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Grassroots
Newsletter of the Grassland Society of Southern Africa

Publication Editor: Pieter Swanepoel
pieters@elsenburg.com
Tel: +27 44 803 3726
Assistant Publication Editors:
Janet Taylor
Keletso Mopipi

Administrator: Freyni du Toit
Admin Assistant: Lisa-Maré Pyper
Layout & Design: Cathrine Versfeld

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Editor's Note

Welcome to this issue of Grassroots! After many years of research, the debate about global warming and climate change is still as heated as ever. Global warming may significantly alter ecological processes in grasslands and agro-ecosystems. Since global climate change can vary local environmental conditions the effect of climate change on grasslands will be region-specific. Changing rainfall patterns, atmospheric CO_2 concentrations and ambient temperatures are some of the expected factors influencing large areas of Southern Africa.

Will these new environmental conditions change the species composition and production potential of agro-ecosystems or natural rangeland? This is an important yet controversial question to ask, since the new environmental conditions may affect plant survival and reproductive output. This issue of Grassroots contains many informative news articles about global warming. The two articles on the role of CO_2 in changes on the African savanna are especially thought-provoking. It is satisfying to see projects and training opportunities for a climate-resilient future in Southern Africa.

You will also find two very interesting feature articles in this issue, one on annual legume seedling and seed populations in commercial crop-pasture systems in the agro-pastoral region of the Western Cape and the second on increasing effectiveness of rangelands and the lessons we can learn from wild herbivores.

The 48th Annual Congress was most successful. Congratulations to the organizing committee for a job well done! Various new concepts were explored and debated and young scientists were exposed to a wealth of experience within the Society's membership.

Pieter Swanepoel

Fires Burn more Fiercely as Northern Forests Warm

Dylan Walsh
(Environment 360 Reporter)

From North America to Siberia, rising temperatures and drier woodlands are leading to a longer burning season and a significant increase in forest fires. Scientists warn that this trend is expected continue in the years ahead.

When the wildfire reached Jon Cummings' backyard last summer, it had already traversed 50 miles of rugged terrain in Idaho's Salmon-Challis National Forest. Thick smoke dimmed daylight and embers sailed on hot currents. While fire-fighters were able to preserve Cummings' house and property, his neighbours up the river were less fortunate. "No houses burned, but when those folks came home it was a total moonscape," he said. Wildfires last summer burned more than 3.6 million hectares across the U.S., predominantly in the West and Southwest. Only two other times in the past 50 years have fires burned so extensively: first in 2006, then again in 2007. Twice more in the last decade fires fell just short of claiming this much acreage. Increasingly, forestry experts say this ominous trend bears the fingerprints of climate change: As average air temperatures rise and water evaporates more rapidly from vegetation and soil, the parallel rise in precipitation needed to offset these changes has not kept pace. Most models predict the deficit will only worsen in years to come.

"The initial signs of climate change — they're here," says Amber Soja, a senior research scientist at NASA who studies the interaction of fire and climate. "We have evidence in our wildfires."

In the Rocky Mountains, reduced snowpack in winter, earlier melting in spring, fewer inches of rainfall, and warmer autumns are all contributing to a fire season that has lengthened by nearly 80 days in the last three decades, researchers say. The duration of individual fires has also jumped, from an average of one week to five weeks. Anthony Westerling, a fire specialist at the University of California, Merced, and an expert on fires in the U.S. West, notes that intensifying aridity in the Rocky Mountains as the region warms will exacerbate the problem. "There is going to be a huge percentage increase in burned area that we've only just begun to see," he said.

Similar changes are emerging around the world, researchers note, most notably in the boreal forests that stretch across the northern latitudes from Alaska east through Siberia. In Canada, the average amount of land burned annually by wildfires has doubled since the 1970s, according to Mike Flannigan, a professor of wildland fire at the University of Alberta.

"And we expect another doubling to quadrupling of fire over this next century," said Flannigan. "We attribute this — and I'll be quite clear — to human-caused climate change."

In Russia, where Soja focuses her research, the figures have also ratcheted up. A bad fire season now burns tens of millions of acres. Just last year, a record 30 million hectares were consumed by wildfire, largely in the taiga of eastern and central Siberia. "It's about time we change our definition of normal, because there is just so much burning in Russia," she said. But growth in the number of acres burned is not all that defines wildfire severity. Of equal concern is the depth to which many fires now reach, pushing farther underground into parched soils.

This is especially problematic in the boreal forests, which store more than 30 percent of the world's terrestrial carbon, much of it bound in peat bogs — essentially carbon-rich mosses that have accreted, layer upon layer, over millennia. As these bogs dry out and become more flammable, wildfires bore farther down, releasing much more carbon than a conventional forest fire.Flannigan pointed to a 2002 study of particularly severe peat fires in Indonesia in 1997 that released the carbon equivalent of an estimated 20 to 30 percent of that year's global greenhouse gas emissions. "But the peat Boreal forests could be contributors to global warming rather than mitigating forces against it. reserves in the boreal dwarf those of Indonesia," he said. "If these go, emissions from the Indonesian fires would be a drop in the bucket."

These changing conditions put northern forests at risk of being transformed from repositories, or sinks, of carbon, to overall sources of CO_2. The forests would then be contributors to global warming rather than mitigating forces against it. The shift from carbon sink to source has already been documented in British Columbia: A 2008 analysis published in Nature concluded that, since 2003, fires and unprecedented tree death from bark beetle infestations had turned almost 388 000 square kilometer of forest in the province — an area the size of Montana — into a source of carbon dioxide emissions. All of Canada's vast forestland now sits precariously on this fulcrum, and may soon emit more carbon than it sequesters, according to the Canadian Forest Service.

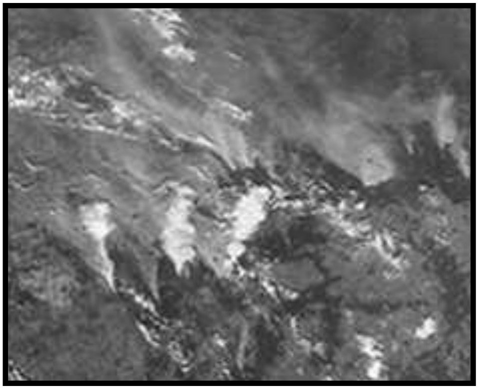
While forest regeneration would normally help to counterbalance these emissions, ecosystem shifts under the pressure of climate change are now casting uncertainty on this cycle. In a process called "green desertification," for instance, grassland steppe across Russia is replacing taiga in the aftermath of severe fires; the standard mix of conifers and hardwoods that constitute the taiga show no signs of returning. "It's likely that the entire 21st century will be dominated by these transition effects," says Westerling, who has observed similar changes in the western U.S. "Places where these fire disturbances are increasing dramatically are going to look very different in the near future." The health effects of severe wildfires also present a growing concern, particularly as populations expand along forest fringes.

Insurance giant Munich Re estimated that particulate matter and "toxic smoke" from Russia's 2010 wildfires, combined with record temperatures, accounted for an additional 56,000 deaths in July and August of that year, most of these in Moscow. And last year a program manager with the Idaho Department of Health and Welfare declared an air quality "crisis" in the small town of Salmon, near Jon Cummings' property. This year, like last, the U.S. Forest Service forecasts persistent drought and elevated fire risks across the western and southern U.S. "We anticipate 2013 to be another challenging year to manage fire," said Tom Tidwell, chief of the Forest Service, in a February 20 memo.

For most of the 20th century, the U.S. Forest Service pursued an aggressive agenda of fire suppression that allowed forest understory — which in earlier eras had been routinely thinned out by fires — to grow thick and fuel more intense blazes. "Forest ecosystems have evolved with fire," explains Keith Konen, a silviculturist for the Forest Service in Montana. "Through 100-plus years of fire suppression this natural process has been altered." In 1995, the Forest Service established a new fire policy, which recognized that "wildland fire, as a critical natural process, must be reintroduced into the ecosystem." Since then, in an effort to remove understory growth, the Forest Service has allowed fires in some federal forests to burn out on their own.
Today, however, climate change has further complicated the Forest Service's job: The agency must oversee the continued use of fuel-culling fires at a time when a warming climate makes controlling these fires riskier, says Scott Stephens, a professor of fire sciences at the University of California, Berkeley. Currently, 26 million hectares of Forest Service land — or one-third of the agency's total holdings — remain at high or very high risk of catastrophic wildfires due to the buildup of fuel. Only a small fraction of this buildup is managed or removed through timber harvesting and fire in a given year.

Under a new planning rule introduced last year, the Forest Service is drawing up management plans for individual national forests that incorporate new science on climate change and fire suppression. Stephens said Forest Service officials are increasingly shying away from mechanical thinning of forests and prescribed burns, in favor of allowing naturally occurring fires to burn in a controlled manner to eliminate thick understory. "Fire management is being funded now to emphasize the resource benefits of lightning fires," said Stephens. He expressed guarded optimism that the Forest Service's new policies will help reduce the severity of fires in the American West. "I think [they] have the potential to get things done at scales that make a difference and reduce the trend of large fires," he said. But other researchers are skeptical. A 2009 study of the boreal forest published in Global Change Biology and coauthored by Flannigan reflects the prevailing sentiment: "There may be only a decade or two before increased fire activity means fire management agencies cannot maintain their current levels of effectiveness," write the authors.

Intensifying wildfires, coupled with austerity budgets that have reduced firefighting capabilities, are a global problem. Soja, the NASA fire expert, said that budget cuts in Russia have led to reduced firefighting capabilities since the early nineties. "It's just not possible for Russia, for the Canadians, to manage these large fires," Soja said. Westerling says that the same may be true of the U.S.



"There may be only a decade or two before increased fire activity means fire management agencies cannot maintain their current levels of effectiveness"

"We just have nothing like the resources you would need to treat these areas on an ongoing basis," he said, referring to the logging, thinning of understory, or controlled burns that can lessen the intensity of forest fires. The Forest Service's fire prevention and suppression funds have been slashed by more than $500 million, or about 15 percent, since 2010. "Fires are simply going to be reintroduced by nature, augmented by climate change," he said. "I think the land's going to burn, and then we'll go from there."

Land Issues

Adopted from: Monitor - A briefing sheet to keep communities informed about what is happening in Parliament

Parliamentary Monitoring Group

The Portfolio Committees overseeing the Departments of Rural Development and Land Reform (DRDLR) and Agriculture, Forestry and Fisheries (DAFF) have, over the last few months, criticised several aspects of the work of these departments. Both committees have cited lack of cooperation from officials and lack of reports, and both have questioned if the departments are capable of delivering on their targets, given lack of capacity and skills, and insufficient monitoring. MPs lambasted DRDLR for promising to attend to redistribution, yet not specifying where and when this was done. DAFF was questioned how it spent 99% of its funds, but achieved only 51% of targets, and MPs demanded full explanations on spending, support to emerging farmers, and seed and tractor distribution. There has been ongoing concern from many committees as to whether emerging farmers are being properly assisted to get access to markets. There is also a wider problem around lack of subsidies to local farmers (particularly when compared to heavy subsidies in other countries) and insufficiently protective import tariff arrangements, which make it cheaper for retailers and food manufacturers to import foodstuffs than to buy from local producers. Parliament has also complained that the Land Claims Commission has only reported once to Parliament since 1994, despite substantial budget allocations being shifted to this programme recently.

Parliament is planning a major campaign in June - which marks one hundred years since the passing of the Native Land Act of 1913 – to highlight the initiatives of the democratic government to reverse the apartheid legacy. All political parties are unanimous on the need to return land to rightful owners. To date, only 8% of the land has been redistributed. South Africa is also under an international treaty obligation to ensure that 17% of its total land estate is put under conservation by 2020. It will not meet this target, nor the target to have 30% redistribution of white-owned agricultural land by 2014.

Although the problems in land redistribution have often been ascribed to the willing-buyer, willing-seller principle, and lack of state money to purchase land, opposition parties have pointed out that substantial land owned by government has not been fully identified and redistributed, which points to state officials not getting to grips with the situation.

Government intends to re-open the land claims process, particularly to allow claims from the Khoi and San people, whose land (and heritage artworks) have been incorporated into farms, and to others who missed the first deadline. However, there is concern whether government will be able to cope with a new influx of claims, particularly since past experiences showed a number of fraudulent claims. Provincial legislature meetings, workshops and public meetings on land issues will be held in [June 2013].

In an official report, The Department of Agriculture, Forestry and Fisheries (DAFF) is calling for interventions to cushion farmers and ensure that farm workers and communities will not be left destitute after the recent farm wage increases. The Minister of Agriculture said the disputes resulted from structural shortcomings that included the decline in the number of commercial farmers, farmers consolidating enterprises to maximise profit, an ageing farm population, struggling small-holder farmers, limited support, and diminishing agricultural skills. All of this was exacerbated by the global financial crisis and high internal costs of fuel and energy, as well as government's minimal support to the agricultural sector. DAFF is considering new plans to assist smallholder farmers to become commercial farmers, negotiating better rates with LandBank, and working on youth employment. It is discussing with the Department of Labour, whether sectorial negotiations or collective bargaining may be more suitable for farm workers meetings on land issues will be held in [June 2013].

Academies of Science Urge Action on Global Challenges

ASSAf

The Academy of Science of South Africa (ASSAf) is one of 14 national science academies to issue a joint call to world leaders to address two of the most pressing global challenges; drug-resistant infectious agents and driving sustainable development, through the use of science, technology and innovation. The joint statements are intended to serve as recommendations to the forthcoming annual G8 Summit in Northern Ireland in June this year. Drug resistance in infectious disease agents is spreading rapidly and is increasingly posing a global threat to humanity.

The current situation is becoming serious with an increasing incidence of detection of resistance to all known drug treatments, especially amongst bacteria. The statement highlights two examples - the incidence of multi-drug resistance (MDR) in Mycobacterium tuberculosis, which can result in untreatable tuberculosis infection. MDR is rising steadily worldwide. According to a recent WHO report, an estimated 440 000 cases of MDR tuberculosis were notified worldwide in 2011. Furthermore, 84 countries have reported untreatable tubercular infection.

The second example is that of common bacterial infections caused by Enterobacteria in hospital settings. Carbapenem-resistant Enterobacteriaceae (CRE) infections are on the rise, and have recently become resistant to 'last-resort antibiotics'. These bacteria are an increasing cause of mortality in many countries. According to a WHO Report the "world is heading towards a post-antibiotic era in which many common infections will no longer have a cure and once again kill unabated".

The resistant organisms are often very difficult to treat. They impose great health risks to individuals and significant costs to society. The academies recommend several actions to reduce the burden of drug resistance to improve global health and to enhance economic well-being.

- Information and education programmes on a more responsible approach to drug prescription for human use.
- Promote integrated global surveillance systems.
- Encourage pharmaceutical companies to develop new antimicrobials.
- Equip developing countries to be a partner in the fight against emerging antimicrobial drug resistance.

In the statement Driving Sustainable Development: the Role of Science, Technology and Innovation, the academies set out perspectives on how science technology and innovation can play a role in ensuring sustainable development against a growing world population, projected to reach 9 billion by 2050. Challenges that are being globally faced are demographic changes, growing urbanisation and providing for the needs of 9 billion people. The wellbeing and social contributions of a growing number of elderly people require special attention and innovations will be necessary if advanced healthcare and valuable societal roles for all are to be provided. The strains brought about by unplanned urbanisation, such as adequate housing and sufficient resources like water, energy sanitation, transport, health care and waste disposal, will likewise require investments in research, innovative new approaches, as well as behavioural changes.

While emphasising the need for action by governments to ensure water availability and adequate nutritious food, the academies call for a range of clean, renewable energy options to provide energy without unacceptable environmental impact. The academies recommend universal promotion of literacy, especially among women, and refer to inquiry-based education as a promising approach to improving education systems.

The statement underscores the role academies of science can play in promoting science, technology and innovation. They, inter alia, pledge to:

- Provide a source of independent, objective expertise, bringing scien tific rigour to gathering evidence, including what is known and not known, which ultimately underpins progress towards sustainable devel opment.

- Collaborate across academies to raise visibility and capacity to pro actively engage with the sustainable development policy community at national, regional and international levels.

- Promote multidisciplinary research for a holistic approach to sustainable development, including engagement with the private sector.

- Improve public awareness of the role of science, technology and in novation can play in promoting sustainable development.

Global Warming: Man or Myth?
Climate Change Impact on Grasslands & Savannas

According to the IPCC (2007), temperate grasslands are important for maintaining soil stability and carbon storage and they also provide food for wild and domestic animals. Tropical savanna systems possess significant wild animal diversity that supports tourism revenue and subsistence livelihoods (food, medicinal plants, and construction material), in addition to cultural, regulating and supporting services. These ecosystems appear to be more sensitive to climate change than previously thought. Ecosystem function and species composition of grasslands and savanna are most likely to be impacted by changes in precipitation and by warming in temperate regions while in tropical systems, CO_2-fertilization and fires will be very important controlling factors. Unfortunately, there are very few studies that assess ecosystem responses to these various factors and experiments on warming, rainfall change or atmospheric CO_2 level are virtually absent in savannas. Most ecosystem studies are confined mainly to temperate grasslands (IPCC, 2007). The IPCC (2007) describes the following impacts:

- Rainfall change and variability is very likely to lead to a reduction in cover and productivity in the southern African savanna in response to the observed drying trend of about 8 mm/yr since 1970.

- Large-scale changes in savanna vegetation cover may also result in a feedback to regional rainfall patterns. Modelled removal of savannas from global vegetation cover has larger effects on global precipitation than for any other biome and, in four out of five savannas studied globally, modelled savanna-grassland conversion resulted in 10% lower rainfall, suggesting positive feedback between human impacts and changing climate.

- Canadian grasslands stored roughly five times as much carbon in a year with 30% higher rainfall, while a 15% rainfall reduction led to a net carbon loss. Similarly, Mongolian steppe grassland switched from carbon sink to source in response to seasonal water stress.

- Trees and shrubs show higher CO_2 responsiveness than do herbaceous forms. Savannas may thus be shifting towards greater tree dominance as atmospheric CO_2 rises, with diminishing grass suppression of faster-growing tree saplings. Climate change impact studies for savanna and grassland fauna are few. The proportion of threatened mammal species may increase to between 10% and 40% between 2050 and 2080.

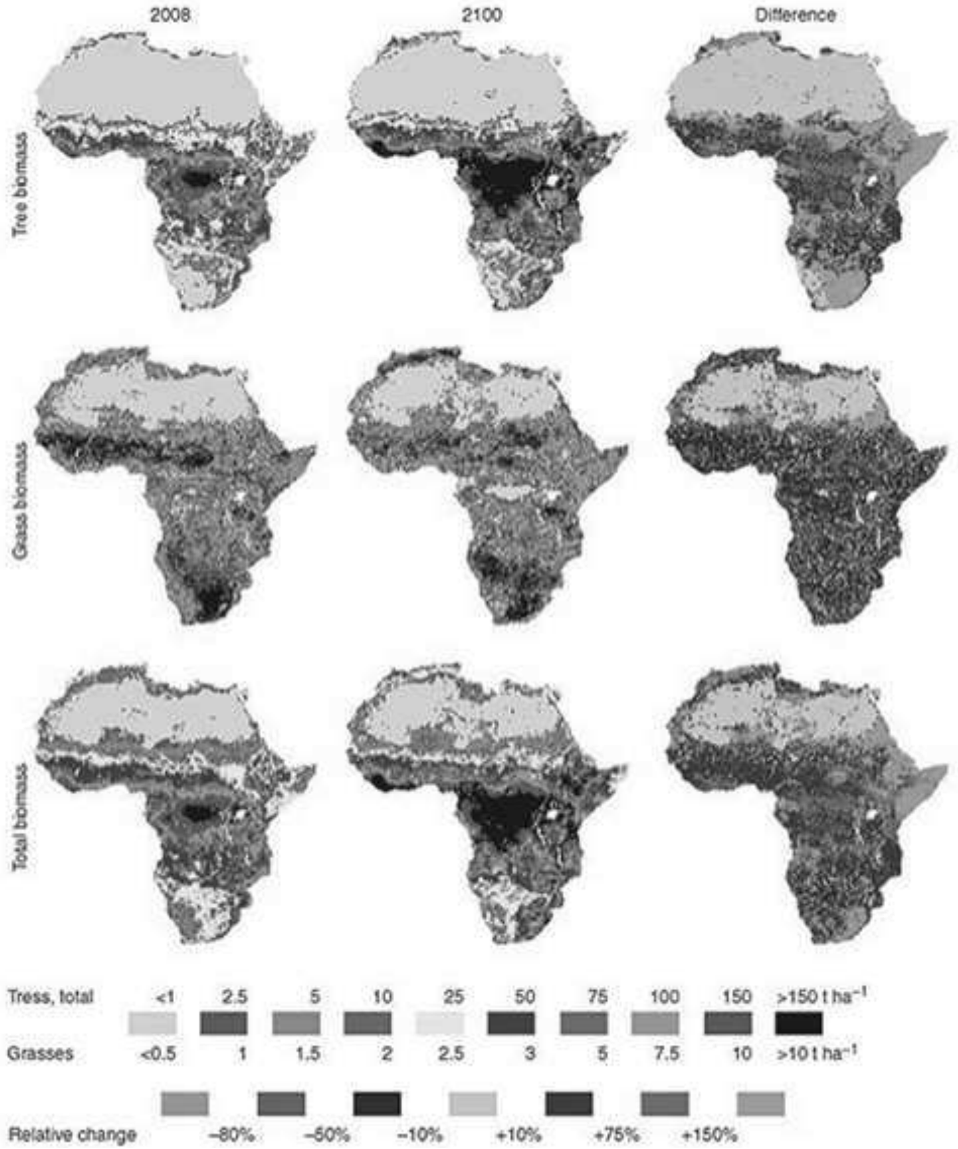
According to Scheiter and Higgins (2009), African savannas are characterized by C_4-grasses and C_3-trees. An increase in CO_2 might favor trees over grasses due to potentially larger benefit that C_3-plants would gain over C_4-plants (IPCC, 2007). On the other hand, an increase in temperature would increase rates of C_4-photosynthesis, C_3-photorespiration and evaporative demand. Each of these temperature-driven factors might directly (or indirectly by promoting fire) favor grasses (Scheiter & Higgins, 2009).

The authors presented a new vegetation model, the adaptive dynamic global vegetation model (aDGVM) specifically developed for tropical vegetation, to simulate the vegetation patterns of Africa in the year 2100 under projected increasing CO_2 levels. Simulations under elevated temperature and atmospheric CO_2 concentrations predicted longer growing periods, higher allocation to roots, higher productivity, more biomass and a dramatic shift toward tree dominated biomes. As shown in the figure below, the model predicts that large parts of today's savannas will be replaced by deciduous woodlands under elevated CO_2 conditions. It is predicted that 34.6% of today's grasslands are transformed into savannas and 45.3% of today's savannas are transformed into deciduous woodlands. The fraction of deciduous woodlands is predicted to increase by 13.2% to 26.9% while the savanna biome is predicted to decrease by 6.1% to 19.7%. The total biomass stored in each of the biomes increases, with high relative changes in grasslands and savannas (by 256% and 241%, respectively). The absolute changes are 420 Pg for savannas, deciduous woodlands and evergreen forests. These changes together imply that the total carbon stored in trees in Africa increases from 74.9 Pg in 2008 to 151.7 Pg in 2100, a difference of 76.8 Pg. (Note: 1 Pg = 1 billion metric tons)

The authors are also careful to note that their study considers the influence of climate on vegetation while it does not account for the fact that vegetation modifies the climate. It is known that the feedbacks between climate and vegetation might significantly influence vegetation. According to the IPCC (2007) modelled removal of savannas from global vegetation cover has larger effects on global precipitation than for any other biome and, in four out of five savannas studied globally, modelled savanna-grassland conversion resulted in 10% lower rainfall, suggesting positive feedback between human impacts and changing climate.

According to the IPCC (2007) the proportion of threatened mammal species may increase to between 10 and 40% between 2050 and 2080 due to the changing savanna and grassland regimes in Africa. Changing migration routes especially threaten large, hoofed animals and their predators. Observed population declines in three African savanna hoofed species suggest that summer rainfall reductions could result in their local extinction if climate change trends continue.

According to The State of the Birds 2010 Report on Climate Change (2010): "Climate change is expected to exacerbate declines in birds that already have declining populations, and several now-common birds will probably be added to concern lists in the near future unless additional conservation measures are taken." Grasslands in the United States are expected to get warmer and drier which will impact many bird species. For example, the desert southwest and northern Mexico Chihuahuan Desert grasslands may become too warm and dry for bird species that typically winter there. "Six species stand out as especially vulnerable. Sharp-tailed Grouse and Lesser and Greater prairie-chicken are less likely than other grassland birds to move in response to changing conditions because they are closely tied to their leks where males display to attract females. Wilson's Phalarope, Bobolink, and Dickcissel are long-distance migrants that may not be able to adapt quickly enough to changing conditions. Although most grassland bird species appear able to move in response to environmental changes, Christmas Bird Count data show that grassland birds were the only group of birds that failed to shift north during the past 40 years in response to warmer winter weather. Perhaps they did not shift because the quality of remaining grasslands in the north is too poor to sustain additional birds" (Ibid).


2008
2100
Difference
Tree biomass
Grass biomass
Total biomass
Tress, total
<1
2.5
5
10
25
50
75
100
150
>150 t ha⁻¹
Grasses
<0.5
1
1.5
2
2.5
3
5
7.5
10
>10 t ha⁻¹
Relative change
−80%
−50%
−10%
+10%
+75%
+150%

Journal News

Susi Vetter
Rhodes University
s.vetter@ru.ac.za

I took over from Peter Scogings as Editor-in-Chief of the African Journal of Range & Forage Science in 2008 (first as acting editor, and from 2009 as the new editor) at a time when many of his efforts were bearing fruit, including indexing in the Thomson ISI Journal Citation Reports and an online submission system. To those of us working with the journal on a daily basis, the time before these improvements seems like a distant and archaic memory. I joined the team as assistant editor in 2003, by which time email had thankfully replaced submissions by hardcopy and "snail mail", but the endless exchanges (and mushrooming folders) of emails, and record keeping in spreadsheets, seem hopelessly antediluvian by comparison with the slick system and good support we have now. For the record, I am thankful every time I do my editorial duties for how much easier my job is than that of my predecessors!

Of course it isn't just technological advances that make the job easy, and I have a fantastic team to thank for their contributions. First in line (as so often) is Freyni du Toit, our journal administrator, who holds it all together, never loses sight of the big picture, manages to nag and remind tardy authors, reviewers and editors in the nicest possible way, and just generally is the "person behind the scenes" without whom things just wouldn't happen. Our Associate Editors are a strong team and do sterling work – thanks to all of you for ensuring a fair and stringent review process. Robert McKenzie, our publishing editor at NISC, is responsible for the finished product and has been a pleasure to work with. And, of course, nothing of this would be possible without the authors who support us by choosing the journal to publish their work. I guess it is becoming obvious where this is going... thank-you speeches seldom come without a catch! Now that the "new era" is in full swing, it is time to hand on the baton.

Not that I am fatigued or fed up or otherwise keen to call it quits, but increased work responsibilities in my department will make it impossible for me to keep up the journal editing. I am very pleased that we have managed to recruit James Bennett as our new Editor-in-Chief, who will take over from July. For those of you who don't know him, James is a Senior Lecturer in Environmental Studies at Coventry University in the UK. He did his PhD research on small-scale cattle production in the Eastern Cape, where he was affiliated with the University of Fort Hare.

Much of his ongoing research is done in South Africa, where he spends regular periods doing field work. So apart from being familiar with the (South) African research context, he will bring an international perspective to publishing our journal which will hopefully help it grow and flourish. He has been part of the team as an Associate Editor and is currently guest editor of a special issue, and his broad range of expertise – covering ecological, agricultural and social aspects of rangelands, from common property management to experimental design and statistical analyses – has proven extremely valuable.

I have greatly enjoyed my ten years working with the journal and have seen it grow from strength to strength. The profile of the journal has been increasing, thanks to ISI indexing and improved marketing by our publishers, and our impact factor has grown from a humble 0.25 in 2011 to a more respectable 0.6 in 2012. With increasing submission rates and some exciting special issues in the pipeline, we expect this trend to continue, and we are aiming to achieve a profile comparable to other international rangeland journals. This will only happen if we publish good quality work and our papers are cited - so please make use of the journal as a resource in your research, cite papers from the journal where relevant, and of course keep in mind the African Journal of Range & Forage Science when next you write up a piece of exciting research!

Look out for Issue 30-1&2 (July 2013), which is a special issue on "Aligning policy with the socio-ecological dynamics of rangeland commons" guest edited by James Bennett. This will be launched at the Congress in Modimolle and will feature our new cover design!

Susi Vetter

The SA Risk and Vulnerability Atlas GeoSpatial Database

Wim Hugo
SAEON

The South African Risk and Vulnerability Atlas is complemented by a GeoSpatial Database (data portal) that is based on internationally adopted standards for data and meta-data management. The data portal supports multiple use cases identified in the development phase, including the ability of registered users to contribute their own content, and control the visibility and publication life cycle of their content.

Several content types are supported. These include simple file uploads and user-controlled web page development in addition to data uploads, meta-data definitions, blogs, news events and complex map or atlas creation. This allows collaboration, sharing and content composition facilities for the distributed creation and management of value-added themes, discussions, community pages, and more.

User community

Registered users at present include theme convenors and their collaborators, but these will soon be extended to include the wider Risk Atlas community, particularly in the emerging regional Risk and Vulnerability Assessment Centres. The infrastructure forms part of a shared platform that also hosts the data portal of the South African Environmental Observation Network (SAEON), the South African Earth Observation System of Systems (SAEOSS), the BioEnergy Atlas for South Africa, and prototype International Council for Science (ICSU) World Data System components for Africa.

The platform is based on a shared and aggregated meta-data repository capable of accepting and working with a range of well-established meta-data standards. These include Dublin Core, SANS 1878, the ISO 19115 family, EML, and FGDC. The list is likely to be extended from time to time to accommodate other standards in widespread use by a user community or new data provider, and should in future include standards widely in use in the earth and environmental observation community. One of the major benefits of this arrangement is the synergy of collective meta-data gathering and maintenance. The basic functionality allows users to search for and visualise or download data in a variety of supported formats, and these components are flexible enough to be customised for inclusion into multiple locations in the portal, as well as in external systems, delivering either open search capabilities or predefined search results to augment, for example, themes within the Atlas. Users can filter and analyse the search results to better understand the availability of data for a given topic, time period, and/or spatial extent.

International stakeholder community

The platform now also links the shared meta-data repositories contributed by South African initiatives to the Group on Earth Observations (GEO) through the GEOSS broker, exposing data sets and resources to an international audience. In broad terms, the platform and its hosted portals are designed to serve a stakeholder community as a resource for the referencing, description, discovery, management and optional archiving of relevant data sets and information objects. It also allows the composite visualisation of distributed data sets, provided that access to these sets is automated and standardised - creation of distributed maps, charts and table representations of data. The platform is currently hosted by SAEON in Pretoria, and a mirror site for test and development has been deployed to the Centre for High Performance Computing in Cape Town. The software is based on Plone, an open source content management system that has been extended to cater for the special data types required by the Atlas.

Additional visualisation tools for map and chart representations were also developed, as well as wizard-driven interfaces for map creation and data uploads.

Current and future developments include:

An ongoing programme to add new data providers and meta-data sources; Development work to accommodate large image collections, SensorWeb data downloads and visualisations, and NetCDF data sources; Implementation of distributed Web Processing Services; Implementation of 'mediation' technology, whereby distributed visualisations and processes can be persisted for future re-use; Automated linking to, and integration with online data publishing initiatives, such as DataCITE; Measures to allow remote authentication into data provider sites; and mechanisms to support data providers with detailed, service-based usage metrics of their data and meta-data.

Typical search results and analysis of search results

Using the GAP application for the SA Risk and Vulnerability Atlas

Elsona van Huyssteen and Johan Maritz
CSIR Built Environment

The Geospatial Analysis Platform (GAP) was developed by the CSIR as an evolving and collaborative initiative (in partnership with The Presidency and the Department of Trade and Industry) to support the South African planning and policy environment.

GAP can be described as a common mesoscale geospatial platform for the assembly, analysis and sharing of strategic information (e.g. demographic, economic, development and demand information). It was essentially developed to make information (map themes) available offline to provide information about:

- what is where;
- how much there is;
- where the main concentrations/hot spots are to be targeted; and
- what can be reached from where.

The application has proved its worth in packaging planning-relevant economic and environmental information, used among others by the Limpopo Economic Development Environment and Tourism Department (LEDET).

User-friendly interface

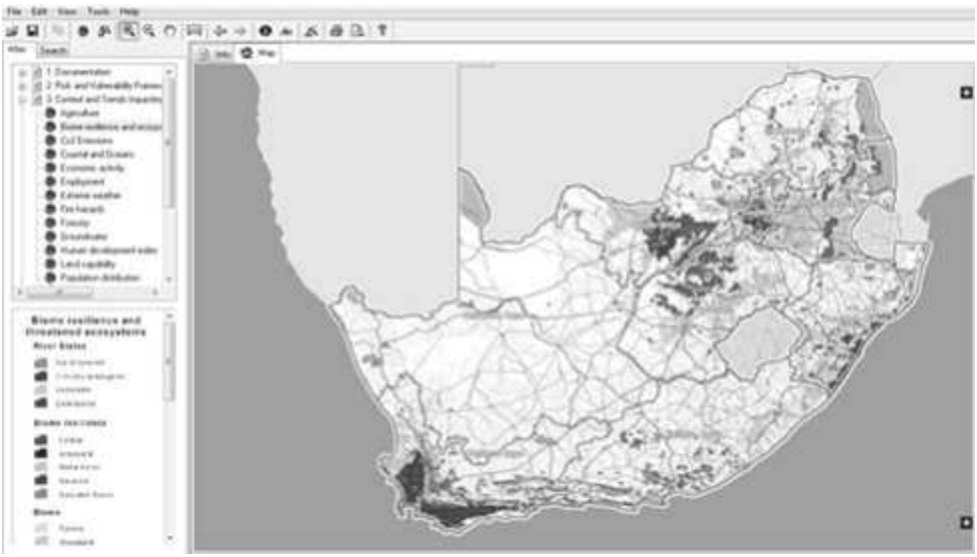
GAP serves as a user-friendly interface that displays the maps, themes as well as other non-spatial content (thus operating like a GIS data viewer). The application was recently customised to meet the needs of the Department of Science and Technology's South African Risk and Vulnerability Atlas. In addition, the South African Risk and Vulnerability Atlas toolbox includes a number of resources that offer insight into global change information, including non-spatial and more comprehensive spatial data for all user types.

The South African Risk and Vulnerability Geospatial Analysis Platform (SARV-GAP) provides an interface that easily displays a range of analyses and information that can be used by planners and decision-makers to contextualise, explore and identify risk and vulnerability of settlements and communities at municipal and regional scales.

SARV-GAP responds to questions posed by a range of municipal and other stake-holders, including:

- What are some of the most critical global change trends facing South Africa and the respective regions?
- Where are different impacts expected to be felt as a result of these changes and what are the associated risks and vulnerabilities?
- Where are the areas and communities that are potentially most vulnerable to a range of risks and hazards?
- Where are the main focus areas and priority intervention areas to be considered and integrated into disaster management, as well as integrated development planning, land use management and spatial planning processes and plans?

SARV-GAP has been developed primarily with planners and decision/policy-makers in mind. However, this tool would also potentially be useful to individuals interested in developing a better understanding of, and identifying global change risks in South Africa and at sub-national levels, including researchers, analysts, consultants, students, businesses and NGOs.



GAP Application Interface

Integrating Climate Change into Municipal Development Planning

Miriam Murambadoro
CSIR Natural Resources and the Environment

The rollout of the Let's Respond toolkit kicked off with several introductory workshops coordinated by the South African Local Government Association (SALGA). In these workshops, role-players from private and public institutions as well as universities shared the work they are doing in collaboration with local governments. The South African Risk and Vulnerability Atlas (SARVA) team was among the role-players taking part in the Lets' Respond toolkit and Guide Climate Change seminars.

Key global change issues in North West

SALGA's North West Climate Change seminar was held at Orkney. The seminar was attended by local government councillors as well as planning and environmental officials from the province. Key global change issues of concern in the North West Province include fragmented urban sprawl, which is straining bulk infrastructure. There is also an extensive occurrence of alien weeds and plant species. The Southern African Plant Invaders Atlas showed that Mafikeng alone had up to 31 alien species. Alien invasion results in replacement of biologically diverse systems with single (or mixed) species stands of aliens and alteration of hydrology. It also poses a threat to indigenous fauna.

The climate change seminar was followed by another training workshop at the SALGA offices in Pretoria. This workshop was attended by local government officials from Emfuleni, Amathole, Thulamela, Thabo Mofutsanyana District Municipality, Western Cape Department of Environmental Affairs, Vhembe District Municipality, Mangaung, Ngwathe Local Municipality, Setsoto Local Municipality, Matjhabeng Local Municipality, Free State Department of Co-operative Governance and Traditional Affairs (DCOG) and North West local government and traditional affairs.

The main objectives of the workshop included training relevant municipal staff and provincial/district government representatives from SALGA, the Department of Environmental Affairs and DCOG on how to use the toolkit to enhance municipal capacity to integrate climate change response in Integrated Development Plans (IDP) and allocate financial resources towards development projects through the regulated IDPs.

The training session was also used as a platform for learning and exchanging knowledge between municipalities and provincial/district representatives to contribute best practices for a nationwide rollout of the toolkit.

A toolkit for change

The Let's Respond toolkit seeks to assist municipalities to prepare and plan for changes in climate by providing them with the necessary steps and a set of tools to identify communities and sectors that are at risk and to explore opportunities to increase resilience. The toolkit also seeks to integrate climate change into an existing planning process rather than create a separate process altogether, given the human capital and financial constraints at municipal level. Local governments are at the helm of service delivery and also play a key role in protecting the country's social, economic and environmental assets.

However, climate change and unforeseen changes make resource management and infrastructure planning more difficult as a result of increased extreme events such as floods and droughts, runaway fires which damage infrastructure and livelihood assets, putting strain on livelihoods and increasing local government's expenditure on disaster recovery projects. The South African Risk and Vulnerability Atlas is a tool that seeks to provide local governments with all the relevant climate change information which can be integrated into their planning process so as to build their community's resilience as they strive towards sustainable development.

The Let's Respond toolkit assists municipalities to prepare and plan for changes in climate.


During the climate change workshop, participants from GIZ, Amathole District Municipality, Sustainable Energy Africa and the South African Risk and Vulnerability Atlas discuss global change issues of concern in the Amathole District.

Climate Variability, Climate Change and Global Warming
The Difference Explained

Climate variability refers to variations in climate on all spatial and temporal scales beyond that of individual weather events. This variability may be caused by natural internal processes within the climate system (so-called *internal variability*). Variations may also be caused by external influences which may be due to naturally occurring phenomena (such as periodic changes in the earth's orbit around the sun) or anthropogenic causes (IPCC 2007). One of the most important (and widely known) examples of natural climate variability is the El Niño-Southern Oscillation (ENSO).

Climate change refers to a change in the average weather experienced in a particular region or location. The change may occur over periods ranging from decades to millennia. It may affect one or more seasons (e.g. summer, winter or the whole year) and involve changes in one or more aspects of the weather, e.g. rainfall, temperature or winds. Its causes may be natural (e.g. due to periodic changes in the earth's orbit, volcanoes and solar variability) or attributable to huma (anthropogenic) activities, e.g. increasing emissions of greenhouse gases such as CO_2, land use change and/or emissions of aerosols. In contemporary society the term 'Climate change' often refers to changes due to anthropogenic causes. When changes in climate occur, they directly impact livelihoods, food security and potentially how societies, economies and political systems function.

Global warming refers only to the overall warming of the Earth, based on average increases in temperature over the entire land and ocean surface. It is important to note that climate change is more than simply an increase in global temperatures; it encompasses changes in regional climate characteristics, including temperature, humidity, rainfall, wind, and severe weather events, which have economic and social dimensions.

*Source: The Climate Risk and Vulnerability Handbook for Southern Africa

After years of continuous heat the earth was incubated and the monster of global warming broke free.

The Seed Industry as Vibrant as Ever

With 1583 participants, the 2013 ISF World Seed Congress in Athens, Greece celebrated a new record. From all continents the seed industry came together to meet in sunny Athens. The Congress provided an excellent venue for seedsmen and seedswomen to converse, learn, network and do deals. At the Opening Ceremony Mr. Tim Johnson, President of ISF underlined that ISF is a strong believer in the benefits of global movement of seeds to improve grower success around the world. Mr. Marcel Bruins, Secretary-General of ISF highlighted that in recent years services to ISF members had gone up, while the congress registration fee had gone down.

The technical meetings during the Congress were an opportunity for the industry to promote and share best practices; they acted as a forum for debate and to receive the latest updates. ISF's main goal is to facilitate the international seed trade, and from that angle, delegates saw a high level line up of speakers from the international arena on the recent developments: the Commission on Phytosanitary Measures, the Nagoya Protocol, the OECD, the International Treaty on Plant Genetic Resources for Food and Agriculture, the International Seed Testing Association, the Global Crop Diversity Trust and the International Plant Protection Convention. All these organizations have a potential impact on the seed industry, and ISF had contributed to shaping them.

Intellectual property and its enforcement were center stage during the Forage and Turf Section meeting. The participants got interesting updates from UPOV and Breeders Trust. A panel discussion led to animated discussions in the meeting of the Field Crops Section. The panellists discussed the outcome of the ISF publication "Collection Systems for Royalties in Wheat – An International Study". The importance of the Incoterms® was underlined in the meeting of the Trade and Arbitration Rules Committee, and the Seed Applied Technologies Committee dedicated ample time for a presentation on the Compass report, outlining the socio-economic value of neonicotinoids seed treatment.

The Vegetable and Ornamental Section saw a change in guard from long standing chairman Mr. Anton van Doornmalen to Mr. Vicente Navarro, and heard interesting presentations on how to do business in China and the SolCAP project. The Dutch ambassador to Greece honored the meeting with his participation. ISF's work on an International Standard for Phytosanitary Measures, specifically for seeds, was an important topic during the meeting of the Phytosanitary Committee.

During the congress, ISF adopted two position papers: the ‘ISF View on Low Level Presence in Seed’ and the ‘ISF Viewpoint on Indirect Seed Health Tests’. Mr. Jean-Christophe Gouache of Limagrain, France, was elected as the new Second Vice-President of ISF. As is tradition, the Trading Floor was buzzing with activity, underlining the importance of the ISF World Seed Congress for the international trade. The beautiful venues of the Welcome Party and Gala Dinner gave every one the opportunity to have fun with friends and colleagues. During the closing Gala Dinner, the Greek Minister of Agriculture, Mr. Mr. Athanasios Tsaftaris addressed the audience on the importance of high quality seed and the investment possibilities in Greece. The Congress showed that the Greek seed industry and farmers have experience in the multiplication of seed and can secure high-quality production combined with a high yield. Greece, due to its placement on the map provides an excellent hub for managing business in South Europe.

The next ISF World Seed Congress will take place in Beijing, China in May 2014.

SEED IS LIFE
ISF

GSSA Spekboom Planting Festival at Modimolle/ Waterberg District

Kedibone Chueu, Tshenolo M Mantji, H W Muswubi, Ntuwiseni E Mmbi & Lesego M Bodibe
DAFF - Animal Production
kedibonec@daff.gov.za

The Grassland Society of Southern Africa's 48th Congress Organising Committee (GSSA C48 OC) held a spekboom (*Portulacaria afra*) planting festival at several schools around the Modimolle Municipal district on the 20 March 2012 as a build-up to its coming congress which will be held at Weesgerus in Modimolle (15th to 19 July 2013). The tree planting festival was a follow-up to the tree planting initiative that was conducted by the GSSA's 47th Congress Organising Committees in 2012, in efforts to educate the public about reducing the carbon footprint through planting trees. The spekboom was particularly selected for the Modimolle tree planting festival because of its drought-tolerant and fire-resistant characteristics as the festival was also organised in support of the National Water Week (18th to 24th March).

The Development Bank of Southern Africa (DBSA) donated 50 spekboom trees, with 5 trees given to 10 selected schools in the Modimolle/Waterberg District. However, the tree planting demonstrations which were officiated by representatives from the Department of Agriculture, Forestry and Fisheries, Limpopo Department of Agriculture (Bela-Bela and Polokwane Offices), Limpopo Department of Economic Development (Modimolle Office), were only conducted at the following five schools:

1. Dagbreek Primary School
2. Lekkerbreek Primary School
3. Hector Peterson High School
4. Phahameng High School
5. Solomon Mahlangu High School

Mr. Lombard Moloto, an official from Limpopo Department of Agriculture and a member of Modimolle Schools Agriculture Development Committee (MSADC) welcomed everyone at selected planting spots were learners were assembled at each school. Mr. Moloto also thanked the GSSA for this worthy initiative as it supports the Modimolle greening concept that is promoted by MSADC at schools to celebrate the various environmental days such as National Water week and Arbor day.

MSADC is a local committee facilitating agricultural and environment education at schools in Modimolle. The planting demonstrations commenced by following a structured programme that comprised of brief overview about the objectives of spekboom planting festival (including the GSSA and DBSA involvement on this initiative), brief information about the spekboom tree (i.e. characteristics, planting methods, potential uses, and management requirements) and the actual spekboom planting demonstration.

The planting demonstrations commenced by following a structured programme that comprised of brief overview about the objectives of spekboom planting festival (including the GSSA and DBSA involvement on this initiative), brief information about the spekboom tree (i.e. characteristics, planting methods, potential uses, and management requirements) and the actual spekboom planting demonstration.

At the end of the planting demonstrations, the representatives of the different schools expressed their appreciation to the spekboom festival organisers for selecting their schools and also indicated that they hope this initiative could be extended to other schools in order to promote the planting of spekboom for reducing the carbon footprint.

The GSSA C48 OC requested Mr. Moloto to give the remaining trees to the other selected 5 schools in Modimolle (i.e Modimolle Primary School, Maokeng Primary School, Eenheid Primary School, Laeskool Nyl and Ulando High School).
The spekboom festival was an astonishing success and GSSA C48 OC would like to thank the DBSA, Modimolle schools and everybody who participated at the spekboom tree festival.

The Surprising Role of CO_2 in Changes on the African Savanna

Adam Welz

Recent studies show that many of the world's savannas, including famed southern African landscapes, are experiencing significant change as rising levels of carbon dioxide in the atmosphere favor the growth of trees over grasslands. Africa's savanna ecosystems — which include the thorn tree-studded plains of the Serengeti, the open woodlands of the Kruger National Park, and the dry, red sand savannas of the Kalahari — occupy about 70% of the continent south of the Sahara Desert. And evidence is mounting that these iconic and biodiverse landscapes are changing as rising levels of carbon dioxide in the atmosphere fuel the growth of trees at the expense of grasses, leading to an increasingly wooded landscape.

A 2012 survey of experimental plots in South African savannas — where fires, rainfall, and herbivore pressure have remained constant for decades — shows large increases in woody plant mass, which the authors primarily attribute to the so-called "CO_2 fertilization effect," the enhancement of plant growth caused by increasing atmospheric carbon dioxide. A modeling study published in the journal Nature last year describes a recent, rapid shift in extensive areas of African grassland and savanna to more densely vegetated, wooded states, a trend that is expected to accelerate in coming decades as atmospheric concentrations of CO_2 rise. Already there are signs that open-country animals like the cheetah are suffering as savanna becomes more wooded. This trend is not confined to Africa. An Australian study released last month, which relied in part on satellite data, concludes that foliage cover in warm, arid areas worldwide has increased by about 11% in the last three decades due to higher CO_2 levels. Randall Donohue and colleagues at the Australian national science agency, known as CSIRO, and the Australian National University said that the CO_2 fertilization effect "is now a significant land surface process" shaping ecosystems across large parts of the planet. Guy Midgley, a prominent South African climate researcher who has authored several papers on CO_2 fertilization, said that the increase in arid-zone greening described in the Australian paper is "phenomenal." The study, he said, was a valuable addition to a growing body of evidence that the rising concentration of atmospheric carbon dioxide is directly changing terrestrial ecosystems, independent of temperature increase.

Although some might view an increase in desert plant growth as positive, an expansion of woody vegetation in savannas and grasslands could have serious negative effects, Midgley cautioned.

It could threaten and wildlife populations and water supplies, as trees and shrubs use more water than grasses. It could even amplify global warming, since trees, being generally darker than grasses, can absorb more solar radiation. Savannas can be seen as the result of a battle for living space between grasses and trees that neither side has won, said Midgley, chief director of the Climate Change and Bioadaptation Division of the South African National Biodiversity Institute. Should grasses win the battle, treeless prairies would result. If trees were to win, savanna would become increasingly dense woodland. Many African savannas are found in areas that have sufficient rainfall to support dense forest, but fire and large herbivores, such as elephants, constantly knock back trees, giving grasses space to grow and maintaining a rough equilibrium between the two sides. The "bush encroachment" observed across large swathes of southern Africa in recent decades is an example of the balance between grasses and trees being upset, he says.

In recent decades, across large tracts of southern Africa, ranchers and wildlife managers have been noticing an increase in woody vegetation. Shrubs and trees have invaded grasslands, transforming them into savannas. Savannas have become more densely wooded, sometimes impenetrably so. Anecdotal evidence and time series photographs indicate that this trend accelerated in the 1980s, and by the end of that decade "bush encroachment" was a commonly used term for what was happening in rangelands and wildlife areas across the subcontinent.

Namibia, a generally arid, thinly populated country to the northwest of South Africa, has been particularly hard hit; about 26 million hectares (64 million acres) of the country has been invaded by undesirable woody plants, which smother grazing areas. Because trees use more rain than grasses, they also significantly reduce groundwater recharge and runoff into rivers. The loss of grasslands is one reason the country's beef production is now 50 to 70% below 1950s levels, according to some estimates. Bush encroachment costs Namibia's small economy as much as $170 million per year.

Changes in savannas are also affecting wildlife. Conservationists in Namibia, home to the world's largest remaining population of cheetahs, began finding starving cheetahs with severe eye injuries about twenty years ago. Not only are their plains-antelope prey being crowded out by trees, but cheetahs — which prefer to hunt in open areas where they can exploit their famous speed — are also being blinded by the thorns of woody plants that are taking over the landscape.

Ornithologists studying the Cape vulture, a threatened southern African scavenger, have found that it avoids foraging for animal carcasses over bush-encroached areas. Cape vultures are large, heavy birds that need a long, clear takeoff run to launch themselves into the air. To avoid becoming meals for predators, it seems that vultures simply don't land where the bush seems too dense for them to take off again. The species, once numerous in Namibia, no longer breeds there.

In the 1980s and '90s, the predominant view was that poor land management, especially overgrazing, was the main cause of bush encroachment because trees easily colonize the patches of bare earth created when too many sheep and cattle destroy perennial grasses. Some experts, however, noted that well-managed farms often suffered bush encroachment, too.

Although overgrazing may contribute to bush encroachment, they felt that some greater environmental change was helping woody plants to dominate grasses. In 2000, Midgley joined with William Bond, a University of Cape Town ecologist, to publish a paper proposing a mechanism whereby increased atmospheric CO_2 could favor trees over grasses in their battle for territory in African savannas. In these savannas, grasses are more flammable and more fire-tolerant than trees — they carry fire through the landscape and regrow rapidly after fire, requiring less time (and less water, soil nutrients, and atmospheric carbon) to achieve maturity than trees.

To become established in the landscape, savanna trees have to reach a height of about four meters to avoid having their stems and crowns destroyed by grass-fueled fire. In other words, trees only become established if they're given a break from fire long enough to build sufficiently tall stems to grow well above the flame zone. (Many African savanna trees are not killed outright by fire, but re-sprout from the roots after having their above-ground parts destroyed.)

Past research showed that savanna trees usually take four or more years to reach fireproof height, but most African savannas burn every one to three years, so it's only when there's a been rare, longer-than-normal break between fires that trees can mature. More CO_2 in the air means that trees can theoretically build their carbon-intensive stems and roots longer, thicker, and faster. Bond and Midgley hypothesized that because of this, trees could be growing and re-sprouting faster after fire than a few decades ago when the atmospheric CO_2 level was lower, thus increasing their chances of reaching fireproof height. Then, by out-competing grasses for water, nutrients, and light, trees could dominate the landscape.

More recently, to test if savanna trees do in fact grow faster in increased atmospheric concentrations of CO_2, Bond and Midgley's colleague, Barney Kgope, grew African savanna tree and grass seedlings in chambers that allowed him to vary the CO_2 levels in the air around the plants. The results, published in 2010, are striking. Some savanna trees grown in an atmosphere of 370 parts per million (ppm) of carbon dioxide (a little lower than today's level of 400 ppm) grew more than twice as fast as the same species grown in the pre-industrial atmosphere of 280 ppm of CO_2. Not only were the trees grown at 370 ppm taller than those grown in pre-industrial concentrations of CO_2, they had bigger thorns to protect them from herbivores and far more extensive root systems than their pre-industrial counterparts. They had, in Bond's terms, become "supertrees."

Researcher Donohue said that although the satellite images used in his new Australian study did not distinguish between green grasses and green woody plants, the trends he and his colleagues observed were consistent with a general increase in plant biomass across Africa due to CO2 fertilization. Although some news outlets have reported his study's results as demonstrating an "upside" to climate change because deserts are "greening," Donohue cautioned against this one-sided interpretation. "There will be winners and losers," he said, because increased vegetation in some arid areas may well increase local biodiversity, but may also harm species adapted to less-vegetated habitats. Guy Midgley has a more pessimistic view of atmospheric CO_2's apparently increasing influence. "We [South Africans] like our non-forest ecosystems," he said, noting that aside from the impacts that an increase in woody plants will have on grassland wildlife and livestock ranching, the country's grasslands form watersheds that feed rivers vital to the economy.

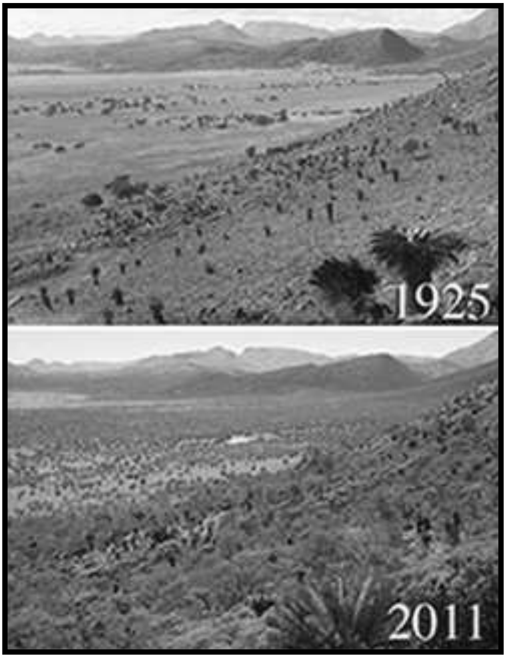
Studies show that water yields of South African grassland catchment areas drop significantly when invaded by alien trees, one reason that the government spends millions of dollars a year to remove them. South African ecologists are trying to figure out how best to stop trees from taking over savannas, perhaps with "fire storms" — controlled fires set on hot, dry days to maximize the heat they generate — or careful tree-thinning. But super-hot fires might have their own negative effects on ecosystems, and manual thinning could be too expensive.

Midgley said that by reaching today's level of 400 ppm of atmospheric carbon dioxide, "we've turned the evolutionary clock back 5 million years in under a century. It's a massive change in how our ecosystems work." He noted that atmospheric CO_2 could hit 600 ppm by 2100, a level last seen during the Eocene epoch of 34 to 55 million years ago, when forests covered nearly all of the planet and long before modern grasses and the large savanna mammals that we know today evolved.

"We're in a brave new world from a plant's perspective," said William Bond. "It's a little frightening. Our plains animals have their backs against the wall." The new invading trees won't do anything meaningful to combat climate change, he said, because they're a negligibly small carbon sink in global terms.

"We've got to stop the problem at source," he said. "We've got to stop burning fossil fuels and sending carbon into the air."

"Wangari Maathai was wrong," he chuckled playfully, referring to the Kenyan environmentalist and Nobel Peace Prize winner who advocated a tree-planting campaign across the continent. "Trees aren't always a good thing."



Changes in South African savanna, from 1925 to 2011.

Meet the Editor

Mr Pieter Swanepoel will be serving on the executive council of the Grassland Society of Southern Africa form July 2013 as Publications Editor. He is a Scientist at the Western Cape Department of Agriculture on the Outeniqua Research Farm near George where he undertakes advanced research for the development of new and adaptation of existing technology in the field of soil quality for pastures, aimed at improving farming efficiency and to transfer technology to the entire agricultural sector. He completed his MSc(Agric) in 2011 on Outeniqua Research Farm under the supervision of Dr Philip Botha, Dr Wayne Truter and Dr Karen Surridge-Talbot. This research was centered around the effects of soil organic matter on effectiveness of symbiotic nitrogen fixation and *Rhizobium* populations in soil. His current research focus is on soil quality for pastures in the southern Cape region and he is in the write-up stages of his PhD on this topic under the supervision of Dr Philip Botha, Prof Hennie Snyman and Prof Chris du Preez. From his research, he has published eight papers in local and international journals, contributed 17 papers or posters at several congresses or symposia and published more than 40 popular articles in local newspapers, magazines and booklets.

Earlier in 2013, he was also appointed Associate Editor of the African Journal of Range and Forage Science.

His mission as Editor is to improve communication between council members and other interested parties by keeping them informed of news, events, publications reports and opportunities in the fields related to Grassland Science. He will also strengthen the connection with the African Journal of Range and Forage Science by publishing brief summaries of accepted manuscripts in Grassroots.

He will be supported by assistant publication editors Janet Taylor from the KwaZulu-Natal Department of Agriculture and Environmental Affairs and Keletso Mopipi from the University of Fort Hare's Department of Livestock & Pasture Science.

New and Resigned Members

New Members

Mr Alois Hlatshwayo, Matopos Research Institute
Ms Angelina Kanduvarisa, Agra Professional Services
Christiaan Harmse Mr, North-West University
Clement Adjorlolo Dr, KZN Department of Agriculture and Environmental Affairs
Dalton Masia Mr, CSIR - Natural Resources and the Environment
Hans Kgasago Mr, Petra Finsch Mine
Jacques Brits Mr, Timbavati Private Nature Reserve
Jenifer Gouza Ms, CapeNature
Johann du Preez Prof, University of the Free State
Linda Luvuno Ms, WESSA
Mabora Thupana Ms, SANBI
Mohau Monyatsi Mr, Bokong Nature Reserve
Nkosikhona Madolo Mr, Fort Hare Dairy Trust
Peter Oosthuizen Mr, KwaZulu-Natal Departement AEA
Rakesh Naik Mr, Plazaboard
Rolivhuwa Morovhi Mr
Support Chavalala Mr, City of Johannesburg Metropolitan Municipality
Tembela Paqula Mr, DAFF - Forest Technical and Information Services
Titus Ramapuputla Mr, Department of Agriculture, Forestry and Fisheries
Tunde Amole Dr, University of Agriculture

Resigned Members

Andries Coetzee Mr, Louwsrust Boerdery
Anthony Mills Dr, C4 EcoSolutions cc
Lutendo Desmond Mr, Malatleng Mining cc
Mamathung Phahlanohlaka Ms, DAFF - Grootfontein ADI
Manie Grobler Mr, Western Cape Department of Agriculture
Wim Landman Mr, Pongola Game Reserve

Recent Publications in the Grassland Science and Related Disciplines

The African Journal of Range and Forage Science now has iFirst which enables rapid online publication of manuscripts accepted for publication in the journal. Rapid online publication of articles dramatically reduces the time that the target audience must wait to see the results of current research. The rapid online publication system further eliminates the problem of the "backlog": accepted but unpublished papers. This is a great asset in many fields, where publishing an article can assure priority of discovery.

AJRFS articles published in this manner lack page spans and can be cited using their DOIs, or Digital Object Identifiers, in addition to the article and journal title, see below. The DOI is a unique number assigned to an article that stays with that article throughout its digital life, allowing researchers to find and reference these articles and to hyperlink to the articles. DOIs are persistent - they will always direct readers back to the definitive version of an article, either the version first published online or the subsequent paginated version in the online journal issue. Once the fully paginated version of the article appears in a volume of the journal, all future citations should be made to the fully paginated version.

All subscribers with online access to the AJRFS can access articles published online (see the 'Latest Articles' tab on the journal home page). These "Latest articles" are later assigned to a particular issue of the journal, given page numbers, and published in final form.

The first two articles to be published using this system by the African Journal of Range and Forage Science are:

The influence of *Pechuel-Loeschea leubnitziae* (wild sage) on grass sward and soil seed bank composition, MJ Tedder*, KP Kirkman, CD Morris, WSW Trollope and MC Bonyongo, doi: 10.2989/10220119.2012.720280, http://www.tandfonline.com/doi/abs/10.2989/10220119.2012.720280

A novel method for estimating tree dimensions and calculating canopy volume using digital photography, AS Barrett* and LR Brown, doi: 10.2989/10220119.2012.727471, http://www.tandfonline.com/doi/abs/10.2989/10220119.2012.727471

Conservation Biology, Volume 26, Issue 6, pages 1156–1158, Toward a More Balanced View of Non-Native Species, Martin A. Schlaepfer, Dov F. Sax, Julian D. Olden, http://onlinelibrary.wiley.com/doi/10.1111/j.1523-1739.2012.01948.x/abstract

Grass and Forage Science, Volume 67, Issue 4, page 606, December 2012, Practical handbook for seed harvest and ecological restoration of species-rich grasslands, Richard G. Jefferson, http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2494.2012.00875.x/abstract

Grass and Forage Science, Volume 67, Issue 4, page 607, December 2012, Grassland productivity and ecosystem services, Alan Hopkins, http://onlinelibrary.wiley.com/doi/10.1111/gfs.12015/full

Restoration Ecology,Volume 20, Issue 6, pages 794–795, Introduction to Restoration Ecology,
Jonathan D. Bakker, http://onlinelibrary.wiley.com/doi/10.1111/j.1526-100X.2012.00921.x/full

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Functional Ecology, Volume 26, Issue 6, pages 1231–1233, December 2012, Community stability does not preclude ecosystem sensitivity to chronic resource alteration, Alan K. Knapp, John M. Briggs, Melinda D. Smith, http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2435.2012.02053.x/abstract

Plant Ecology, Spatio-temporal patterns of tree establishment are indicative of biotic interactions during early invasion of a montane meadow, Janine M. Rice, Charles B. Halpern, Joseph A. Antos, Julia A. Jones, http:/andrewsforest.oregonstate.edu/pubs/pdf/pub4710.pdf

African Journal of Range & Forage Science 2012, 29 (2) : 97–99, Zimbabwe's Land Reform: Myths and Realities, MJ Roodt, http://www.nisc.co.za/oneAbstract.php?absId=4546

Remote Sensing, 4(1), 303-326, 2012, Exploring Simple Algorithms for Estimating Gross Primary Production in Forested Areas from Satellite Data, Hashimoto, Hirofumi, http://www.mdpi.com/2072-4292/4/1/303/htm

Movers & Shakers

Dr Mitsuru Tsubo
tsubom@arc.agric.za

He was previously employed at Tottori University, Arid Land Research Centre in Japan. He has been appointed as Programme Manager (Agro-Climatology) of Agricultural Research Council-Institute for Soil, Climate and Water where he is managing research and development of the Agro-Climatology Programme including the Agro-Climate Weather Station Network.

Member Profile

Jenifer Gouza
CapeNature
jgouza@capenature.co.za

Jenifer Gouza is a Programme Manager within the Western Cape Nature Conservation Board (CapeNature), focussing on landscape scale conservation initiatives including Biodiversity Corridors, Biosphere Reserves and World Heritage sites and is based at the West Coast Regional Office in Porterville. Jenifer has worked in the conservation sector for the past 10 years and she holds a Bachelor of Science from the Nelson Mandela Metropolitan University (formally the University of Port Elizabeth) with majors in botany and microbiology. She also holds a B.Phil in Sustainable Development Management and Planning from the University of Stellenbosch. She has a keen interest in environmental governance, co-management, climate change, restoration, Biodiversity and Business initiatives and landscape conservation.

Landscape Literacy: Addressing Critical Ecohydrology Issues within their Drainage Ecosystem Context

Hugh Pringle, Ibo Zimmermann, Kuniberth Shamathe and Colin Nott
Ecosystem Management Understanding (EMU) ™ and Edith Cowan University, PO Box 8522, Alice Springs, NT 0871, Australia
hpringle1@bigpond.com

Through the Southern African Science Service Centre for Climate Change and Adaptive Land Use (SASSCAL) a project has been instigated that fortuitously integrates conventional site-based grazing management and research (Snyman 2005) with drainage ecosystem ecology in order to address rangeland dehydration issues that affect most valuable rangelands in most rangelands globally. What is often overlooked in conventional rangeland management is the fact that any landscape incision, be it a track, an animal path or major road culvert provides the nickpoint for accelerating headward incision and rangeland dehydration that can occur in even the best managed veld (Cooke and Reeves 1976; Pringle and Tinley 2003; Pringle, Zimmerman et al. 2011). Landscape Literacy (Task 41 of Southern African Science Service Centre for Climate Change and Adaptive Land Use (SASSCAL)) aims to study these issues in more detail with case studies in Namibia (at least as a starting point). The impetus of this work is the downward spiralling Rain Use Efficiency of Namibian rangelands in both commercial and communal lands where landscape incision ("nickpoints") accelerate the flow of water out of local landscapes into an induced "canal" system (Pringle, Zimmerman et al. 2011).

If climate change projections are accurate –even as tentatively expressed as they are currently – extremes of dry and flooding are likely. Adaptation (acting locally to be prepared for changes) will be critical. In such circumstances it is important that existing breached base levels are restored and landholders, Government, road grader operators, miners and other land users are made aware that their activities can have an extreme negative impact on the drainage ecosystem in which they live or work. That is, existing breaches of drainage ecosystems need to be re-plugged or filtered (depending on issues of energy of flows and cost-effectiveness). As importantly, conventional land management practices that incise the landscape need to be halted so that there aren't ever expanding nickpoint initials for further accelerated rangeland draining. Let's get raindrops into the soil as close to where they land as possible. Clearly, good grazing management can enhance local infiltration of raindrops, but in some cases even the healthiest rangelands can be destroyed by gullies that draw water to them in an inexorable downward spiral.

Sometimes grazing management is not enough to restore breached catchment ecosystems. What isn't widely appreciated is that gully heads obey the laws of physics and while they are often prominent in historically severely degraded areas, they can equally etch into and drain locally very healthy veld (Tinley 1977). Cattle are a major culprit of landscape incision and gully (donga) development because they have a habit of traversing land in single file when not grazing. This is particularly so where cattle graze year round without any recovery period. Thus the location of watering points that are visited regularly can be a key component of landscape incision; cattle are particularly efficient at grazing for least effort – along the drainage alley (Pringle, Watson et al. 2006). However, in well managed rangelands where landscapes have ample recovery time between grazing periods, cattle paths recover between grazing episodes (Purvis 1986). It is fortuitous then that the Polytechnic of Namibia (PoN) and the Integrated Rural Development and Nature Conservation (IRDNC) are partners in this research given their common interests in landscape scale management issues. While the PoN will develop educational materials and processes for use in both landholder and "expert" fields, IRDNC will be at the forefront of linking grazing management strategies to rangeland rehydration in communal areas (as well as contributing to the educational materials). In the latter case, the culprits (cattle) may well be a key part of the solution in levelling gully heads and preparing soil surfaces ready to respond to rain. This approach was already taken during the first fieldwork of this project when various restoration activities were conducted by 41 PoN students at farm Krumhuk. These included the construction of:

(1) a kraal around a large gully head, into which cattle were herded for two successive nights to trample down and smoothen the steep gully walls while fertilizing the soil (Figures 1 and 2);
(2) strategically placed filters in rills and gully heads, comprising branches of thorn bushes tied down with wire secured to nearby trees or steel posts hammered into the ground (Figure 3);
(3) suspended filters across pinch points in gullies where fierce water flow can be calmed down as it lifts the hanging branches while flowing underneath without ripping them off the wire (Figure 4).

In addition, a patch of thick bushes was cleared from a critical position at the head of an alluvial fan to encourage runoff water to once again spread out over a large grassy plain instead of rushing down a gully, now partially blocked by a dense filter. The damage caused by grader drivers who divert water runoff on tracks down steep spoon drains was also demonstrated, while the correct procedures for track construction were explained for minimising disruption of water flow across the landscape.

We are very keen to collaborate with other groups looking to rehydrate rangelands and maintain quickly declining natural grasslands in previously seasonally inundated landscapes. There are already plans to seek funding for a group of Australian Aboriginal cattlemen to visit Herero and other counterparts to see how cattle and rangelands are managed.

Figure 1. A pick is used to break down steep gully heads to avoid injury of cattle.

Figure 2. Cattle further smoothen gully heads while preparing a seed bed and fertilizing the soil.

Figure 3. A filter of thorn bushes was tied down at a gully head.

Figure 4. A filter is suspended from wire tied across a gully.

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A Case Study of Annual Legume Seedling and Seed Populations in Commercial Crop-Pasture Systems in the Agro-Pastoral region of the Western Cape

Johann M van Heerden
Agricultural Research Council- Animal Production
jmvh@sun.ac.za

This study was conducted to try and quantify the condition of annual legume pastures on commercial farms in the agro-pastoral region of the Western Cape Province of South Africa. Pastures were surveyed on 114 paddocks on 30 commercial farms. The potential of these pasture paddocks to generate legume pasture, grass weed and broadleaf weed seedlings was determined by collecting soil samples during late summer to mid-autumn, wetting the samples in a glasshouse and counting the seedlings which had germinated.

The number of non-germinated legume seeds was also determined. Burr (*Medicago polymorpha L.*) and barrel medics (*Medicago truncatula Gaertn.*), were the most common pasture legumes while clovers such as subterranean (*Trifolium subterraneum L.),* balansa (*Trifolium michelianum Savi.)* and rose (*Trifolium hirtum All.)* clover formed only a small portion on most farms. Only seven of the farms generated more than 300 legume seedlings m-2. A positive correlation was derived between the number of legume seeds and seedlings. This finding emphasised the importance of maintaining adequate legume seed reserves in the soil. Negative correlations were derived between weed and legume seedling populations. This finding indicated that inadequate weed control possibly limited pasture productivity on the farms.
Keywords: *Trifolium species, Medicago truncatula, M. polymorpha*, grass weeds, broadleaf weeds.

Introduction

The winter rainfall agro-pastoral area of South Africa is mainly situated within the Western Cape Province. The Western Cape is relatively poor in natural resources and agriculture is one of the most important socio-economic drivers. The main cropping areas of the province, the Swartland, Rûens and Overberg, receive on average 300 to 500 mm of predominantly (70 to 90%) winter (April/May to September/October) rainfall per annum. The region has an estimated 2 500 000 ha of cultivated land with mainly shallow, stony shale soils, of which approximately 600 000 ha are utilised for legume pastures (1989, Unpublished report by Western Cape Department of Agriculture). These pastures are mainly grazed by sheep, for wool and mutton production, but also by increasing numbers of beef and dairy cattle.

The pastures are rotated with crops such as wheat (*Triticum aestivum L.),* barley (*Hordeum vulgare L.)* and canola (*Brassica napus L.).* The major portion of the Overberg and Rûens is planted to longer phase (> five seasons) lucerne pastures (*Medicago sativa L.)* which is usually followed by approximately five consecutive cropping seasons. However, in the Swartland and the Overberg and Rûens pasture-crop rotation systems with one season of self-regenerating pasture legumes, such as annual medics and clover, followed by one season of crop are, are also used. Medics such as barrel *(Medicago truncatula Gaertn.)* and burr (M. polymorpha L.) medic dominate these pastures, but clovers such as balansa (*Trifolium michelianum Savi.),* subterranean (*T. subterraneum L.)* and rose (*T. hirtum All.)* clover are also used to a more limited extent in some areas. This study will focus on the latter type of pasture.

Legume pastures are important for sustainable crop and animal production in the Western Cape. These pastures fix large quantities of nitrogen which reduce the nitrogen fertilizer needs of subsequent crops (Ladd et al., 1981). Equally important, however, is the fact that grass weeds can be most effectively controlled in the legume pasture phase of such systems. Le Roux, et al. (1995) found an 89% decrease in numbers of grass weed plants in a subsequent wheat crop, a 51% decrease in take-all (*Gaeumannomyces graminins var. tritici*) and a 34% increase in wheat yield when grass weeds are controlled in a previous medic pasture.

Similar advantages have been documented in such systems in Australia (MacLeod, et al., 1993). The other important advantages of legumes are the fact that they supply an even distribution of dry matter, alleviating the shortage of dry matter during critical periods, and the positive influence they have on individual animal production, which is important for high animal production (Van Heerden & Tainton, 1987). Legume based pastures outyield grass dominant pastures in terms of animal products (Van Heerden, et al., 1989, Nicol & Edwards, 2011). The control of grass weeds in dryland medic pastures also has a positive influence on medic pod production and sustainability (Van Heerden, 1990). The successful implementation of the legume pasture-crop system is made possible by the use of self regenerating annual pasture legumes which are able to survive one or two cropping seasons, between pasture phases (Carter, 1987).

These legumes produce a large number of seeds at the end of each growing season and most of the seeds break dormancy during late summer and early autumn only after one or more seasons in or on top of the soil. Farmers and advisors have reported a decrease in the productivity of annual legume pastures on commercial farms A similar decline in the productivity of annual legume pastures in the southern Australian agro-pastoral zone was found to be due to a decrease in the number of legume seedlings re-establishing after the crop phase (Carter et al., 1982; Gillespie, 1983).

Gillespie (1983) also attributed the deterioration of subterranean clover pastures in Australia to changes in winter rainfall characteristics, increased cropping frequency and longer cropping phases, changing crop and pasture management practices, poor grazing management and increased incidence of diseases and insect pests. Carter (1987) implicated the same factors with medic pasture rundown in Australia. The common reason for the failure of legume pastures in the Australian cereal belt has been found to be inadequate seed reserves and consequent low seedling density (Carter & Porter, 1993).

According to Carter & Porter (1993) the major constraints are also inadequate control of insect pests, the inadequate control of summer-autumn grazing of medic pods and clover burrs (especially on very hard setting soils) and the inadequate control of the depth of tillage. Kotzé, et al. (1998) also found at Riviersonderend in the Rûens that deep cultivation, during the cropping phase, depressed medic seedling regeneration. The proportion of ingested medic seed voided in sheep faeces differ between species and cultivars. Kotzé, et al. (1995) found that burr medic was superior to barrel medic in this regard and that sheep voided 23% of ingested burr medic seeds, but only 4% of barrel medic seeds. According to Reed, et al. (1989) the persistence of self-regenerating annual legumes within distinctly winter rainfall climates is also determined by factors such as seed production, seed conservation and adaptation. A survey was conducted in order to try and quantify the legume seedling regeneration potential and residual (non-germinating) seed levels and grass and broad leaf weed seedling numbers within annual legume pastures in commercial crop-pasture systems. This survey was conducted on 30 farms in the Western Cape region of South Africa.

Materials and Methods

A total of 114 randomly selected paddocks were sampled on 30 commercial farms distributed through the Swartland (22 farms), Rûens and Overberg (8 farms) regions, during February to April over a period stretching from 1998 to 2004. Four to six paddocks were randomly selected per farm, originally established with mixtures of barrel and burr medic cultivars and, in a few cases, subterranean, rose and balansa clover. The pastures were originally established between five and ten years ago and were all part of one year pasture and one year crop systems and were sampled after the crop phase.

The top 50 mm of the soil was sampled with the aid of 100 mm long round steel tubes with a sampling area of 0.066 m^2. A total of 12 samples were randomly taken within each paddock. Paddock sizes were on average between 30 and 50 ha. The samples were moved to a water cooled greenhouse, placed in two liter (220 x 150 x 75 mm) well drained plastic containers. The samples were wetted immediately after collection and daily thereafter and the seedlings were allowed to establish at 15 to 18 ^oC night and 20 to 25 ^oC day temperatures, which approximates the average late autumn/early winter temperature regime of the region, for three to four weeks.

Seedlings of each legume species were identified and counted. The weed seedlings were categorised into grass and broadleaf weeds and also counted. Subsequently the non-germinated legume seeds remaining in each soil sample were extracted by hand sorting and counted, after removing the soil by washing and then drying the samples. Non-germinated seeds were visually categorised into barrel and burr medic and clover seeds. The data was expressed as number m-2 by multiplying with a factor. The viability of the non-germinated seeds was not tested and no field seedling counts were done. Soil samples of each sample site were analysed. The pH, salinity, P, K, Cu, Mn and Zn content of these samples were determined. The farms were compared for legume seed and seedling and weed seedling numbers, using individual paddocks (between four and six) as replicates and a least squares statistical method (Draper and Smith, 1966).

Results and Discussion

The total number of legume seedlings (Table 1a and 1b) varied between 26 and 758 seedlings m^{-2}, the total medic seedling varied between 5 and 725 seedlings m-2 and the total clover seedlings between 0 and 246 seedlings m^{-2}. Previous research has shown that legume seedling numbers of more than 600 seedlings m^{-2} are ideal, while 200 to 300 seedlings m^{-2} seems to be the minimum acceptable level (van Heerden, unpublished data). According to this norm only seven of the farms had sufficient numbers of total legume seedlings.

Medics on average formed the main component (86.3%) of the legume seedlings. The average number of burr medic seedlings (49.3%) tended to be higher than that of barrel (37.6%) medics, although only 13 farms had more burr than barrel medic seedlings. Although not significantly so ($P < 0.05$), the proportion of barrel medic seedlings tended to be higher on the Rûens and Overberg (44.4%), than the Swartland (21.0%) farms. There seems to be a greater variation between farms and paddocks in the seedling numbers of the burr than the barrel medics. The average number of clover seedlings (13.6%) was lower and only three farms had more than 100 clover seedlings m^{-2}, which consisted of subterranean, balansa and rose clover.

The grass and broadleaf weed seedling count varied significantly ($P < 0.05$) between farms. The grass weed seedling count varied from 2 grass seedlings m^{-2} to 946 seedlings m^{-2}. On average the number of broadleaf weed seedlings (67.5% of total weed seedlings) tended to be higher than that of the grass seedlings. However, ten farms, of which eight were in the Swartland, had more grass than broad leaf weeds. Pieterse (2008) found that the resistance of both grass and broadleaf weeds to chemical herbicides, used in the pasture and crop phases, was becoming an ever greater problem. In the light of these findings it is interesting to note that grasses seem to be more effectively controlled chemically in these systems than broadleaf weeds. This seems to indicate that broadleaf weeds are more of a problem than grasses in the pasture phase of most of the farms. This is in accordance with observations made by farmers and advisors.

Farm	Region	Legumes (number m^{-2})			Weeds (number m^{-2})		
		Medic Total	Clover Total	Total Legumes	Grass	Broad Leaf	Total Weeds
1	Swartland	4.5 d	47.9 ab	52.4 f	531.8 abcd	488.3 de	1020.1 bcdef
2	Swartland	31.5 cd	0.0 b	31.5 f	161.5 cdef	1598.5 a	1760.0 abc
3	Swartland	56.3 cd	9.2 b	65.5 def	37.0 f	1205.3 ab	1242.3 abcde
4	Swartland	39.1 cd	0.0 b	39.1 ef	318.6 cdef	106.0 de	424.6 def
5	Swartland	31.1 cd	0.0 b	31.1 f	179.1 cdef	645.1 bcde	824.2 cdef
6	Swartland	24.0 d	2.3 b	26.3 f	206.9 cdef	378.5 de	585.4 def
7	Swartland	45.4 cd	17.7 b	63.1 ef	89.6 def	364.6 de	454.2 def
8	Swartland	58.0 cd	119.5 ab	177.5 def	401.8 abcdef	331.8 de	733.6 def
9	Swartland	122.3 cd	0.0 b	122.3 def	188.7 cdef	524.1 cde	712.8 def
10	Swartland	26.5 d	4.8 b	31.3 f	61.2 ef	1132.9 abc	1194.1 bcde
11	Swartland	84.5 cd	245.8 ab	330.3 cdef	555.4 abc	651.8 bcde	1207.2 bcde
12	Swartland	82.0 cd	2.5 b	84.5 def	232.1 cdef	534.9 cde	767.0 cdef
13	Swartland	64.3 cd	37.9 ab	102.2 def	214.5 cdef	1731.0 a	1945.5 ab
14	Rûens & Overberg	62.2 cd	9.2 b	71.4 def	170.7 cdef	467.6 de	638.3 def
15	Rûens & Overberg	235.5 bcd	0.8 b	236.3 cdef	1.7 f	91.7 de	93.4 f
16	Rûens & Overberg	100.1 cd	0.8 b	100.9 def	41.2 f	667.0 bcd	708.2 def
17	Rûens & Overberg	120.5 cd	0.0 b	120.5 def	184.8 cdef	264.9 de	449.7 def
18	Rûens & Overberg	133.7 cd	10.3 b	144.0 def	788.5 ab	614.4 bcde	1402.9 abcd
19	Rûens & Overberg	110.2 cd	28.0 ab	138.2 def	68.1 ef	116.4 de	184.5 f
20	Swartland	214.4 bcd	7.9 ab	222.3 cde	306.6 cdef	213.9 de	520.5 def
21	Rûens & Overberg	357.0 bc	0.0 b	357.0 cd	77.0 def	160.2 de	237.2 ef
22	Rûens & Overberg	293.3 bcd	0.0 b	293.3 cdef	14.2 f	76.7 de	90.9 f
23	Rûens & Overberg	226.3 bcd	83.0 ab	309.3 cdef	500.5 abcde	1708.7 a	2209.2 a
24	Swartland	211.3 bcd	134.5 a	345.8 cdef	945.6 a	153.9 de	1099.5 bcdef
25	Swartland	163.6 cd	1.2 b	164.8 def	178.5 cdef	31.4 de	209.9 f
26	Swartland	249.8 bcd	6.1 b	255.9 cdef	189.2 cdef	152.4 de	341.6 ef
27	Swartland	247.9 bcd	3.8 b	251.7 cdef	162.8 cdef	212.6 de	375.4 ef
28	Swartland	503.0 ab	4.2 b	507.2 bc	259.1 cdef	221.2 de	480.3 def
29	Rûens & Overberg	725.4 a	0.0 b	725.4 ab	115.4 cdef	43.5 de	158.9 f
30	Swartland	698.4 a	59.5 ab	757.9 a	28.6 f	53.3 de	81.9 f
Average		**177.4**	**27.9**	**205.3**	**240.4**	**498.1**	**738.4**

Table 1a - Average number of medic, clover, total legume, grass, broad leaf weed and total weed seedlings m^{-2} on the 30 farms sampled

Farm	Region	Medics (number m^{-2})			Clover (number m^{-2})			
		Barrel	Burr	Total	Rose	Bal-ansa	Sub-Terranean	Total
1	Swartland	3.2 f**	1.3 d	4.5 d	33.4 a	2.5 b	12.0 b	47.9 ab
2	Swartland	26.5 ef	5.0 d	31.5 cd	0.0 b	0.0 b	0.0 b	0.0 b
3	Swartland	39.5 cdef	16.8 d	56.3 cd	0.8 b	0.0 b	8.4 b	9.2 b
4	Swartland	24.6 ef	14.5 d	39.1 cd	0.0 b	0.0 b	0.0 b	0.0 b
5	Swartland	26.9 ef	4.2 d	31.1 cd	0.0 b	0.0 b	0.0 b	0.0 b
6	Swartland	21.5 ef	2.5 d	24.0 d	0.0 b	2.3 b	0.0 b	2.3 b
7	Swartland	29.0 ef	16.4 d	45.4 cd	3.8 b	2.5 b	11.4 b	17.7 b
8	Swartland	29.0 ef	29.0 d	58.0 cd	0.0 b	4.7 ab	114.8 ab	119.5 ab
9	Swartland	92.0 cdef	30.3 d	122.3 cd	0.0 b	0.0 b	0.0 b	0.0 b
10	Swartland	24.0 ef	2.5 d	26.5 d	0.0 b	4.8 b	0.0 b	4.8 b
11	Swartland	84.5 cdef	0.0 d	84.5 cd	35.1 a	5.9 ab	204.8 a	245.8 ab
12	Swartland	82.0 cdef	0.0 d	82.0 cd	0.0 b	2.5 b	0.0 b	2.5 b
13	Swartland	49.2 cdef	15.1 d	64.3 cd	0.0 b	0.0 b	37.9 b	37.9 ab
14	Rûens & Overberg	0.0 f	62.2 d	62.2 cd	4.2 b	5.0 b	0.0 b	9.2 b
15	Rûens & Overberg	84.1 cdef	151.4 cd	235.5 bcd	0.0 b	0.8 b	0.0 b	0.8 b
16	Rûens & Overberg	35.3 def	64.8 d	100.1 cd	0.0 b	0.8 b	0.0 b	0.8 b
17	Rûens & Overberg	60.6 cdef	59.9 d	120.5 cd	0.0 b	0.0 b	0.0 b	0.0 b
18	Rûens & Overberg	63.1 cdef	70.6 d	133.7 cd	1.3 b	6.5 ab	2.5 b	10.3 b
19	Rûens & Overberg	83.1 cdef	27.1 d	110.2 cd	1.3 b	7.0 ab	19.7 b	28.0 ab
20	Swartland	152.0 abcd	62.4 d	214.4 bcd	0.6 b	6.7 ab	0.6 b	7.9 ab
21	Rûens & Overberg	117.3 cdef	239.7 bcd	357.0 bc	0.0 b	0.0 b	0.0 b	0.0 b
22	Rûens & Overberg	253.6 ab	39.7 d	293.3 bcd	0.0 b	0.0 b	0.0 b	0.0 b
23	Rûens & Overberg	81.2 cdef	145.1 cd	226.3 bcd	5.9 b	4.8 ab	72.3 ab	83.0 ab
24	Swartland	160.2 abc	51.1 d	211.3 bcd	0.6 b	4.6 a	129.3 ab	134.5 a
25	Swartland	22.1 ef	141.5 cd	163.6 cd	0.0 b	1.2 b	0.0 b	1.2 b
26	Swartland	111.0 cdef	138.8 cd	249.8 bcd	0.0 b	6.1 b	0.0 b	6.1 b
27	Swartland	140.0 bcde	107.9 cd	247.9 bcd	0.0 b	3.8 b	0.0 b	3.8 b
28	Swartland	107.7 cdef	395.3 abc	503.0 ab	0.0 b	3.4 b	0.8 b	4.2 b
29	Rûens & Overberg	272.5 a	452.9 ab	725.4 a	0.0 b	0.0 b	0.0 b	0.0 b
30	Swartland	24.7 ef	673.7 a	698.4 a	12.1 ab	5.6 ab	41.8 b	59.5 ab
Average		**76.7**	**100.7**	**177.4**	**3.3**	**2.7**	**21.9**	**27.9**

Table 1b - Average number of medic, clover, total legume, grass, broad leaf weed and total weed seedlings m^{-2} on the 30 farms sampled

Farm	Region	Medic (number m^{-2})			Total clover (number m^{-2})	Total legume (number m^{-2})
		Barrel	Burr	Total		
1	Swartland	7.6 g*	6.1 b	12.1 b	242. b	36.3 b
2	Swartland	48.4 g	0.0 b	48.4 b	0.0 b	48.4 b
3	Swartland	87.8 efg	27.3 b	115.1 b	9.1 b	124.1 b
4	Swartland	92.4 defg	75.7 b	168.0 b	0.0 b	168.0 b
5	Swartland	101.4 defg	95.4 b	198.3 b	0.0 b	198.3 b
6	Swartland	246.8 cdefg	93.9 b	339.1 b	0.0 b	339.1 b
7	Swartland	375.5 bcdefg	84.8 b	460.2 b	13.6 b	473.9 b
8	Swartland	131.7 cdefg	63.6 b	195.3 b	230.1 b	423.9 b
9	Swartland	246.8 cdefg	198.3 b	446.6 b	0.0 b	446.6 b
10	Swartland	508.7 bcd	22.7 b	531.4 b	0.0 b	531.4 b
11	Swartland	230.1 cdefg	1.5 b	231.6 b	125.7 b	357.3 b
12	Swartland	504.1 bcde	7.6 b	511.7 b	0.0 b	511.7 b
13	Swartland	528.4 bc	6.1 b	534.4 b	4.5 b	540.5 b
14	Rûens & Overberg	101.4 defg	505.7 b	607.1 b	1.5 b	608.6 b
15	Rûens & Overberg	115.1 cdefg	345.2 b	460.2 b	0.0 b	460.2 b
16	Rûens & Overberg	210.4 cdefg	372.4 b	582.9 b	0.0 b	582.9 b
17	Rûens & Overberg	366.4 bcdefg	295.2 b	660.1 b	0.0 b	660.1 b
18	Rûens & Overberg	192.3 cdefg	430.0 b	622.2 b	1.5 b	623.8 b
19	Rûens & Overberg	160.5 cdefg	520.8 b	679.8 b	39.4 b	720.6 b
20	Swartland	327.0 cdefg	222.6 b	549.6 b	1.5 b	551.1 b
21	Rûens & Overberg	219.5 cdefg	370.9 b	590.4 b	0.0 b	590.4 b
22	Rûens & Overberg	996.2 a	0.0 b	996.2 b	0.0 b	996.2 b
23	Rûens & Overberg	317.9 cdefg	449.6 b	767.6 b	28.8 b	796.3 b
24	Swartland	221.0 cdefg	455.7 b	676.7 b	239.2 b	915.9 b
25	Swartland	383.0 bcdefg	714.6 b	1097.6 b	0.0 b	1097.6 b
26	Swartland	487.5 bcdef	598.0 b	1085.5 b	0.0 b	1085.5 b
27	Swartland	779.7 ab	407.3 b	1186.5 b	0.0 b	1186.9 b
28	Swartland	207.4 cdefg	905.3 b	1112.8 b	0.0 b	1112.8 b
29	Rûens & Overberg	510.2 bcd	1090.1 b	1600.3 b	0.0 b	1600.3 ab
30	Swartland	68.1 fg	3465.5 b	3532.1 b	43.9 b	3576.0 a
Average		**292.4**	**394.4**	**686.7**	**25.4**	**712.2**

Table 2. Average number of non-germinated legume seeds m^{-2} on the 30 farms

The average number of non-germinated medic seeds in the soils (687 m^{-2}) was higher than the number of medic seedlings (177 m-2) and implied that 20.5% of the total medic (seedlings plus non-germinated seed) seed reserve established as seedlings. This proportion was very similar for burr (20.4%) and barrel (20.9%) medics. In the case of the clovers the non-germinated seed (25 m^{-2}) and seedlings (28 m^{-2}) numbers were very similar and 52.8% of the total clover seed reserve established as seedlings. Clover seed was therefore less dormant than the medic seed. This is probably and important factor limiting clover seedling numbers. As in the case of the seedling numbers, the number of non-germinated legume seeds varied significantly ($P < 0.05$) between farms. Soil sampled on farm 30 had the highest number of non-germinated legume seeds (3 576 m-2) while farm 1 had the lowest number (36 m^{-2}). The average number of non-germinated seeds for barrel medic varied between 8 and 996 m^{-2}, for burr medic between 0 and 3466 m^{-2} and for total clovers between 0 and 239 m^{-2}. On average burr medic seeds formed 55.3% of the total number of non-germinated legume seeds, barrel medics 41.0% and clovers only 3.5%. The greater number of non-germinated burr than barrel medic seeds seems to support the research of Kotze, et al. (1995), which showed that a smaller proportion of burr than barrel medic seed is destroyed when ingested by sheep. The danger of overgrazing medic pods during summer, suggested by Carter & Porter (1993), should thus be less of a problem with burr than barrel medics.

A multiple regression analysis was performed using the factors legume seedling and seed numbers, weed and grass and broad leaved weed seedling numbers, soil analysis parameters using only the data for which soil parameters were determined. The only factors which significantly ($P < 0.05$) correlated with legume seedling numbers were total legume seed content and weed seedling numbers. Using all the data sampled statistical relationships were developed between these three factors. A significantly ($P < 0.05$) positive polynomial relationship was derived between the total number of legume seeds and the number of legume seedlings which had regenerated (Figure 1). This emphasizes the importance of maintaining high residual legume seed reserves to ensure the regeneration of adequate numbers of legume seedlings. This supported the view of Carter & Porter (1993) who stressed the importance of maintaining high seed levels. As a smaller proportion the medic than clover seeds regenerated as viable seedlings the percentage of the seed bank which regenerates each year will therefore be determined by the species composition of the seed bank. It also shows that a much greater seed bank of medic than clover seeds are needed to ensure that adequate numbers of legume seedlings regenerate. On the other hand, clover seed populations should be more vulnerable to adverse conditions such as seasons with a false break during odd years, due to unseasonal late summer rains followed by dry hot weather. Significantly ($P < 0.05$) negative relationships exist between the total number of legume seedlings and the total weed seedling and the broadleaf weed seedling numbers (Figure 2).

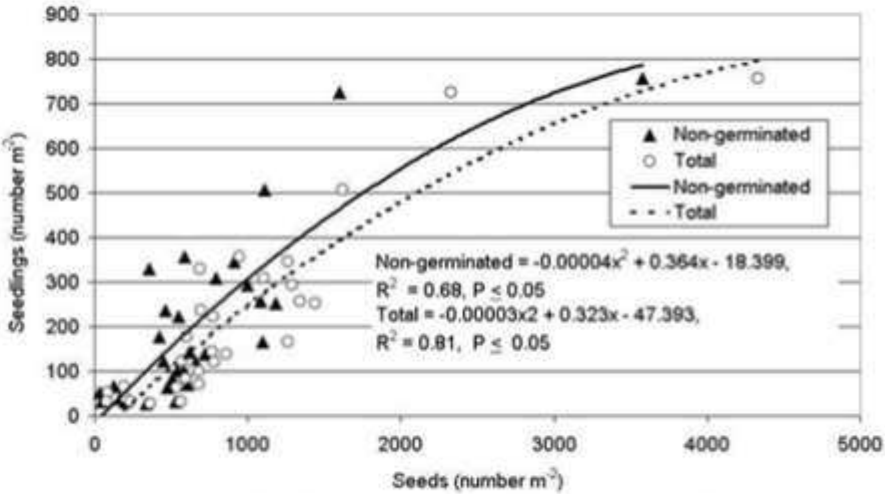

Figure 1. Relationship between the number of non-germinated and total legume seeds and the number of legume seedlings on 30 farms

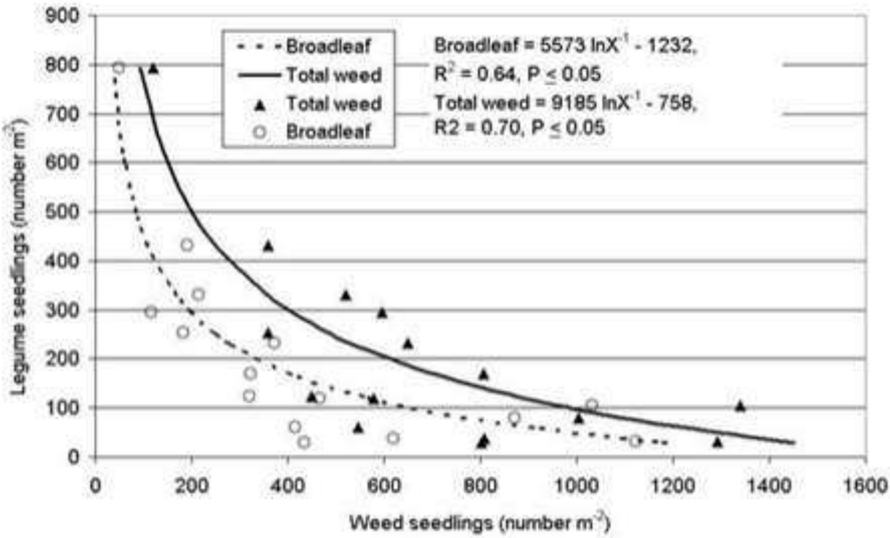

Figure 2. Relationship between the number of broadleaf and total weed seedlings and the number of legume seedlings on 30 farms

No significant relationship was found between the number of grass seedlings and the number of legume seedlings. This can be attributed to the fact that the annual grass weeds were generally effectively controlled by the application of chemical herbicides in the pasture phase of these systems (Le Roux et al., 1995), while it was much more difficult to control broadleaf weeds selectively in this phase. From Figure 2 it seems as if the total weed seedling numbers should ideally be below 100 m-2 in the pasture to ensure maximum legume seedling regeneration.

The data shows that weed infestation may be one of the major factors limiting pasture productivity on commercial farms and can be attributed to the negative influence of weed competition on medic pod and seed production (Van Heerden, 1990). The pastures of farmers who kept weed populations in both their crops and pastures under control, therefore, also had higher numbers of legume seedlings. The increased resistance to the herbicides used in both the pasture and crop phases reported by industry (Pieterse, 2008) may, however, in future result in grass weeds also increasingly becoming a major factor limiting pasture productivity.

Conclusions

The number of legume seedlings which had regenerated in the pastures of most farms (77%), was lower than what is needed to attain high pasture yields. The significant relationships which were derived between legume seed and seedling maintaining high residual legume seed reserves to ensure the regeneration of adequate numbers of legume seedlings. The large difference in legume seedling and non-germinated seed numbers between farms is, however, indicative of a rather serious variance in management practices and the control of broadleaf weeds seem to be the main problem. Farmers are inclined to focus more on weed control during the crop than the pasture phases.

For greater productivity and sustainability of annual legume pastures they should, however, endeavor to also control both grass and broad leaf weeds during the pasture phase. Farmers are reluctant to do this due to the fact that herbicides are expensive and the removal of weeds often reduces grazing capacity. Van Heerden (1990), however, showed that the removal of weeds result in increased medic pod production and improve medic seed reserve levels and thus the sustainability of medic pastures on the long term. The higher proportion of legumes in pastures submitted to adequate weed control should also have a positive influence on individual animal production (Van Heerden & Tainton, 1987, Van Heerden, et al., 1989).

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Utilizing our Rangeland more Effectively: What can We Learn from Wild Herbivores?

Rina (C) C.Grant[1] and Mike J.S. Peel[2]
[1] Scientific Services, SANParks Skukuza rina.grant@sanparks.org
[2] Range and Forage Institute, Agricultural Research Council, Nelspruit
MikeP@arc.agric.za

The increasingly challenging economic climate that livestock and wildlife managers are confronted with necessitates novel approaches to rangeland management. Increasing production while maintaining lower input costs to ensure viable economic and ecological margins is becoming more imperative, but how achievable is this?

We propose that the foraging strategies applied by wild herbivores to utilize the available forage may give us some pointers to such novel approaches. From extensive work on factors that determine herbivore densities and distribution we know that rainfall and soil nutrients and moisture are critical drivers of rangeland ecosystems driving differences in forage biomass, forage nutrient content and species composition (Coe et al. 1976; East 1984; Fritz & Duncan 1994). Thus one would expect the highest density of herbivores in areas with high rainfall and high soil nutrients. Nutrient rich soils have more organic material often with a higher clay content, yielding a grass sward and tree layer with many palatable plant species. The lowest herbivore densities would thus be expected in low rainfall areas on nutrient poor sandy soils.

Why does the Kruger National Park not exhibit the expected herbivore biomass pattern? Research showed that the grazers concentrate on nutritious patches such as sodic sites and termite mounds in the granites (Grant & Scholes 2006) (Figure 2). The same pattern has been described in other studies especially in East Africa where grazing lawns were found to be favoured by grazers (McNaughton 1984); (Augustine et al. 2003). Old kraal sites have also been shown to be attractive to grazers with significantly higher forage nutrients even 40 years after being abandoned (Scholes & Walker 1993; Van der Waal et al. 2011). For many years managers have been primarily concerned about plant production. This concern led to the development of grazing systems aimed at increasing plant production by ensuring that key plant species of high forage quality could produce sufficient biomass to enhance livestock production in the long term.

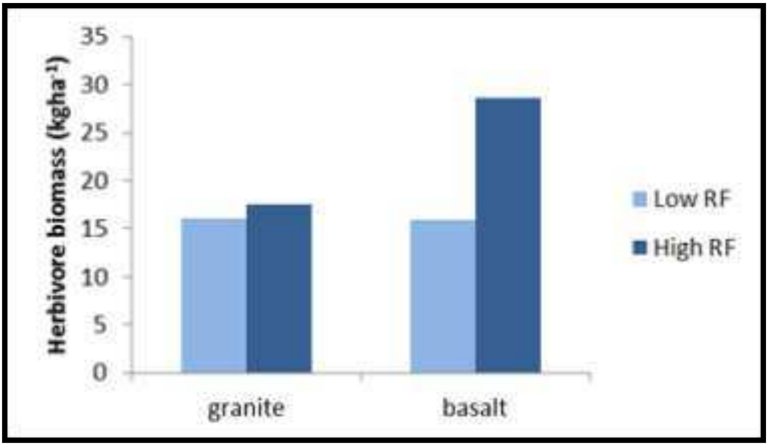

Figure 1. Mean herbivore densities in low and high rainfall zones in the Kruger National Park on low nutrient granites vs. high nutrient basalts.

Figure 2. Selection of short grass forage patch in a granitic landscape.

These systems aimed to ensure uniform animal distribution at a relatively high stocking density, thus avoiding the spatially heterogeneous patch grazing described above. The intention of rotational grazing systems is to improve species composition and production by ensuring a rest period during the growing season (Briske et al. 2008).

Results of research investigating the outcome of these different grazing systems vary, making the selection of appropriate systems difficult. Continuous grazing systems generally perform better than rotational grazing systems. (Briske et al. (2008) compared the production obtained in experiments following different grazing systems to production from continuous grazing. They reported that plant production was equal or greater in continuous compared to rotational grazing in 87% (20 of 23) of these experiments. Animal production per head and per area was equal in 92% (35 of 38) or greater in 84% (27 of 32) in continuous compared to rotational grazing experiments.

The fact that production was generally higher in continuous grazing systems, poses the question whether these animals perform better because they can select and maintain nutritious forge patches as illustrated by the patchy utilization of rangeland by wildlife. Both domestic and wild herbivores require protein and phosphorous rich forage to reproduce and to gain weight (Meissner et al. 1981; Prins & Beekman 1987).

These nutrient-rich patches often supply islands of the required high quality forage in a sea of low quality. This raises the question whether the current use of rotational grazing systems should not be re-evaluated to enable animals to utilize and maintain nutritious patches thus enhancing effective animal production in Africa.

Nutritious foraging patches and Herbivore Production

There are a number of types of nutritious foraging patches. The easiest way to identify these are that they are areas of short grass, often within areas of much taller and less utilized grass. Grazing lawns are a striking example of such foraging patches.

A simple definition of grazing lawns is that they are areas where grasses are kept in a short, productive, palatable and digestible state by the action of grazers (after Coetsee et al. 2011). The stoloniferous grasses that are dominant in these lawns, are very short grasses that maintain high cover and production despite severe grazing pressure (Stock et al. 2009). In fact the stoloniferous species occurring on these lawns are able to outcompete the other species under high grazing levels. These lawns tend to form more easily on nutrient enriched sites such as around termitaria, large trees and in lower lying areas where the clay content is higher.

The actively growing grasses are attractive to animals and their continuous presence on these lawns probably increases nutrient concentrations through their dung and urine thus maintaining and enriching these areas (McNaughton 1979; van der Waal et al. 2011). In this system resting causes the replacement of these palatable and productive grasses with less palatable tuft grasses (Archibald 2008) so that the stoloniferous grasses loose the competition with the other grass species, lowering the capacity of the forage and especially lowering the forage quality to support animal production. Although nutritious hotspots can be created naturally by termitaria and large trees (Holdo & McDowell 2004; Treydte et al. 2008), they can also be created by mowing (Archibald et al. 2005) and fertilization (Cromsigt & Olff 2008).

Mowing does not have to be mechanical but bunched cattle and rhinos can also mow lawns to a sufficient height and thereby facilitate other herbivores to utilize these areas too. We still need to establish the ideal ratio between such nutritious patches in the grasslands. First approximations are that these short grass areas should probably not cover more than 30 % of the available forage. We propose that a change in our approach to animal production from rangeland should be considered. Although many of the climax grass species benefit from low utilization and long periods of rest, grazing tolerant grasses can only be maintained at a highly productive and nutritious state by regular defoliation.

Allowing animals to utilize these heterogeneous areas with nutritious patches continuously will reduce management inputs such as supplementation while fencing can be reduced with no production losses. These ideas will be tested further in a range of wildlife areas and on cattle ranches to improve our understanding of the interaction between grazers and the plants that are fed with them. We hope this research will supply a viable alternative to conventional grazing practises.

Acknowledgements

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Landscape Literacy: Addressing Critical Ecohydrology Issues within their Drainage Ecosystem Context

Hugh Pringle, Ibo Zimmermann, Kuniberth Shamathe and Colin Nott
Ecosystem Management Understanding (EMU) ™ and Edith Cowan University, PO Box 8522, Alice Springs, NT 0871, Australia
hpringle1@bigpond.com

Through the Southern African Science Service Centre for Climate Change and Adaptive Land Use (SASSCAL) a project has been instigated that fortuitously integrates conventional site-based grazing management and research (Snyman 2005) with drainage ecosystem ecology in order to address rangeland dehydration issues that affect most valuable rangelands in most rangelands globally. What is often overlooked in conventional rangeland management is the fact that any landscape incision, be it a track, an animal path or major road culvert provides the nickpoint for accelerating headward incision and rangeland dehydration that can occur in even the best managed veld (Cooke and Reeves 1976; Pringle and Tinley 2003; Pringle, Zimmerman et al. 2011). Landscape Literacy (Task 41 of Southern African Science Service Centre for Climate Change and Adaptive Land Use (SASSCAL)) aims to study these issues in more detail with case studies in Namibia (at least as a starting point). The impetus of this work is the downward spiralling Rain Use Efficiency of Namibian rangelands in both commercial and communal lands where landscape incision ("nickpoints") accelerate the flow of water out of local landscapes into an induced "canal" system (Pringle, Zimmerman et al. 2011).

If climate change projections are accurate –even as tentatively expressed as they are currently – extremes of dry and flooding are likely. Adaptation (acting locally to be prepared for changes) will be critical. In such circumstances it is important that existing breached base levels are restored and landholders, Government, road grader operators, miners and other land users are made aware that their activities can have an extreme negative impact on the drainage ecosystem in which they live or work. That is, existing breaches of drainage ecosystems need to be re-plugged or filtered (depending on issues of energy of flows and cost-effectiveness). As importantly, conventional land management practices that incise the landscape need to be halted so that there aren't ever expanding nickpoint initials for further accelerated rangeland draining. Let's get raindrops into the soil as close to where they land as possible. Clearly, good grazing management can enhance local infiltration of raindrops, but in some cases even the healthiest rangelands can be destroyed by gullies that draw water to them in an inexorable downward spiral.

Sometimes grazing management is not enough to restore breached catchment ecosystems. What isn't widely appreciated is that gully heads obey the laws of physics and while they are often prominent in historically severely degraded areas, they can equally etch into and drain locally very healthy veld (Tinley 1977). Cattle are a major culprit of landscape incision and gully (donga) development because they have a habit of traversing land in single file when not grazing. This is particularly so where cattle graze year round without any recovery period. Thus the location of watering points that are visited regularly can be a key component of landscape incision; cattle are particularly efficient at grazing for least effort – along the drainage alley (Pringle, Watson et al. 2006). However, in well managed rangelands where landscapes have ample recovery time between grazing periods, cattle paths recover between grazing episodes (Purvis 1986). It is fortuitous then that the Polytechnic of Namibia (PoN) and the Integrated Rural Development and Nature Conservation (IRDNC) are partners in this research given their common interests in landscape scale management issues. While the PoN will develop educational materials and processes for use in both landholder and "expert" fields, IRDNC will be at the forefront of linking grazing management strategies to rangeland rehydration in communal areas (as well as contributing to the educational materials). In the latter case, the culprits (cattle) may well be a key part of the solution in levelling gully heads and preparing soil surfaces ready to respond to rain. This approach was already taken during the first fieldwork of this project when various restoration activities were conducted by 41 PoN students at farm Krumhuk. These included the construction of:

(1) a kraal around a large gully head, into which cattle were herded for two successive nights to trample down and smoothen the steep gully walls while fertilizing the soil (Figures 1 and 2);
(2) strategically placed filters in rills and gully heads, comprising branches of thorn bushes tied down with wire secured to nearby trees or steel posts hammered into the ground (Figure 3);
(3) suspended filters across pinch points in gullies where fierce water flow can be calmed down as it lifts the hanging branches while flowing underneath without ripping them off the wire (Figure 4).

In addition, a patch of thick bushes was cleared from a critical position at the head of an alluvial fan to encourage runoff water to once again spread out over a large grassy plain instead of rushing down a gully, now partially blocked by a dense filter. The damage caused by grader drivers who divert water runoff on tracks down steep spoon drains was also demonstrated, while the correct procedures for track construction were explained for minimising disruption of water flow across the landscape.

We are very keen to collaborate with other groups looking to rehydrate rangelands and maintain quickly declining natural grasslands in previously seasonally inundated landscapes. There are already plans to seek funding for a group of Australian Aboriginal cattlemen to visit Herero and other counterparts to see how cattle and rangelands are managed.

Figure 1. A pick is used to break down steep gully heads to avoid injury of cattle.

Figure 2. Cattle further smoothen gully heads while preparing a seed bed and fertilizing the soil.

Figure 3. A filter of thorn bushes was tied down at a gully head.

Figure 4. A filter is suspended from wire tied across a gully.

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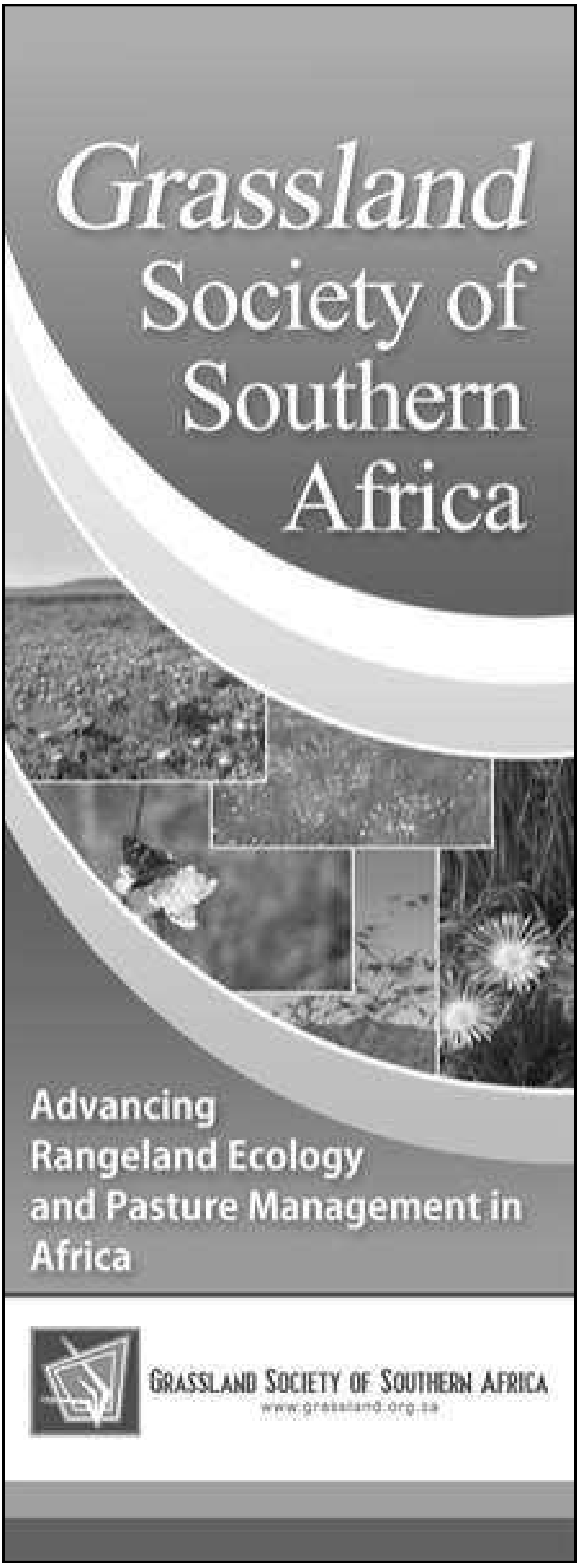

A Case Study of Annual Legume Seedling and Seed Populations in Commercial Crop-Pasture Systems in the Agro-Pastoral region of the Western Cape

Johann M van Heerden
Agricultural Research Council- Animal Production
jmvh@sun.ac.za

This study was conducted to try and quantify the condition of annual legume pastures on commercial farms in the agro-pastoral region of the Western Cape Province of South Africa. Pastures were surveyed on 114 paddocks on 30 commercial farms. The potential of these pasture paddocks to generate legume pasture, grass weed and broadleaf weed seedlings was determined by collecting soil samples during late summer to mid-autumn, wetting the samples in a glasshouse and counting the seedlings which had germinated.

The number of non-germinated legume seeds was also determined. Burr (*Medicago polymorpha L.*) and barrel medics (*Medicago truncatula Gaertn.*), were the most common pasture legumes while clovers such as subterranean (*Trifolium subterraneum L.),* balansa (*Trifolium michelianum Savi.)* and rose (*Trifolium hirtum All.)* clover formed only a small portion on most farms. Only seven of the farms generated more than 300 legume seedlings m-2. A positive correlation was derived between the number of legume seeds and seedlings. This finding emphasised the importance of maintaining adequate legume seed reserves in the soil. Negative correlations were derived between weed and legume seedling populations. This finding indicated that inadequate weed control possibly limited pasture productivity on the farms.
Keywords: *Trifolium species, Medicago truncatula, M. polymorpha*, grass weeds, broadleaf weeds.

Introduction

The winter rainfall agro-pastoral area of South Africa is mainly situated within the Western Cape Province. The Western Cape is relatively poor in natural resources and agriculture is one of the most important socio-economic drivers. The main cropping areas of the province, the Swartland, Rûens and Overberg, receive on average 300 to 500 mm of predominantly (70 to 90%) winter (April/May to September/October) rainfall per annum. The region has an estimated 2 500 000 ha of cultivated land with mainly shallow, stony shale soils, of which approximately 600 000 ha are utilised for legume pastures (1989, Unpublished report by Western Cape Department of Agriculture). These pastures are mainly grazed by sheep, for wool and mutton production, but also by increasing numbers of beef and dairy cattle.

The pastures are rotated with crops such as wheat (*Triticum aestivum L.),* barley (*Hordeum vulgare L.)* and canola (*Brassica napus L.).* The major portion of the Overberg and Rûens is planted to longer phase (> five seasons) lucerne pastures (*Medicago sativa L.)* which is usually followed by approximately five consecutive cropping seasons. However, in the Swartland and the Overberg and Rûens pasture-crop rotation systems with one season of self-regenerating pasture legumes, such as annual medics and clover, followed by one season of crop are, are also used. Medics such as barrel *(Medicago truncatula Gaertn.)* and burr (M. polymorpha L.) medic dominate these pastures, but clovers such as balansa (*Trifolium michelianum Savi.),* subterranean (*T. subterraneum L.)* and rose (*T. hirtum All.)* clover are also used to a more limited extent in some areas. This study will focus on the latter type of pasture.

Legume pastures are important for sustainable crop and animal production in the Western Cape. These pastures fix large quantities of nitrogen which reduce the nitrogen fertilizer needs of subsequent crops (Ladd et al., 1981). Equally important, however, is the fact that grass weeds can be most effectively controlled in the legume pasture phase of such systems. Le Roux, et al. (1995) found an 89% decrease in numbers of grass weed plants in a subsequent wheat crop, a 51% decrease in take-all (*Gaeumannomyces graminins var. tritici*) and a 34% increase in wheat yield when grass weeds are controlled in a previous medic pasture.

Similar advantages have been documented in such systems in Australia (MacLeod, et al., 1993). The other important advantages of legumes are the fact that they supply an even distribution of dry matter, alleviating the shortage of dry matter during critical periods, and the positive influence they have on individual animal production, which is important for high animal production (Van Heerden & Tainton, 1987). Legume based pastures outyield grass dominant pastures in terms of animal products (Van Heerden, et al., 1989, Nicol & Edwards, 2011). The control of grass weeds in dryland medic pastures also has a positive influence on medic pod production and sustainability (Van Heerden, 1990). The successful implementation of the legume pasture-crop system is made possible by the use of self regenerating annual pasture legumes which are able to survive one or two cropping seasons, between pasture phases (Carter, 1987).

These legumes produce a large number of seeds at the end of each growing season and most of the seeds break dormancy during late summer and early autumn only after one or more seasons in or on top of the soil. Farmers and advisors have reported a decrease in the productivity of annual legume pastures on commercial farms A similar decline in the productivity of annual legume pastures in the southern Australian agro-pastoral zone was found to be due to a decrease in the number of legume seedlings re-establishing after the crop phase (Carter et al., 1982; Gillespie, 1983).

Gillespie (1983) also attributed the deterioration of subterranean clover pastures in Australia to changes in winter rainfall characteristics, increased cropping frequency and longer cropping phases, changing crop and pasture management practices, poor grazing management and increased incidence of diseases and insect pests. Carter (1987) implicated the same factors with medic pasture rundown in Australia. The common reason for the failure of legume pastures in the Australian cereal belt has been found to be inadequate seed reserves and consequent low seedling density (Carter & Porter, 1993).

According to Carter & Porter (1993) the major constraints are also inadequate control of insect pests, the inadequate control of summer-autumn grazing of medic pods and clover burrs (especially on very hard setting soils) and the inadequate control of the depth of tillage. Kotzé, et al. (1998) also found at Riviersonderend in the Rûens that deep cultivation, during the cropping phase, depressed medic seedling regeneration. The proportion of ingested medic seed voided in sheep faeces differ between species and cultivars. Kotzé, et al. (1995) found that burr medic was superior to barrel medic in this regard and that sheep voided 23% of ingested burr medic seeds, but only 4% of barrel medic seeds. According to Reed, et al. (1989) the persistence of self-regenerating annual legumes within distinctly winter rainfall climates is also determined by factors such as seed production, seed conservation and adaptation. A survey was conducted in order to try and quantify the legume seedling regeneration potential and residual (non-germinating) seed levels and grass and broad leaf weed seedling numbers within annual legume pastures in commercial crop-pasture systems. This survey was conducted on 30 farms in the Western Cape region of South Africa.

Materials and Methods

A total of 114 randomly selected paddocks were sampled on 30 commercial farms distributed through the Swartland (22 farms), Rûens and Overberg (8 farms) regions, during February to April over a period stretching from 1998 to 2004. Four to six paddocks were randomly selected per farm, originally established with mixtures of barrel and burr medic cultivars and, in a few cases, subterranean, rose and balansa clover. The pastures were originally established between five and ten years ago and were all part of one year pasture and one year crop systems and were sampled after the crop phase.

The top 50 mm of the soil was sampled with the aid of 100 mm long round steel tubes with a sampling area of 0.066 m^2. A total of 12 samples were randomly taken within each paddock. Paddock sizes were on average between 30 and 50 ha. The samples were moved to a water cooled greenhouse, placed in two liter (220 x 150 x 75 mm) well drained plastic containers. The samples were wetted immediately after collection and daily thereafter and the seedlings were allowed to establish at 15 to 18 ^oC night and 20 to 25 ^oC day temperatures, which approximates the average late autumn/early winter temperature regime of the region, for three to four weeks.

Seedlings of each legume species were identified and counted. The weed seedlings were categorised into grass and broadleaf weeds and also counted. Subsequently the non-germinated legume seeds remaining in each soil sample were extracted by hand sorting and counted, after removing the soil by washing and then drying the samples. Non-germinated seeds were visually categorised into barrel and burr medic and clover seeds. The data was expressed as number m-2 by multiplying with a factor. The viability of the non-germinated seeds was not tested and no field seedling counts were done. Soil samples of each sample site were analysed. The pH, salinity, P, K, Cu, Mn and Zn content of these samples were determined. The farms were compared for legume seed and seedling and weed seedling numbers, using individual paddocks (between four and six) as replicates and a least squares statistical method (Draper and Smith, 1966).

Results and Discussion

The total number of legume seedlings (Table 1a and 1b) varied between 26 and 758 seedlings m^{-2}, the total medic seedling varied between 5 and 725 seedlings m-2 and the total clover seedlings between 0 and 246 seedlings m^{-2}. Previous research has shown that legume seedling numbers of more than 600 seedlings m^{-2} are ideal, while 200 to 300 seedlings m^{-2} seems to be the minimum acceptable level (van Heerden, unpublished data). According to this norm only seven of the farms had sufficient numbers of total legume seedlings.

Medics on average formed the main component (86.3%) of the legume seedlings. The average number of burr medic seedlings (49.3%) tended to be higher than that of barrel (37.6%) medics, although only 13 farms had more burr than barrel medic seedlings. Although not significantly so ($P < 0.05$), the proportion of barrel medic seedlings tended to be higher on the Rûens and Overberg (44.4%), than the Swartland (21.0%) farms. There seems to be a greater variation between farms and paddocks in the seedling numbers of the burr than the barrel medics. The average number of clover seedlings (13.6%) was lower and only three farms had more than 100 clover seedlings m^{-2}, which consisted of subterranean, balansa and rose clover.

The grass and broadleaf weed seedling count varied significantly ($P < 0.05$) between farms. The grass weed seedling count varied from 2 grass seedlings m^{-2} to 946 seedlings m^{-2}. On average the number of broadleaf weed seedlings (67.5% of total weed seedlings) tended to be higher than that of the grass seedlings. However, ten farms, of which eight were in the Swartland, had more grass than broad leaf weeds. Pieterse (2008) found that the resistance of both grass and broadleaf weeds to chemical herbicides, used in the pasture and crop phases, was becoming an ever greater problem. In the light of these findings it is interesting to note that grasses seem to be more effectively controlled chemically in these systems than broadleaf weeds. This seems to indicate that broadleaf weeds are more of a problem than grasses in the pasture phase of most of the farms. This is in accordance with observations made by farmers and advisors.

Farm	Region	Legumes (number m^{-2})			Weeds (number m^{-2})		
		Medic Total	Clover Total	Total Legumes	Grass	Broad Leaf	Total Weeds
1	Swartland	4.5 ^{d}	47.9 ^{ab}	52.4 ^{f}	531.8 ^{abcd}	488.3 ^{de}	1020.1 ^{bcdef}
2	Swartland	31.5 ^{cd}	0.0 ^{b}	31.5 ^{f}	161.5 ^{cdef}	1598.5 ^{a}	1760.0 ^{abc}
3	Swartland	56.3 ^{cd}	9.2 ^{b}	65.5 ^{def}	37.0 ^{f}	1205.3 ^{ab}	1242.3 ^{abcde}
4	Swartland	39.1 ^{cd}	0.0 ^{b}	39.1 ^{ef}	318.6 ^{cdef}	106.0 ^{de}	424.6 ^{def}
5	Swartland	31.1 ^{cd}	0.0 ^{b}	31.1 ^{f}	179.1 ^{cdef}	645.1 ^{bcde}	824.2 ^{cdef}
6	Swartland	24.0 ^{d}	2.3 ^{b}	26.3 ^{f}	206.9 ^{cdef}	378.5 ^{de}	585.4 ^{def}
7	Swartland	45.4 ^{cd}	17.7 ^{b}	63.1 ^{ef}	89.6 ^{def}	364.6 $_{de}$	454.2 ^{def}
8	Swartland	58.0 ^{cd}	119.5 ^{ab}	177.5 ^{def}	401.8 abcdef	331.8 ^{de}	733.6 ^{def}
9	Swartland	122.3 ^{cd}	0.0 ^{b}	122.3 ^{def}	188.7 ^{cdef}	524.1 ^{cde}	712.8 ^{def}
10	Swartland	26.5 ^{d}	4.8 ^{b}	31.3 ^{f}	61.2 ^{ef}	1132.9 ^{abc}	1194.1 ^{bcde}
11	Swartland	84.5 ^{cd}	245.8 ^{ab}	330.3 ^{cdef}	555.4 ^{abc}	651.8 ^{bcde}	1207.2 ^{bcde}
12	Swartland	82.0 ^{cd}	2.5 ^{b}	84.5 ^{def}	232.1 ^{cdef}	534.9 ^{cde}	767.0 ^{cdef}
13	Swartland	64.3 ^{cd}	37.9 ^{ab}	102.2 ^{def}	214.5 ^{cdef}	1731.0 ^{a}	1945.5 ^{ab}
14	Rûens & Overberg	62.2 ^{cd}	9.2 ^{b}	71.4 ^{def}	170.7 ^{cdef}	467.6 ^{de}	638.3 ^{def}
15	Rûens & Overberg	235.5 ^{bcd}	0.8 ^{b}	236.3 ^{cdef}	1.7 ^{f}	91.7 ^{de}	93.4 ^{f}
16	Rûens & Overberg	100.1 ^{cd}	0.8 ^{b}	100.9 ^{def}	41.2 ^{f}	667.0 ^{bcd}	708.2 ^{def}
17	Rûens & Overberg	120.5 ^{cd}	0.0 ^{b}	120.5 ^{def}	184.8 ^{cdef}	264.9 ^{de}	449.7 ^{def}
18	Rûens & Overberg	133.7 ^{cd}	10.3 ^{b}	144.0 ^{def}	788.5 ^{ab}	614.4 ^{bcde}	1402.9 ^{abcd}
19	Rûens & Overberg	110.2 ^{cd}	28.0 ^{ab}	138.2 ^{def}	68.1 ^{ef}	116.4 ^{de}	184.5 ^{f}
20	Swartland	214.4 ^{bcd}	7.9 ^{ab}	222.3 ^{cde}	306.6 ^{cdef}	213.9 ^{de}	520.5 ^{def}
21	Rûens & Overberg	357.0 ^{bc}	0.0 ^{b}	357.0 ^{cd}	77.0 ^{def}	160.2 ^{de}	237.2 ^{ef}
22	Rûens & Overberg	293.3 ^{bcd}	0.0 ^{b}	293.3 ^{cdef}	14.2 ^{f}	76.7 ^{de}	90.9 ^{f}
23	Rûens & Overberg	226.3 ^{bcd}	83.0 ^{ab}	309.3 ^{cdef}	500.5 ^{abcde}	1708.7 ^{a}	2209.2 ^{a}
24	Swartland	211.3 ^{bcd}	134.5 ^{a}	345.8 ^{cdef}	945.6 ^{a}	153.9 ^{de}	1099.5 ^{bcdef}
25	Swartland	163.6 ^{cd}	1.2 ^{b}	164.8 ^{def}	178.5 ^{cdef}	31.4 ^{de}	209.9 ^{f}
26	Swartland	249.8 ^{bcd}	6.1 ^{b}	255.9 ^{cdef}	189.2 ^{cdef}	152.4 ^{de}	341.6 ^{ef}
27	Swartland	247.9 ^{bcd}	3.8 ^{b}	251.7 ^{cdef}	162.8 ^{cdef}	212.6 ^{de}	375.4 ^{ef}
28	Swartland	503.0 ^{ab}	4.2 ^{b}	507.2 ^{bc}	259.1 ^{cdef}	221.2 ^{de}	480.3 ^{def}
29	Rûens & Overberg	725.4 ^{a}	0.0 ^{b}	725.4 ^{ab}	115.4 ^{cdef}	43.5 ^{de}	158.9 ^{f}
30	Swartland	698.4 ^{a}	59.5 ^{ab}	757.9 ^{a}	28.6 ^{f}	53.3 ^{de}	81.9 ^{f}
Average		**177.4**	**27.9**	**205.3**	**240.4**	**498.1**	**738.4**

Table 1a - Average number of medic, clover, total legume, grass, broad leaf weed and total weed seedlings m^{-2} on the 30 farms sampled

Farm	Region	Medics (number m^{-2})			Clover (number m^{-2})			
		Barrel	Burr	Total	Rose	Bal-ansa	Sub-Terranean	Total
1	Swartland	3.2^{f**}	1.3^{d}	4.5^{d}	33.4^{a}	2.5^{b}	12.0^{b}	47.9^{ab}
2	Swartland	26.5^{ef}	5.0^{d}	31.5^{cd}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}
3	Swartland	39.5^{cdef}	16.8^{d}	56.3^{cd}	0.8^{b}	0.0^{b}	8.4^{b}	9.2^{b}
4	Swartland	24.6^{ef}	14.5^{d}	39.1^{cd}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}
5	Swartland	26.9^{ef}	4.2^{d}	31.1^{cd}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}
6	Swartland	21.5^{ef}	2.5^{d}	24.0^{d}	0.0^{b}	2.3^{b}	0.0^{b}	2.3^{b}
7	Swartland	29.0^{ef}	16.4^{d}	45.4^{cd}	3.8^{b}	2.5^{b}	11.4^{b}	17.7^{b}
8	Swartland	29.0^{ef}	29.0^{d}	58.0^{cd}	0.0^{b}	4.7^{ab}	114.8^{ab}	119.5^{ab}
9	Swartland	92.0^{cdef}	30.3^{d}	122.3^{cd}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}
10	Swartland	24.0^{ef}	2.5^{d}	26.5^{d}	0.0^{b}	4.8^{b}	0.0^{b}	4.8^{b}
11	Swartland	84.5^{cdef}	0.0^{d}	84.5^{cd}	35.1^{a}	5.9^{ab}	204.8^{a}	245.8^{ab}
12	Swartland	82.0^{cdef}	0.0^{d}	82.0^{cd}	0.0^{b}	2.5^{b}	0.0^{b}	2.5^{b}
13	Swartland	49.2^{cdef}	15.1^{d}	64.3^{cd}	0.0^{b}	0.0^{b}	37.9^{b}	37.9^{ab}
14	Rûens & Overberg	0.0^{f}	62.2^{d}	62.2^{cd}	4.2^{b}	5.0^{b}	0.0^{b}	9.2^{b}
15	Rûens & Overberg	84.1^{cdef}	151.4^{cd}	235.5^{bcd}	0.0^{b}	0.8^{b}	0.0^{b}	0.8^{b}
16	Rûens & Overberg	35.3^{def}	64.8^{d}	100.1^{cd}	0.0^{b}	0.8^{b}	0.0^{b}	0.8^{b}
17	Rûens & Overberg	60.6^{cdef}	59.9^{d}	120.5^{cd}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}
18	Rûens & Overberg	63.1^{cdef}	70.6^{d}	133.7^{cd}	1.3^{b}	6.5^{ab}	2.5^{b}	10.3^{b}
19	Rûens & Overberg	83.1^{cdef}	27.1^{d}	110.2^{cd}	1.3^{b}	7.0^{ab}	19.7^{b}	28.0^{ab}
20	Swartland	152.0^{abcd}	62.4^{d}	214.4^{bcd}	0.6^{b}	6.7^{ab}	0.6^{b}	7.9^{ab}
21	Rûens & Overberg	117.3^{cdef}	239.7^{bcd}	357.0^{bc}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}
22	Rûens & Overberg	253.6^{ab}	39.7^{d}	293.3^{bcd}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}
23	Rûens & Overberg	81.2^{cdef}	145.1^{cd}	226.3^{bcd}	5.9^{b}	4.8^{ab}	72.3^{ab}	83.0^{ab}
24	Swartland	160.2^{abc}	51.1^{d}	211.3^{bcd}	0.6^{b}	4.6^{a}	129.3^{ab}	134.5^{a}
25	Swartland	22.1^{ef}	141.5^{cd}	163.6^{cd}	0.0^{b}	1.2^{b}	0.0^{b}	1.2^{b}
26	Swartland	111.0^{cdef}	138.8^{cd}	249.8^{bcd}	0.0^{b}	6.1^{b}	0.0^{b}	6.1^{b}
27	Swartland	140.0^{bcde}	107.9^{cd}	247.9^{bcd}	0.0^{b}	3.8^{b}	0.0^{b}	3.8^{b}
28	Swartland	107.7^{cdef}	395.3^{abc}	503.0^{ab}	0.0^{b}	3.4^{b}	0.8^{b}	4.2^{b}
29	Rûens & Overberg	272.5^{a}	452.9^{ab}	725.4^{a}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}
30	Swartland	24.7^{ef}	673.7^{a}	698.4^{a}	12.1^{ab}	5.6^{ab}	41.8^{b}	59.5^{ab}
Average		**76.7**	**100.7**	**177.4**	**3.3**	**2.7**	**21.9**	**27.9**

Table 1b - Average number of medic, clover, total legume, grass, broad leaf weed and total weed seedlings m^{-2} on the 30 farms sampled

Farm	Region	Medic (number m^-2^) Barrel	Burr	Total	Total clover (number m^{-2})	Total legume (number m^{-2})
1	Swartland	7.6 ^{g*}	6.1 ^{b}	12.1 ^{b}	242. ^{b}	36.3 ^{b}
2	Swartland	48.4 ^{g}	0.0 ^{b}	48.4 ^{b}	0.0 ^{b}	48.4 ^{b}
3	Swartland	87.8 ^{efg}	27.3 ^{b}	115.1 ^{b}	9.1 ^{b}	124.1 ^{b}
4	Swartland	92.4 ^{defg}	75.7 ^{b}	168.0 ^{b}	0.0 ^{b}	168.0 ^{b}
5	Swartland	101.4 ^{defg}	95.4 ^{b}	198.3 ^{b}	0.0 ^{b}	198.3 ^{b}
6	Swartland	246.8 ^{cdefg}	93.9 ^{b}	339.1 ^{b}	0.0 ^{b}	339.1 ^{b}
7	Swartland	375.5 ^{bcdefg}	84.8 ^{b}	460.2 ^{b}	13.6 ^{b}	473.9 ^{b}
8	Swartland	131.7 ^{cdefg}	63.6 ^{b}	195.3 ^{b}	230.1 ^{b}	423.9 ^{b}
9	Swartland	246.8 ^{cdefg}	198.3 ^{b}	446.6 ^{b}	0.0 ^{b}	446.6 ^{b}
10	Swartland	508.7 ^{bcd}	22.7 ^{b}	531.4 ^{b}	0.0 ^{b}	531.4 ^{b}
11	Swartland	230.1 ^{cdefg}	1.5 ^{b}	231.6 ^{b}	125.7 ^{b}	357.3 ^{b}
12	Swartland	504.1 ^{bcde}	7.6 ^{b}	511.7 ^{b}	0.0 ^{b}	511.7 ^{b}
13	Swartland	528.4 ^{bc}	6.1 ^{b}	534.4 ^{b}	4.5 ^{b}	540.5 ^{b}
14	Rûens & Overberg	101.4 ^{defg}	505.7 ^{b}	607.1 ^{b}	1.5 ^{b}	608.6 ^{b}
15	Rûens & Overberg	115.1 ^{cdefg}	345.2 ^{b}	460.2 ^{b}	0.0 ^{b}	460.2 ^{b}
16	Rûens & Overberg	210.4 ^{cdefg}	372.4 ^{b}	582.9 ^{b}	0.0 ^{b}	582.9 ^{b}
17	Rûens & Overberg	366.4 ^{bcdefg}	295.2 ^{b}	660.1 ^{b}	0.0 ^{b}	660.1 ^{b}
18	Rûens & Overberg	192.3 ^{cdefg}	430.0 ^{b}	622.2 ^{b}	1.5 ^{b}	623.8 ^{b}
19	Rûens & Overberg	160.5 ^{cdefg}	520.8 ^{b}	679.8 ^{b}	39.4 ^{b}	720.6 ^{b}
20	Swartland	327.0 ^{cdefg}	222.6 ^{b}	549.6 ^{b}	1.5 ^{b}	551.1 ^{b}
21	Rûens & Overberg	219.5 ^{cdefg}	370.9 ^{b}	590.4 ^{b}	0.0 ^{b}	590.4 ^{b}
22	Rûens & Overberg	996.2 ^{a}	0.0 ^{b}	996.2 ^{b}	0.0 ^{b}	996.2 ^{b}
23	Rûens & Overberg	317.9 ^{cdefg}	449.6 ^{b}	767.6 ^{b}	28.8 ^{b}	796.3 ^{b}
24	Swartland	221.0 ^{cdefg}	455.7 ^{b}	676.7 ^{b}	239.2 ^{b}	915.9 ^{b}
25	Swartland	383.0 ^{bcdefg}	714.6 ^{b}	1097.6 ^{b}	0.0 ^{b}	1097.6 ^{b}
26	Swartland	487.5 ^{bcdef}	598.0 ^{b}	1085.5 ^{b}	0.0 ^{b}	1085.5 ^{b}
27	Swartland	779.7 ^{ab}	407.3 ^{b}	1186.5 ^{b}	0.0 ^{b}	1186.9 ^{b}
28	Swartland	207.4 ^{cdefg}	905.3 ^{b}	1112.8 ^{b}	0.0 ^{b}	1112.8 ^{b}
29	Rûens & Overberg	510.2 ^{bcd}	1090.1 ^{b}	1600.3 ^{b}	0.0 ^{b}	1600.3 ^{ab}
30	Swartland	68.1 ^{fg}	3465.5 ^{b}	3532.1 ^{b}	43.9 ^{b}	3576.0 ^{a}
Average		**292.4**	**394.4**	**686.7**	**25.4**	**712.2**

Table 2. Average number of non-germinated legume seeds m^{-2} on the 30 farms

The average number of non-germinated medic seeds in the soils (687 m^{-2}) was higher than the number of medic seedlings (177 m-2) and implied that 20.5% of the total medic (seedlings plus non-germinated seed) seed reserve established as seedlings. This proportion was very similar for burr (20.4%) and barrel (20.9%) medics. In the case of the clovers the non-germinated seed (25 m^{-2}) and seedlings (28 m^{-2}) numbers were very similar and 52.8% of the total clover seed reserve established as seedlings. Clover seed was therefore less dormant than the medic seed. This is probably and important factor limiting clover seedling numbers. As in the case of the seedling numbers, the number of non-germinated legume seeds varied significantly ($P < 0.05$) between farms. Soil sampled on farm 30 had the highest number of non-germinated legume seeds (3 576 m-2) while farm 1 had the lowest number (36 m^{-2}). The average number of non-germinated seeds for barrel medic varied between 8 and 996 m^{-2}, for burr medic between 0 and 3466 m^{-2} and for total clovers between 0 and 239 m^{-2}. On average burr medic seeds formed 55.3% of the total number of non-germinated legume seeds, barrel medics 41.0% and clovers only 3.5%. The greater number of non-germinated burr than barrel medic seeds seems to support the research of Kotze, et al. (1995), which showed that a smaller proportion of burr than barrel medic seed is destroyed when ingested by sheep. The danger of overgrazing medic pods during summer, suggested by Carter & Porter (1993), should thus be less of a problem with burr than barrel medics.

A multiple regression analysis was performed using the factors legume seedling and seed numbers, weed and grass and broad leaved weed seedling numbers, soil analysis parameters using only the data for which soil parameters were determined. The only factors which significantly ($P < 0.05$) correlated with legume seedling numbers were total legume seed content and weed seedling numbers. Using all the data sampled statistical relationships were developed between these three factors. A significantly ($P < 0.05$) positive polynomial relationship was derived between the total number of legume seeds and the number of legume seedlings which had regenerated (Figure 1). This emphasizes the importance of maintaining high residual legume seed reserves to ensure the regeneration of adequate numbers of legume seedlings. This supported the view of Carter & Porter (1993) who stressed the importance of maintaining high seed levels. As a smaller proportion the medic than clover seeds regenerated as viable seedlings the percentage of the seed bank which regenerates each year will therefore be determined by the species composition of the seed bank. It also shows that a much greater seed bank of medic than clover seeds are needed to ensure that adequate numbers of legume seedlings regenerate. On the other hand, clover seed populations should be more vulnerable to adverse conditions such as seasons with a false break during odd years, due to unseasonal late summer rains followed by dry hot weather. Significantly ($P < 0.05$) negative relationships exist between the total number of legume seedlings and the total weed seedling and the broadleaf weed seedling numbers (Figure 2).

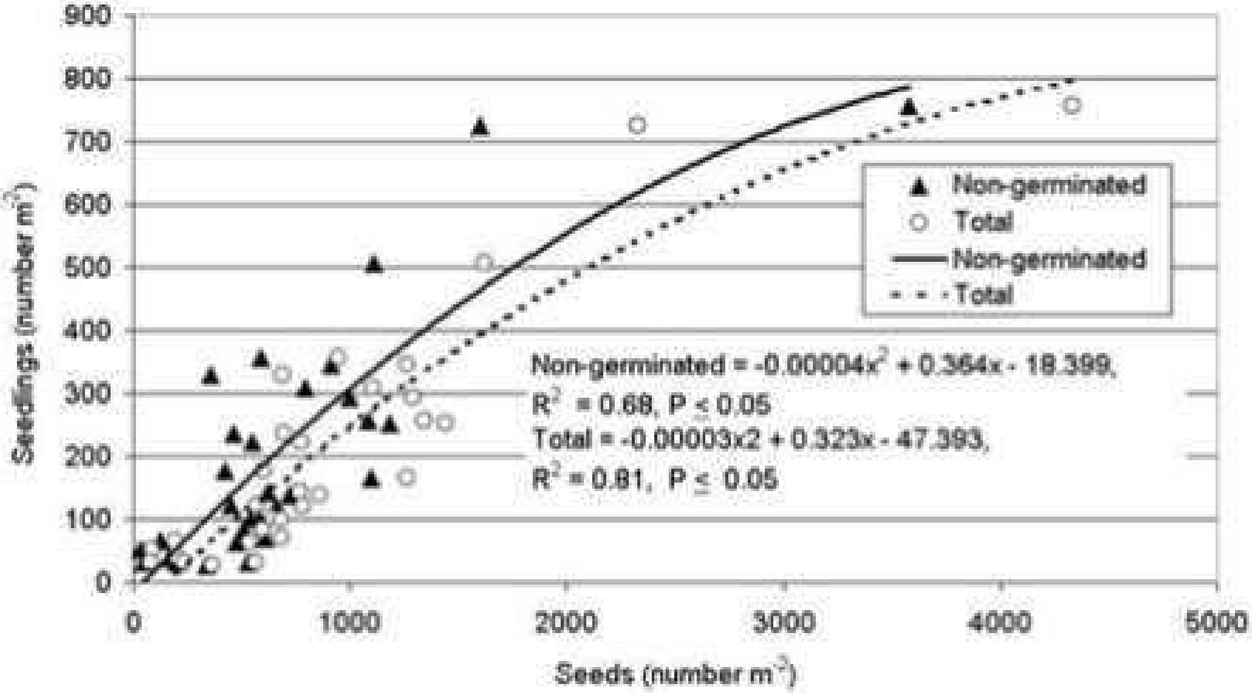

Figure 1. Relationship between the number of non-germinated and total legume seeds and the number of legume seedlings on 30 farms

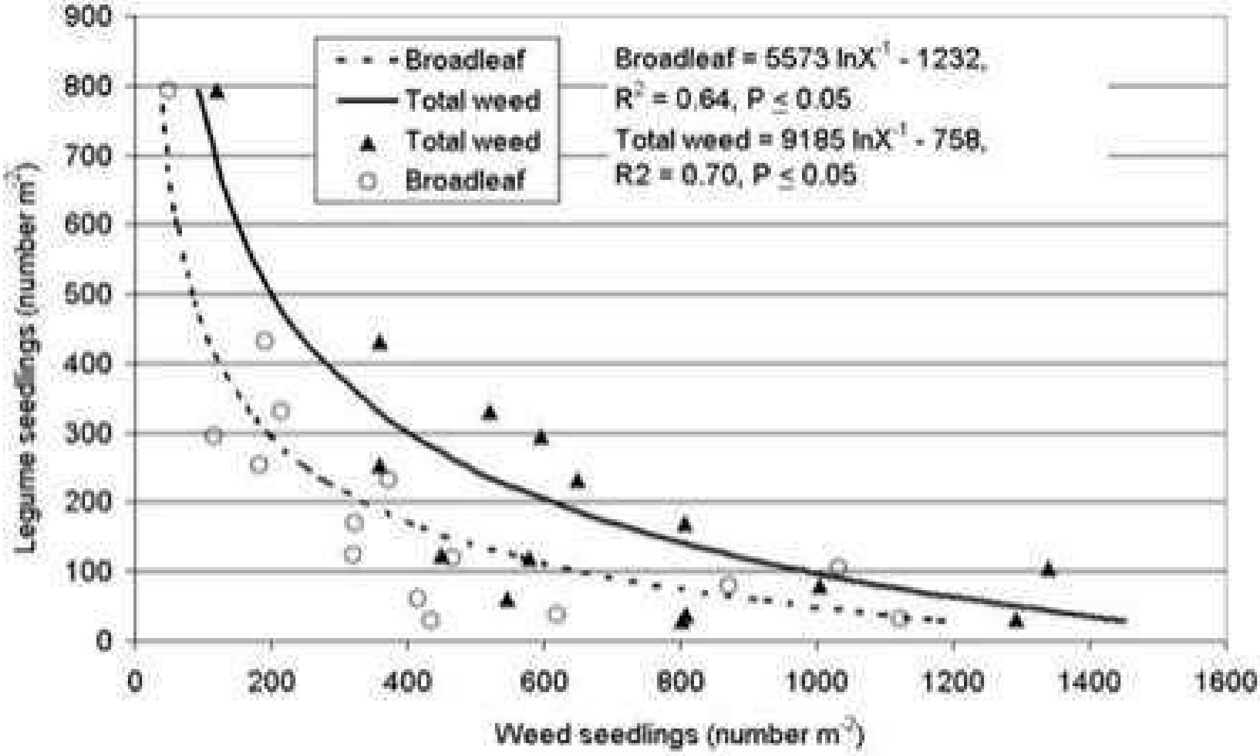

Figure 2. Relationship between the number of broadleaf and total weed seedlings and the number of legume seedlings on 30 farms

No significant relationship was found between the number of grass seedlings and the number of legume seedlings. This can be attributed to the fact that the annual grass weeds were generally effectively controlled by the application of chemical herbicides in the pasture phase of these systems (Le Roux et al., 1995), while it was much more difficult to control broadleaf weeds selectively in this phase. From Figure 2 it seems as if the total weed seedling numbers should ideally be below 100 m-2 in the pasture to ensure maximum legume seedling regeneration.

The data shows that weed infestation may be one of the major factors limiting pasture productivity on commercial farms and can be attributed to the negative influence of weed competition on medic pod and seed production (Van Heerden, 1990). The pastures of farmers who kept weed populations in both their crops and pastures under control, therefore, also had higher numbers of legume seedlings. The increased resistance to the herbicides used in both the pasture and crop phases reported by industry (Pieterse, 2008) may, however, in future result in grass weeds also increasingly becoming a major factor limiting pasture productivity.

Conclusions

The number of legume seedlings which had regenerated in the pastures of most farms (77%), was lower than what is needed to attain high pasture yields. The significant relationships which were derived between legume seed and seedling maintaining high residual legume seed reserves to ensure the regeneration of adequate numbers of legume seedlings. The large difference in legume seedling and non-germinated seed numbers between farms is, however, indicative of a rather serious variance in management practices and the control of broadleaf weeds seem to be the main problem. Farmers are inclined to focus more on weed control during the crop than the pasture phases.

For greater productivity and sustainability of annual legume pastures they should, however, endeavor to also control both grass and broad leaf weeds during the pasture phase. Farmers are reluctant to do this due to the fact that herbicides are expensive and the removal of weeds often reduces grazing capacity. Van Heerden (1990), however, showed that the removal of weeds result in increased medic pod production and improve medic seed reserve levels and thus the sustainability of medic pastures on the long term. The higher proportion of legumes in pastures submitted to adequate weed control should also have a positive influence on individual animal production (Van Heerden & Tainton, 1987, Van Heerden, et al., 1989).

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Utilizing our Rangeland more Effectively: What can We Learn from Wild Herbivores?

Rina (C) C.Grant[1] and Mike J.S. Peel[2]
[1] Scientific Services, SANParks Skukuza rina.grant@sanparks.org
[2] Range and Forage Institute, Agricultural Research Council, Nelspruit
MikeP@arc.agric.za

The increasingly challenging economic climate that livestock and wildlife managers are confronted with necessitates novel approaches to rangeland management. Increasing production while maintaining lower input costs to ensure viable economic and ecological margins is becoming more imperative, but how achievable is this?

We propose that the foraging strategies applied by wild herbivores to utilize the available forage may give us some pointers to such novel approaches. From extensive work on factors that determine herbivore densities and distribution we know that rainfall and soil nutrients and moisture are critical drivers of rangeland ecosystems driving differences in forage biomass, forage nutrient content and species composition (Coe et al. 1976; East 1984; Fritz & Duncan 1994). Thus one would expect the highest density of herbivores in areas with high rainfall and high soil nutrients. Nutrient rich soils have more organic material often with a higher clay content, yielding a grass sward and tree layer with many palatable plant species. The lowest herbivore densities would thus be expected in low rainfall areas on nutrient poor sandy soils.

Why does the Kruger National Park not exhibit the expected herbivore biomass pattern? Research showed that the grazers concentrate on nutritious patches such as sodic sites and termite mounds in the granites (Grant & Scholes 2006) (Figure 2). The same pattern has been described in other studies especially in East Africa where grazing lawns were found to be favoured by grazers (McNaughton 1984); (Augustine et al. 2003). Old kraal sites have also been shown to be attractive to grazers with significantly higher forage nutrients even 40 years after being abandoned (Scholes & Walker 1993; Van der Waal et al. 2011). For many years managers have been primarily concerned about plant production. This concern led to the development of grazing systems aimed at increasing plant production by ensuring that key plant species of high forage quality could produce sufficient biomass to enhance livestock production in the long term.

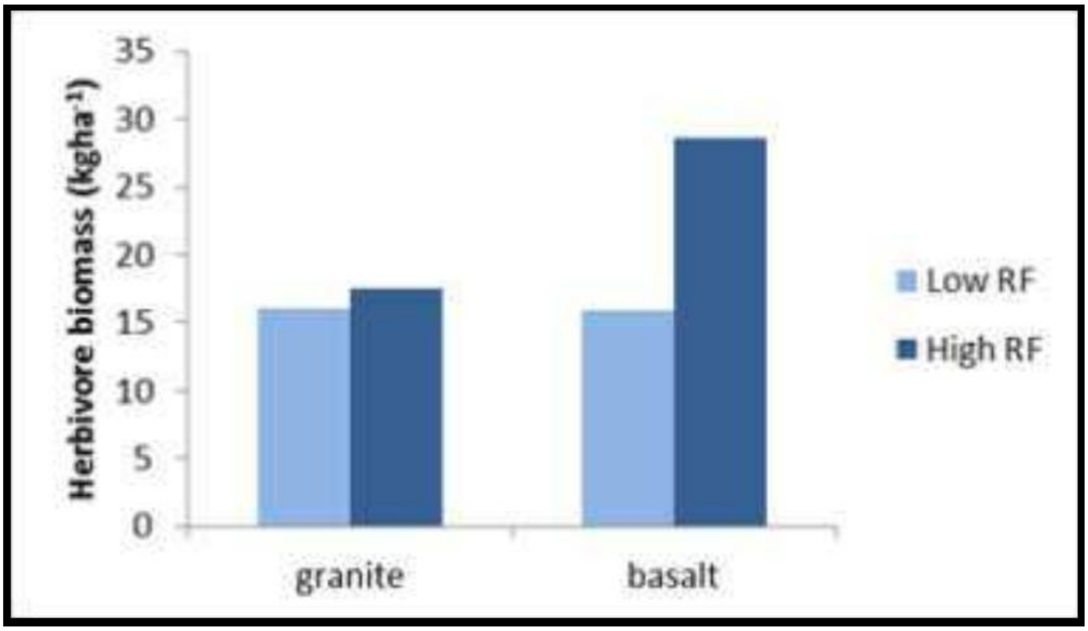

Figure 1. Mean herbivore densities in low and high rainfall zones in the Kruger National Park on low nutrient granites vs. high nutrient basalts.

Figure 2. Selection of short grass forage patch in a granitic landscape.

These systems aimed to ensure uniform animal distribution at a relatively high stocking density, thus avoiding the spatially heterogeneous patch grazing described above. The intention of rotational grazing systems is to improve species composition and production by ensuring a rest period during the growing season (Briske et al. 2008).

Results of research investigating the outcome of these different grazing systems vary, making the selection of appropriate systems difficult. Continuous grazing systems generally perform better than rotational grazing systems. (Briske et al. (2008) compared the production obtained in experiments following different grazing systems to production from continuous grazing. They reported that plant production was equal or greater in continuous compared to rotational grazing in 87% (20 of 23) of these experiments. Animal production per head and per area was equal in 92% (35 of 38) or greater in 84% (27 of 32) in continuous compared to rotational grazing experiments.

The fact that production was generally higher in continuous grazing systems, poses the question whether these animals perform better because they can select and maintain nutritious forge patches as illustrated by the patchy utilization of rangeland by wildlife. Both domestic and wild herbivores require protein and phosphorous rich forage to reproduce and to gain weight (Meissner et al. 1981; Prins & Beekman 1987). These nutrient-rich patches often supply islands of the required high quality forage in a sea of low quality. This raises the question whether the current use of rotational grazing systems should not be re-evaluated to enable animals to utilize and maintain nutritious patches thus enhancing effective animal production in Africa.

Nutritious foraging patches and Herbivore Production

There are a number of types of nutritious foraging patches. The easiest way to identify these are that they are areas of short grass, often within areas of much taller and less utilized grass. Grazing lawns are a striking example of such foraging patches.

A simple definition of grazing lawns is that they are areas where grasses are kept in a short, productive, palatable and digestible state by the action of grazers (after Coetsee et al. 2011). The stoloniferous grasses that are dominant in these lawns, are very short grasses that maintain high cover and production despite severe grazing pressure (Stock et al. 2009). In fact the stoloniferous species occurring on these lawns are able to outcompete the other species under high grazing levels. These lawns tend to form more easily on nutrient enriched sites such as around termitaria, large trees and in lower lying areas where the clay content is higher.

The actively growing grasses are attractive to animals and their continuous presence on these lawns probably increases nutrient concentrations through their dung and urine thus maintaining and enriching these areas (McNaughton 1979; van der Waal et al. 2011). In this system resting causes the replacement of these palatable and productive grasses with less palatable tuft grasses (Archibald 2008) so that the stoloniferous grasses loose the competition with the other grass species, lowering the capacity of the forage and especially lowering the forage quality to support animal production. Although nutritious hotspots can be created naturally by termitaria and large trees (Holdo & McDowell 2004; Treydte et al. 2008), they can also be created by mowing (Archibald et al. 2005) and fertilization (Cromsigt & Olff 2008).

Mowing does not have to be mechanical but bunched cattle and rhinos can also mow lawns to a sufficient height and thereby facilitate other herbivores to utilize these areas too. We still need to establish the ideal ratio between such nutritious patches in the grasslands. First approximations are that these short grass areas should probably not cover more than 30 % of the available forage. We propose that a change in our approach to animal production from rangeland should be considered. Although many of the climax grass species benefit from low utilization and long periods of rest, grazing tolerant grasses can only be maintained at a highly productive and nutritious state by regular defoliation.

Allowing animals to utilize these heterogeneous areas with nutritious patches continuously will reduce management inputs such as supplementation while fencing can be reduced with no production losses. These ideas will be tested further in a range of wildlife areas and on cattle ranches to improve our understanding of the interaction between grazers and the plants that are fed with them. We hope this research will supply a viable alternative to conventional grazing practises.

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