The role of GEOSS in monitoring ecosystems and their services

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Abstract - Global declines in biodiversity and ecosystem services have triggered national and international agreements to halt and reverse these trends (e.g. the Convention on Biological Diversity's target of achieving a significant reduction in the current rate of biodiversity loss by 2010). These agreements have highlighted the need for monitoring systems which accurately describe the conditions and trends of biodiversity and ecosystem services, as well as the drivers of change. GEOSS aims to contribute to these needs in the ecosystems and biodiversity benefit areas. We demonstrate the benefits of GEOSS in the monitoring and assessment of biodiversity and ecosystem services using a case study from a semi-arid biodiversity hotspot in South Africa. Using data poor (non-GEOSS) and data rich (GEOSS) scenarios we highlight the substantial differences found in biodiversity and ecosystem service condition. We link these findings to the need for careful and well informed management of ecosystems in semi-arid regions. We conclude with a summary of the costs and benefits of improved data.

Keywords: Biodiversity, indicators, degradation, overgrazing, cost-benefit

1. INTRODUCTION

Global declines in biodiversity have been more rapid in the past 50 years than at any other time in human history with indications that losses will to continue well into the future with little indication of changes in the drivers that cause them (MA, 2005). These declines are concerning, not just because they represent a substantial loss of life and diversity on earth, but also because they threaten our basic life support systems. Biodiversity makes up these life support systems which provide many benefits (or ecosystem services) to humans. These services include provisioning (e.g. food and timber), regulating (e.g. clean air and water), and cultural (e.g. tourism and spiritual values) services which are important to many components of human well-being, including security, basic material for a good life, health, good social relations, and freedom of choice and action (MA 2005). The Millennium Ecosystem Assessment demonstrated that, in a similar way to biodiversity, most ecosystem services are in a degraded and declining state and will substantially diminish the benefits that future generations obtain from ecosystems, representing a significant barrier to achieving the Millennium Development Goals (MA 2005).

An awareness of these declines, as well as an increasing appreciation of the negative impacts they will have on human wellbeing, have led to a number of national and international agreements and conventions aimed at stopping this degradation of biodiversity and ecosystem services. The Convention of Biological Diversity's target to achieve a significant reduction in the current rate of biodiversity loss by 2010 (UNEP, 2002) is an example of such an agreement. These agreements have highlighted the need for good monitoring systems; and simple and practical indicators to measure progress towards these targets (Reyers *et al*. 2007). At the same time they have pointed to the inadequate data and knowledge currently available with which to populate these indicators and monitoring programs (MA 2005). The absence of well-documented, comparable, time-series information for many components of ecosystems poses significant barriers to the measurement of the condition and trends in ecosystems and their services.

The Global Earth Observation System of Systems (GEOSS), in its 10 year implementation plan, takes note of these needs for improved ecosystem monitoring and aims to provide improved observations of ecosystems for decision-makers in the field of natural resource management at the global, regional and national levels (GEO 2005). It focuses on methods and products of ecosystem extent and ecosystem condition with an ultimate aim of enabling: "the production of spatially-resolved information on ecosystem change, condition and trend, in relation to their capacity to deliver sustainable ecosystem services in sufficient quantities to meet societal needs; i.e. maps of ecosystem health, risk and vulnerability with sufficient resolution to support national and global decision-making".

This study, as part of the EC funded GEOBENE project, aims to assess the benefits of such improvements in earth observation, specifically within the Societal Benefit Areas of biodiversity and ecosystems. It does so using a case study from South Africa where high quality earth observation products are used to assess the condition and trends in ecosystem services. These high quality products are similar to those outlined by the GEOSS 10 year plan. These results are then compared to an assessment of ecosystem services using lower quality earth observation products (a non GEOSS scenario). This comparison allows for the quantification of the benefits of improved earth observation data.

2. METHODS

The study is based in the Little Karoo of South Africa (~19 000 km^2); a semi-arid, intermontane basin, where vegetation associated with three globally-recognized biodiversity hotspots intersects and intermingles. Rainfall varies from < 200 mm to > 1200 mm and high levels of solar radiation (>80%) result in potential evapotranspiration of > 10 times the rainfall (2250 mm/yr). The major form of land-use has, since the 1730s, been extensive grazing and browsing by livestock, chiefly ostriches, but also sheep and goats. Historical records indicate certain districts in this region have been heavily overstocked by cattle, horses, donkeys, sheep, goats and ostriches, leaving large areas of degraded vegetation and soil (Dean & Milton 2003; Cupido 2005).

The area has been the site of a long term research project on ecosystem services and biodiversity and as a result has several high quality databases on biodiversity, ecosystem services and

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land cover. Of particular relevance is a database on the spatial extent of land transformation and degradation of the Little Karoo mapped at a 1:50 000 scale (Thompson *et al*. In Press). This map depicts areas of pristine vegetation and transformed (cultivated and urban) areas, but importantly it also maps moderately and severely degraded areas. Moderately degraded areas are those where although the plant communities have been impacted by grazing, this impact is limited mostly to the trampling and degradation of biotic crusts, some soil loss and declines in the populations of palatable species. Severely degraded areas have been substantially overgrazed and have no biological soil crusts, severe soil loss and totally altered plant communities (complete loss of palatable species). Land degradation was quantified using a novel technique, based on intra-annual variance in NDVI values, calibrated for different vegetation units mapped at 1: 50 000 scale, and ground truthed via expert assessment (Thompson *et al*., In Press).

These land cover data, as well as spatially explicit data on biodiversity and the ecosystem services of forage for livestock grazing, water flow regulation, carbon storage, erosion control and tourism were collated. Using data extracted from (Rouget *et al*. 2006; Reyers *et al*. In Press) on the ecosystem specific impacts of land cover on biodiversity and each ecosystem service, the study quantified changes in biodiversity and ecosystem services as a result of land cover change in the Little Karoo. As the land cover data were only available for 2005, our analyses are based on the difference between the 2005 data and the pre-colonial condition where all areas are assumed to be pristine (as per Scholes and Biggs 2005). This assessment represents what would be possible if GEOSS were in place and is termed the "GEOSS scenario".

We then repeated the above methods, but this time using land cover data available at a national scale. These data, suitable for 1:50 000 scale applications, were derived from seasonal (two seasons satellite imagery), ortho-rectified, standardised, high resolution digital satellite imagery from Landsat 7 Enhanced Thematic Mapper (ETM+), which were acquired principally during 2000 – 2002. No ground truthing, post processing or expert assessment was performed on these data. This assessment of ecosystem service and biodiversity condition was chosen to represent the "non-GEOSS scenario".

3. RESULTS

The results of the GEOSS scenario assessment indicate that the Little Karoo's is currently comprised of 38% natural vegetation cover with another 10% cultivated or urban areas; the remainder is made up of moderately (37%) and severely (14%) degraded areas (Figure 1). The non GEOSS scenario shows the Little Karoo has 93.6% of its areas still covered with natural vegetation and only 5.8% in cultivated or urban areas; the remainder of 0.7% is classified as degraded (with no distinction between severe or moderate levels of degradation).

This large discrepancy in land cover composition has implications for the assessment of biodiversity and ecosystem service condition. An indicator of biodiversity condition called the Biodiversity Intactness Index (BII), provides a score of 65.4% for the GEOSS scenario, while the non GEOSS provides a score of 86.5% (Rouget *et al*. 2006). The Biodiversity Intactness Index is a measure of the average population size (abundance) of all well-described taxa, relative to their reference populations in a particular ecosystem type (nominally those of the pre-colonial period; Scholes and Biggs 2005).

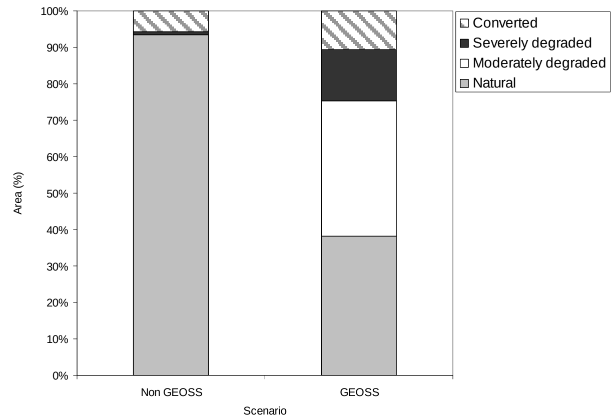

Figure 1: Land cover categories and percentage coverage based on GEOSS and non GEOSS scenario databases for the Little Karoo of South Africa.

These changes in biodiversity condition, as well as the assessed changes in ecosystem services are reflected in Figure 2. The changes are represented as proportions of the potential supply of the ecosystem service for both GEOSS and non GEOSS scenarios. When compared to potential service supply, the GEOSS scenario demonstrates that erosion control shows the largest declines (44%), followed by forage production, carbon storage and tourism viewsheds (25, 27 and 28% reductions); water flow regulation shows the smallest decline of 18% in potential volume of the sustained flows. The non GEOSS scenario finds < 10% declines in most ecosystem services and a 15% decline in the service of erosion control.

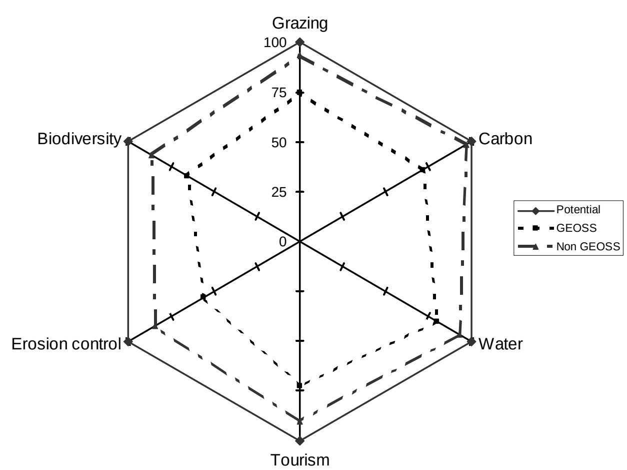

Figure 2: Changes in ecosystem service supply in the Little Karoo, based on GEOSS and non GEOSS scenario databases. Change is reflected as a percentage of the potential supply (nominally that of the pre-colonial period).

When converted these difference between the GEOSS and non GEOSS scenarios (Figure 2) into actual ecosystem service quantities which equate to: over 5000 Large Stock Units, 28 million tons of Carbon, 61 million cubic meters of water, 1000 km^2 of tourism viewsheds and 8 hectares of areas important to erosion control.

4. DISCUSSION

The results of the above GEOSS scenario for ecosystem service and biodiversity assessment provides important information on the current status and capacity of the ecosystems of the Little Karoo, as well as the magnitude of recent changes in these ecosystems and their services. They highlight the substantial impact of land cover change on ecosystem services in the Little Karoo, particularly the impact of extensive overgrazing and subsequent degradation. They point to the fact that past land-use decisions have driven the Little Karoo into a tight corner – with decreased ecosystem service levels, threatened biodiversity, high unemployment levels and narrowing future options for the region and its inhabitants. The assessment provides useful and accurate information on the current state and vulnerabilities of the region's ecosystems and emphasizes the need to make careful land use decisions in the future. It also shows that the region is not meeting its or the country's targets in terms of biodiversity conservation and ecosystem service management.

The results of the non GEOSS scenario assessment tells a very different story of relatively intact ecosystems with biodiversity and ecosystem service levels very similar to what they were during pre-colonial times. It contradicts many studies in the region which highlight the significant declines in ecosystem health and human wellbeing in the region (e.g. Le Maitre *et al.* 2007; O'Farrell *et al.* 2008). The message a decision maker could take from this assessment would be one of good ecosystem state and capacity and little need to change any of the current management practices or land uses.

5. CONCLUSION

For a relatively small investment of 9000 Euros for the GEOSS scenario land cover data (Rouget *et al*. 2006), the study demonstrates substantial improvements in our ability to monitor the condition of the ecosystems of the Little Karoo. It would be useful to be able to contrast this investment with the benefits realized, however the procedure for quantifying the economic benefits of improved environmental information is poorly developed. What we can do is to compare the costs of better data with the costs of bad decisions resulting from absent or weak data. Here Herling *et al*. (In Press) estimate a cost of 2000 euros per hectare to restore overgrazed and degraded land in the Little Karoo. This works out at more than 500 million Euros to restore all severely degraded pieces of land. This is a cost that could potentially have been avoided with good data, early warning and informed management decisions. A further cost related to inappropriate management decisions is the cost of flood damage. In the Little Karoo region floods associated with a cut-off low (a relatively common occurrence in this part of the world) incurred damages to agriculture and infrastructure totaling R35.3 million Euros in 2006. Some of the damages and costs could have been minimized through informed management of human land uses, especially in degraded areas important to erosion control.

The key emergent message from this case study is that small strategic investments in earth observation systems can have disproportionately large effects on our ability to manage biodiversity and ecosystem services. However, determining what the optimal investment in such systems is remains clouded by our inability to quantify the benefits of improved ecosystem management.

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