadcast seed Roll with teff roller

Table 3: The total annual dry matter production of different components and whole sward for cocksfoot-perennial legume mixtures over-sown using different methods during year 1.

Method	Clover	Sown grass	Kikuyu	Other	Whole sward
Mulch	3.11^{b}	0.84^{c}	1.45^{a}	6.46^{ab}	11.9^{a}
Planter	3.91^{ab}	1.31^{bc}	1.34^{ab}	8.45^{a}	15.0^{a}
Rotavate	4.28^{ab}	2.27^{ab}	0.27^{c}	4.85^{bc}	11.7^{a}
Par + Mulch	4.71^{ab}	1.53^{abc}	0.56^{bc}	5.06^{bc}	11.9^{a}
Par + Plant	4.80^{ab}	2.02^{ab}	1.63^{a}	5.27^{abc}	13.7^{a}
Par + Rot	5.41^{a}	2.63^{a}	0.05^{c}	2.95^{c}	11.0^{a}
Gly + Mulch	5.89^{a}	1.86^{abc}	0.01^{c}	3.66^{bc}	11.4^{a}
Gly + Plant	4.29^{ab}	1.94^{abc}	0.01^{c}	5.83^{abc}	12.1^{a}
Gly + Rot	4.18^{ab}	2.61^{a}	0.01^{c}	3.37^{bc}	11.4^{a}
LSD (0.05)	2.068	1.112	0.778	3.373	4.259

LSD (0.05) compares within component

^{abc}Means with no common super script differed significantly

Table 4: The total annual dry matter production of different components and whole sward for cocksfoot-perennial legume mixtures over-sown using different methods during year 2.

Method	Clover		Sown grass		Kikuyu		Other		Whole Sward	
	Perennial	Over-sow	Perennial	Over-sow	Perennial	Over-sow	Perennial	Over-sow	Perennial	Over-sow
Mulch	1.55^{abcde}	1.37^{abcde}	3.32^{abc}	3.06^{bc}	2.33^{b}	2.07^{bc}	3.48^{abcd}	2.32^{abcde}	11.4^{ab}	9.62^{b}
Planter	2.25^{a}	1.35^{abcde}	2.11^{c}	3.14^{bc}	4.50^{a}	1.72^{bcde}	3.78^{ab}	4.10^{a}	14.7^{a}	12.0^{ab}
Rotavate	2.08^{ab}	1.16^{bcde}	4.84^{ab}	4.38^{abc}	0.96^{bcdef}	0.51^{cdef}	1.56^{cde}	2.10^{abcde}	10.4^{ab}	8.62^{b}
Par + Mulch	1.71^{abcde}	0.83^{de}	4.10^{abc}	3.96^{abc}	2.21^{b}	0.42^{def}	1.85^{bcde}	1.85^{bcde}	11.0^{ab}	8.05^{b}
Par + Plant	1.91^{abcd}	1.63^{abcde}	4.19^{abc}	4.45^{abc}	1.97^{bcd}	1.93^{bcd}	2.90^{abcde}	2.18^{abcde}	11.0^{ab}	10.2^{ab}
Par + Rot	2.03^{abc}	1.05^{bcde}	5.40^{ab}	4.33^{abc}	0.50^{cdef}	0.15^{ef}	2.68^{abcde}	1.36^{de}	11.4^{ab}	7.90^{b}
Gly + Mulch	1.73^{abcde}	0.70^{e}	5.60^{a}	4.33^{abc}	0.02^{f}	0.04^{f}	1.29^{e}	1.28^{e}	9.50^{b}	7.25^{b}
Gly + Plant	2.26^{a}	1.25^{abcde}	4.35^{abc}	3.81^{abc}	0.02^{f}	0.03^{f}	3.54^{abc}	1.73^{bcde}	10.8^{ab}	7.73^{b}
Gly + Rot	2.30^{a}	0.99^{cde}	5.05^{ab}	5.33^{ab}	0.13^{ef}	0.03^{f}	3.45^{abcd}	2.13^{abcde}	11.7^{ab}	9.32^{b}
LSD (0.05)	1.084		2.381		1.630		2.138		4.771	

LSD (0.05) compares within component

^{abc}Means with no common superscript differed significantly

The establishment methods used during the study were aimed at including techniques based on herbicidal and mechanical control of kikuyu. A detailed description of the nine establishment methods is given in Table 2. When herbicides formed part of the treatment, it was applied to the specific plots 14 days prior to the any tillage/mechanical actions at a rate of 5 L ha^{-1} for both paraquat (contact) and glyphosate (systemic). The remaining material on herbicide plots was removed by grazing prior to establishment as recommended by Fulkerson and Slack (1996) and Fulkerson and Reeves (1996).

It has been recommended that temperate species be over-sown into kikuyu on an annual basis in order to maintain maximum returns from fertilizer and irrigation inputs on such pastures (Goodchild et al. 1982). In current kikuyu systems, perennial ryegrass is over-sown on an annual basis due to poor persistence (Botha et al. 2008, Van der Colf 2011), but the persistence of other temperate perennial species over years and the effect of annual over-sowing on botanical composition is not fully understood. In order to evaluate the changes that occur in un-renovated pastures over years and to determine whether annual over-sowing is the most economical means whereby production of these systems will be maintained, plots were divided into sub-plots that either remained un-renovated or were annually over-sown during the trial period. Annually over-sown plots were grazed to 50 mm during April, mulched to ground level and legumes and grasses were planted with a no-till Irrigation was scheduled using tensiometer readings placed at a depth of 150 mm. Irrigation commenced at a tensiometer reading of –25 kPa (Botha 2002). Soil samples were taken before the commencement of pasture establishment to a depth of 100 mm. Fertiliser was applied according to soil analysis results to raise soil P level (citric acid method) to 35 mg kg^{-1}, K level to 80 mg kg^{-1} and the pH (KCl) to 5.5 (Beyers 1973). Pastures received a once-off nitrogen dressing of 50 kg N ha^{-1} during winter in year 2.

Dry matter yield (kg DM ha^{-1}) was determined every 28 days by cutting four 0.25 m^2 quadrats to a height of 50 mm per plot before and after grazing. Samples were dried at 60ºC for 72 hours, DM content was determined and the yield estimated as kg DM ha^{-1}. Botanical composition was determined on a seasonal basis from grab samples. Pastures were grazed by lactating Jersey cows when pasture where deemed ready for grazing (between 28 and 35 days), with grazing management aimed maintaining a post grazing height of approximately 50 mm above ground level.

An appropriate analysis of variance (ANOVA) was performed, normality of residuals was tested (Shapiro and Wilk 1965) and Student's t-LSD (Ott 1993) calculated at a 5% significance level to compare treatment means. The STATS module of SAS version 9.2 was used to analyse data (SAS 2008).

Table 5: The total annual dry matter production of different components and whole sward for fescue-perennial legume mixtures over-sown using different methods during year 1.

Method	Clover	Sown grass	Kikuyu	Other	Whole sward
Mulch	3.43^{ab}	1.41^{ab}	0.93^{a}	4.71^{ab}	10.5^{a}
Planter	3.17^{b}	1.05^{abc}	1.07^{a}	4.83^{ab}	10.1^{a}
Rotavate	4.87^{ab}	1.27^{abc}	0.36^{a}	2.93^{b}	10.2^{a}
Par + Mulch	5.02^{ab}	0.26^{c}	1.01^{a}	3.49^{ab}	11.2^{a}
Par + Plant	4.99^{ab}	0.92^{abc}	0.85^{a}	5.55^{a}	12.3^{a}
Par + Rot	6.14^{ab}	1.92^{a}	0.17^{a}	2.88^{b}	11.1^{a}
Gly + Mulch	6.08^{ab}	0.61^{bc}	0.06^{a}	5.22^{ab}	12.9^{a}
Gly + Plant	5.02^{ab}	0.64^{bc}	0.06^{a}	5.77^{a}	11.5^{a}
Gly + Rot	6.46^{a}	0.59^{bc}	0^{a}	3.50^{ab}	11.8^{a}
LSD (0.05)	3.070	1.075	1.146	2.378	3.459

Results and discussion

Cocksfoot-perennial legume mixture

The total annual DM production of different components and the whole sward for a cocksfoot-perennial legume mixture over-sown into kikuyu using different establishment methods during year 1 is shown in Table 3. The total annual DM yield of the whole sward of the cocksfoot-perennial legume mixture was not affected by establishment method in year 1. All methods, except the mulcher method had both a clover and sown grass yield that was the highest or similar to the highest during year 1. When sown grass yield is considered alone, all methods except the mulcher and planter methods had a higher DM production. The mulcher, planter and par+planter methods had both kikuyu and other yields that were the highest or similar to the highest yield in year 1. The total annual DM production of different components and the whole sward for a cocksfoot-perennial legume mixture over-sown into kikuyu using different establishment methods during year 2 is shown in Table 4. During year 2 there were no differences in the sward, clover or sown grass production between pastures that were un-renovated or over-sown annually in year 2. This may be attributable to the production that is 'sacrificed' when annually over-sown pastures are establishing. Results indicate that if a high sown grass and clover component is desired for a cocksfoot-perennial legume mixture, shallow cultivation or herbicidal control is recommended. The most suitable method of these methods employed will likely be . determined by establishment costs, rather than yield alone

Fescue-perennial legume mixture

The total annual DM production of different components and the whole sward for a fescue-perennial legume mixture over-sown into kikuyu using different establishment methods during year 1 is shown in Table 5. The whole sward yield and kikuyu yield was not affected by establishment method for the fescue-perennial legume mixture during year 1. The mulcher, rotavate, par+plant and par-rot were the only methods where both the clover yield and sown grass yield was highest or similar to the highest during year 1. The total annual DM production of different components and the whole sward for a fescue-perennial legume mixture over-sown into kikuyu using different establishment methods during year 2 is shown in Table 6. During year 2 the total sward yield was lower in annually over-sown than un-renovated fescue-perennial legume mixtures for the mulcher, Par+planter, Par+rot and Gly+plant methods. Once again, this was likely due to production 'sacrificed' during the establishment phase after annually over-sowing. The un-renovated Par + Rot, Gly+Mulch, Gly+Plant and Gly+Rot were the only treatments that had both a clover and sown grass yield that was highest or similar to the highest in year 2.

The preferable methods to manage a fescue-perennial legume mixture over-sown into kikuyu was thus to use herbicide in the initial establishment, and managed as a perennial pasture that is not over-sown on an annual basis.

Table 6: The total annual dry matter production of different components and whole sward for fescue-perennial legume mixtures over-sown using different methods during year 2.

Method	Clover		Sown grass		Kikuyu		Other		Whole Sward	
	Perennial	Over-sow	Perennial	Over-sow	Perennial	Over-sow	Perennial	Over-sow	Perennial	Over-sow
Mulch	1.30^{de}	1.19^{e}	2.64^{a}	1.57^{abc}	2.51^{ab}	0.77^{cdef}	3.25^{ab}	3.36^{ab}	10.6^{a}	7.95^{c}
Planter	1.70^{cde}	1.22^{e}	1.46^{bc}	1.67^{abc}	3.13^{a}	0.93^{bcdef}	3.07^{b}	3.64^{ab}	10.2^{ab}	8.50^{bc}
Rotavate	1.64^{cde}	2.86^{abcd}	2.25^{ab}	1.33^{bc}	1.72^{abcde}	0.98^{bcdef}	3.57^{ab}	2.90^{b}	9.67^{abc}	8.76^{abc}
Par + Mulch	2.21^{bcde}	1.62^{cde}	1.40^{bc}	1.16^{bc}	2.20^{abc}	2.00^{abcd}	3.55^{ab}	3.28^{ab}	10.3^{ab}	8.84^{abc}
Par + Plant	2.16^{bcde}	1.52^{cde}	1.09^{c}	1.14^{bc}	1.81^{abcde}	1.07^{bcdef}	4.63^{ab}	3.48^{ab}	10.2^{ab}	8.02^{c}
Par + Rot	3.08^{abc}	1.40^{de}	2.08^{abc}	1.91^{abc}	0.60^{def}	0.67^{cdef}	3.78^{ab}	3.53^{ab}	10.6^{a}	8.38^{bc}
Gly + Mulch	3.46^{ab}	1.88^{bcde}	1.95^{abc}	1.20^{bc}	0.24^{ef}	0.11^{f}	4.33^{ab}	4.90^{ab}	10.3^{ab}	9.05^{abc}
Gly + Plant	2.88^{abcd}	1.98^{bcde}	1.61^{abc}	1.58^{abc}	0.39^{ef}	0.01^{f}	5.11^{a}	3.89^{ab}	10.6^{a}	8.39^{bc}
Gly + Rot	4.03^{a}	2.84^{abcd}	1.54^{abc}	1.42^{bc}	0.01^{f}	0.0^{6}	4.00^{ab}	3.38^{ab}	10.4^{ab}	8.72^{abc}
LSD (0.05)	1.609		1.117		1.601		2.032		2.014	

LSD (0.05) compares within component

^{abc}Means with no common superscript differed significantly

Conclusions

The establishment method to over-sow cocksfoot- and fescue-perennial legume mixtures into kikuyu did not affect total DM production of the sward. For both mixtures and methods where some degree of cultivation occurred or herbicide was sprayed resulted in a higher sown grass and clover yield. For cocksfoot-perennial legume mixtures the annual over-sowing did not affect total, clover or sown grass production. Fescue-perennial mixtures had higher clover, sown grass and sward yields for un-renovated treatments. When over-sowing temperate grass-legume mixtures into kikuyu the component yields (sown grass and clover) and costs related to different methods should be considered when selecting an over-sowing method.

Message to the farmer

Grass-legume mixtures can be over-sown into kikuyu using various mechanical and herbicidal methods. The decision on which method to use should be based on the species being sown and costs related to establishment.

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Scrub invasion of Open Grasslands: Soil Moisture Balance

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Open grasslands as a pure physiognomic type have no trees or shrubs emergent above the mature grass canopy level. Where woody plants grow out above the grass canopy level open grassland becomes a savanna or wooded grassland system. Certain grasslands, as on the southern Mozambique Coastal Plain sands, contain colonies of dwarf shrubs within the mature grass canopy which are only exposed by fire or overgrazing. There are desert (deep sands/hardpan), coastal (deep sands/high watertable), and many kinds of impeded drainage open grasslands (Tinley 1977, 1982; Fey 2010; Pringle et al. 2013). Only varieties of the latter types from across Southern Africa are used here as examples. These grasslands are supported by soils with poor subsoil drainage that undergo extreme seasonal contrasts in soil moisture – from waterlogged to edaphic drought. These edaphic controls reflect both the soil types and terrain drainage factors.

Examples include all duplex, plinthic, vertic and gley soils, the hydromorphic vleis (dambos) and floodplains, and heavy clays such as those that develop on basalt and dolerite. For example, the Highveld, East Cape and Natal podzol-like soils of Van der Merwe (1962), now classified as plinthic in revised terminology (Fey 2010). In the rainy growing season these soils become waterlogged due to the clay or gley subsoil that is impermeable to through flow of moisture and to plant root penetration. In the dry season this perched watertable condition is followed by extreme soil desiccation often with cracks in the clay subsoils. These edaphic conditions preclude woody seedling survival at both extremes, hence the occurrence of grasslands without trees. Soil moisture balance (SMB) is the amount of moisture required to support and maintain a particular kind of plant community in a state of dynamic equilibrium or balance. Anything that shifts this balance towards drier or wetter conditions entrains changes in the plant cover's physiognomy and species composition as adjustments to the altered edaphic condition develop. In regard to open grasslands on poor draining soils, any factor such as erosion that changes the moisture balance condition towards a better drained aerobic state enables woody seedlings to become established. SMB is also of course a fundamental determinant not only of plant growth and their patterns of occurrence, but also of phenology at all scales.

For example at the macroscale across the subcontinent tropics from Namibia to Mozambique (between 18 and 20 degrees south latitude) is the phenomenon of the pre-rain woody plant spring flowering beginning in the last week of July, and the grass spring growth delayed until the first summer rains in November due to edaphic drought in their root zone (Tinley 1977).

Several examples serve to illustrate how changes in the soil moisture balance of impeded drainage soils is affected by site or area disturbances. These changes result in the development of increasing successional complexity in habitat form and structure, biotic composition, and herbivore carrying capacity. Depending from which side of the Highveld Grassland Region invasive woody succession plants are coming – these can be of karroid shrubland, arid savanna, savanna woodland, thickets, or forest in the Drakensberg.

(1) Rock outcrops: Rainwater is shed and follows the underground rock surface bypassing the impervious gley horizon. This enables seeds to become established as their roots also follow the rock surface past the moisture barrier (as shown from soil trenches).

(2) Fence posts: Something as simple as belting a fence post into or through the gley horizon will, similarly to the above example, enable seedlings to become established, their roots closely following the pole into the subsoil. Bird mediated bushclumps around fence-posts in the Eastern Cape for example.

(3) Edaphic drought: Edaphic drought from one, or a combination of factors, including fire intensity and frequency, and/or overgrazing, results in a shorter and more widely spaced grass cover increasing rain run-off loss and hence soil profile dehydration. The more obvious factors are rill and gully erosion and the more subtle are overgrazing, excessive annual fires, or ungrazed or unburnt moribund grass cover, resulting in topsoil loss and pedestalling of grass tufts. Edaphic drought from all these factors serve to the advantage of scrub seed establishment. The drying out is also too often initiated or exacerbated by erosion gutters caused by stock or game paths, roads, tracks, and fencelines. Decreased waterlogging with cracks in the drying clay during the growing season is exploited by acacia seedling roots that penetrate through the subsoil horizon and enhance free drainage further. Once established, each acacia, like the fence-posts, serve as perch sites for bird dispersal of berry plants that often develop into thickets. In the eastern Cape and KwaZulu Natal the grasslands have in many areas been transformed by acacia scrub invasion whose seeds are dispersed by stock and game (*Acacia karroo* in the Eastern Cape; *A. nilotica* and *A. tortilis* in middle and lowveld KwaZulu Natal, and *A. sieberiana* in upland Natal).

(4) Planting trees for gardens or plantations: the planting of tree saplings 50 to 100 cm in height typically requires soil pits to be dug which exposes the impeding horizon, or breaks through it, providing free drainage and aerating the soil profile.

(5) Wetlands and vlei drainage: Climate change, over-abstraction and pollution are seen to be the greatest threats to wetlands and run-on habitats of all kinds (e.g. Rochier et al. 2001; Neke & du Plessis 2004). However, the continually overlooked primary threat to vlei grasslands and wetlands is the breaching of their ponding sills by upstream migrating gully erosion that is worsened with every rain (Tinley & Pringle 2014). Initially a subtle and insidious process in terrain of low relief, the slightest drainage incision such as a cattle path can initiate the unplugging of wetlands and their replacement by scrub, resulting in the ongoing haemorrhaging of soil moisture across landscapes. To re-instate vlei grasslands and rehydrate the landscape the first step is to re-establish the ponding sills. The second step is to review the run-off condition of the catchment to identify where simple yet effective rainwater harvesting and spreading interventions can be established to replenish soil moisture (Tinley & Pringle 2014). In aridlands run-on surfaces such as pans, outwash fans, vlei drainage and seasonally or irregularly waterlogged grasslands are vitally important habitats. In Namibia for example these are widespread inland down the length of the country, all liable to loss by donga breaching (Pringle et al. 2013).

(6) Mozambique vertisol floodplain grasslands (Tinley 1977): Where the ponding sill of a Rift Valley lake surrounded by floodplain grasslands has been breached by drainage incision these open grasslands are invaded from the savanna margins by fever trees (*Acacia xanthophloea*). This scrub occurs in even aged/size bands related to the still-stand periods of the dropping flood level reach, with smallest most recent scrub closest to the contemporary standing water level and oldest/largest mature woodlands up the faint slope. Where these base-rich vertisols are no longer flooded and have become converted to aridosols they are colonized on the raised rims of the gilgai microbasins by mopane, *Colophospermum mopane*.

(7) Basalt and Dolerite Clay Open Grasslands: Like the duplex gleys and tropical vertisols, these clays also exhibit seasonal extremes of soil moisture. The Drakensberg heavy clays on the steep basal slopes have a granular clayey topsoil over a heavier clay subsoil which becomes massive and plastic when wet. In contrast, during the winter dry season, the profile becomes desiccated and compact, any moisture remaining is tightly bound and mostly unavailable to plants. Hence, the woody plant distribution pattern is confined to aerobic, moist sites provided by rock outcrops, or where slumping and incision of slopes occur, or at sinkholes formed by pipe drainage. This vegetation pattern is reinforced by grassfires pruning back the woody plants in the dry season. The clays of the steep basal slopes do not only undergo extremes of soil moisture, but are subject to gravity-induced slip scar formation that relates to their plastic condition when wet. The crescent shaped scars, aligned transverse to slope, are enlarged in winter by frost heaving as the moisture holding subsoil clay is exposed at the scar surface.

(8) Frost & Fire: On the Highveld, as exemplified by the Free State, it is the valleys that are subjected to the lowest winter frost temperatures due to temperature-inversion and cold air drainage. However, this is where the densest woody growth occurs along the incised stream courses that unplugged and replaced the vlei grassland systems. The early ideas that frost and/or fire are the cause of treeless grasslands in the Highveld, are negated by the fact that frost and fire occur in the dry season dormant period, and by the proven evidence of the edaphic controls ("…fire acts mainly in widening the boundaries of open grasslands formed by other causes…" (Michelmore 1939). In Etosha and the Okavango, shrub coppice ("dwarf") mopane occur on the slightly lower ground of unplugged dense grass drainage flats where they are burnt back by black frosts and fire. Abutting such flats on interfluves, that are only some 80 cm higher than the floor of the flats, are tall mopane trees in woodland form with sparse grasses that are rarely burnt.

In Conclusion

These examples of changes in SMB do not of course occur in isolation but within drainage geoecosystem units and tributary sub-unit compartments bound by their watershed divides. Modification of terrain by erosion in one part of a drainage system can eventually effect spreading changes in SMB and hence of the biotic make-up of the entire system both upstream and downstream. Unless they are stabilised these geomorphic processes result in the ongoing demise of upslope wetlands (and topsoil loss in Highveld grasslands for example) enabling the encroachment of woody plants from many sides. Unless re-plugged to restore seasonally high moisture edaphic conditions, most efforts to counter scrub encroachment such as burning, heavy goat browsing, or chemicals, are unlikely to be long lasting solutions. The field evidence indicates that soil moisture balance is the most significant edaphic feature controlling landscape change as it overrides or influences all other factors. This evidence has been derived from nearly six decades of field ecology investigations across Southern Africa, Saudi Arabia and Western Australia with soil profile scrutiny everywhere with the aid of spade, pick and auger.

Typical even-aged patterns of scrub invasion of grassland in response to the baring and drying of the soil, by a vehicle track, fence-line and cattle pad, also on overgrazed paddock at right.

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Invasive scrub initials are one of the first signs that floodplain grasslands are in a drying trend from the breaching (unplugging) of their overflow outlets. This example is of the gilgai soil microrelief pattern. The scrub pioneers are confined to colonising the drier micro-ridges between the micro-basins.

In Memorium

Patricia Berjak
1939 – 2015

Renowned scientist and Vice-President of the Academy of Science of South Africa (ASSAf), Prof Patricia Berjak, has passed away. She was Professor Emeritus and Head of the Centre for Plant Germplasm Conservation Research in the School of Life Sciences at the University of KwaZulu-Natal, where she worked for most of her distinguished 40-year academic career. Prof Berjak had been a long-serving member of the ASSAf Council since 2006 and was elected Vice-President in 2008. She was a loyal and dedicated Council member, serving the Academy in various capacities, most recently as the Chair of the Human Resources Committee of Council. She will be sadly missed by her fellow Councillors, who will miss her incisive intellect and commitment to the values of the Academy. She was a world leader in the study of seeds and achieved significant success in her career. She obtained a BSc degree at the University of the Witwatersrand in 1962 and graduated as a biochemist before doing a Masters degree in medicine. She became a cell biologist focused on seed biology after being introduced to seeds and electron microscopy by the biologist-tutor Trevor Villiers in the late 1960s.

Prof Berjak's research was widely acclaimed. She was an elected Member of ASSAf, a Fellow of the University of KwaZulu-Natal, the Royal Society of South Africa, and of The World Academy of Sciences (TWAS). In 2001 Prof Berjak was awarded the Silver Medal of the South African Association of Botanists for research excellence. In 2004, she received the Department of Science and Technology's Distinguished Woman Scientist Award for consistent contributions to science. This was followed by the award of the National Order of Mapungubwe (Silver) in 2006 and then the National Research Foundation's Lifetime Achiever Award in 2008. Most recently, in 2010, she was honoured by the eThekwini Municipality (Durban) with its Living Legends award for her seed science research.

Over and above her awards, Prof Berjak has been an inspiring and generous role-model and mentor to a whole generation of women scientists locally and globally.

Together with her husband and fellow scientist, Prof Norman Pammenter, Pat Berjak has supervised generations of South African students, many of whom have carved out distinguished careers for themselves. ASSAf extends its sincere condolences to Prof Pammenter on the passing of his life partner of almost 50 years.

New and Resigned Members

New Members

Christie Rheeder- Western Cape Dept of Agriculture
Clinton Carbutt - Ezemvelo KZN Wildlife
Halcyone Muller - Conservation South Africa
Khululiwe Ntombela - Agricultural Research Council
Luke Gallant - Agricultural Research Council
Natalie Uys - Northern Cape Department of Environment and Nature Conservation
Sindiso Chamane - University of KwaZulu Natal
Siphiwe Lutibezi - Polytechnic of Namibia
Livhuwani Nevhufumba - Limpopo Department of Agriculture
Mulalo Munyai - Limpopo Department of Agriculture
Olga Kupika -UNISA
Robyn Nicolay - Hygrotech SA
Warren Beets - Guardian Wildlife cc

Resigned Members

Annamarie van Heerden - McGregor Museum
Antonia Bezhuidenhout - Gauteng Department of Agriculture
Brent Corcoran - Mondi
Doreen Atkinson -
Ernst Penzhorn - Penzhorn Attorneys
Hugo Bezuidenhout - Sanparks
Izak Smit - San parks
Jakes Jacobs - Retired.
John Clatworthy
Mark Berry - Mmabolela Estates
Mark Robertson - University of Pretoria
Roger Uys - Ministry of Environment - New Zealand
Serf Serfontein - Serfontein Seedlings
William Pringle - Farmer
Wolfgang Kanz - Afzelia Environmental Consultants