VERIFICATION REPORT ON THE GLADA LAND DEGRADATION STUDY WITH THE TITLE:

Land Degradation and Improvement in South Africa

Identification by Remote Sensing

by

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CONTENTS

1. INTRODUCTION

The implementation of the Land Degradation Assessment in Drylands (LADA) programme in South Africa has been included as one of the deliverables in the Strategic Plan of the Department of Agriculture since 2007. One of the first activities in the LADA work plan is the review of the *Global Assessment of Land Degradation and Improvement* (GLADA) products and methods developed by the International Soil Reference and Information Centre (ISRIC) in Wageningen, Holland (Bai and Dent, 2007).

This project was undertaken to meet the need for quantitative, up-to-date information to support policy development for food and water security, environmental integrity, and economic development. The main aim of this project was to map land degradation and improvement according to change in net primary productivity (NPP, the rate of removal of carbon dioxide from the atmosphere and its conversion to biomass).

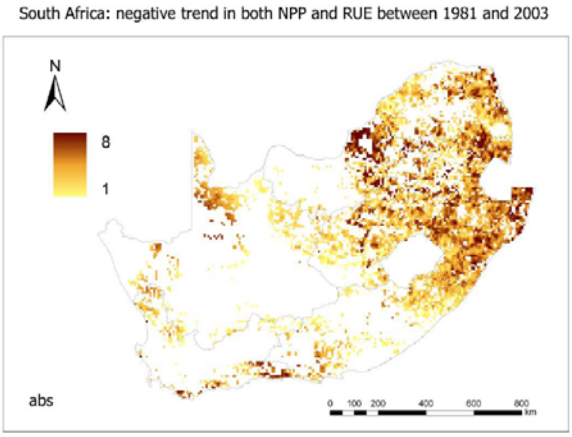
Satellite measurements of the normalised difference vegetation index (NDVI or greenness index) for the period 1981-2003 was used as a proxy for NPP. According to the report NDVI data have been widely used in studies of land degradation from the field scale to the global scale (e.g. Tucker and others 1991, Bastin and others 1995, Stoms and Hargrove 2000, Wessels and others 2004, 2007, Singh and others 2006). It was however stated that remote sensing can provide only indicators of land degradation and improvement: a negative trend in greenness does not necessarily mean land degradation, nor does a positive trend necessarily mean land improvement. Greenness depends on several factors including climate (especially fluctuations in rainfall, temperature, sunshine and the length of the growing season), land use and management; changes may be interpreted as land degradation or improvement only when these other factors are accounted for. Where productivity is limited by rainfall, rain-use efficiency (RUE, the ratio of NPP to rainfall) accounts for variability of rainfall and, to some extent, local soil characteristics. RUE is strongly correlated with rainfall; in the short term, it says more about rainfall fluctuation than land degradation but we judge that its long-term trends distinguish between rainfall variability and land degradation. To get around the correlation of RUE with rainfall, Wessels and others (2007) have suggested the alternative use of residual trends of NDVI (RESTREND) – the difference between the observed NDVI and that modeled from the local rainfall-NDVI relationship. In their report, land degradation is identified by a declining trend in *both* NDVI and RUE; in addition the comparable RESTREND values were also presented.

2. EVALUATION PROCEDURE

The evaluation of the GLADA report on Land Degradation and Improvement in South Africa was based on:

- Field and visual verification by the Department of Agriculture
- An expert evaluation of the methodology and results by professor MC Laker
- A review of the applied methodology by Dr. K Wessels

The main aim of this report is to give a brief overview of field observations, SPOT 5 data interpretation as well as expert knowledge regarding the accuracy of the negative and positive trends for both NPP and RUE between 1981 and 2003 (Figure 1). **It is by no means a comprehensive verification of the spatial data produced in the report although dedicated field observations were conducted to support some of the expert observations.**



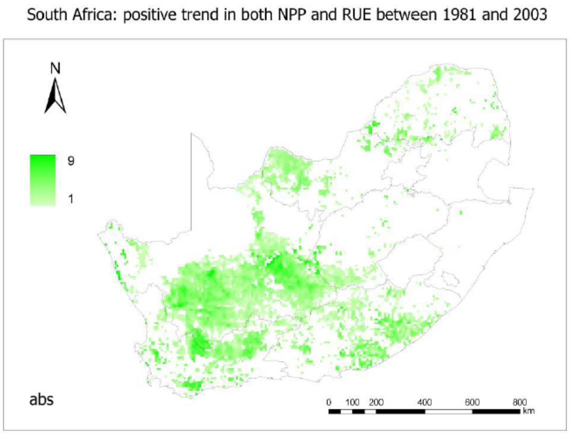


Figure 1. Negative and positive trend analysis for NPP and RUE between 1981 and 2003 (GLADA report).

A total of 165 sites were selected to investigate the accuracy of the GLADA results (Figure 2). Most of these sites were selected in areas that showed high negative NPP and RUE trends. The main reason for this was the obvious high negative trends in the eastern, higher rainfall as well as higher productive parts of the country.

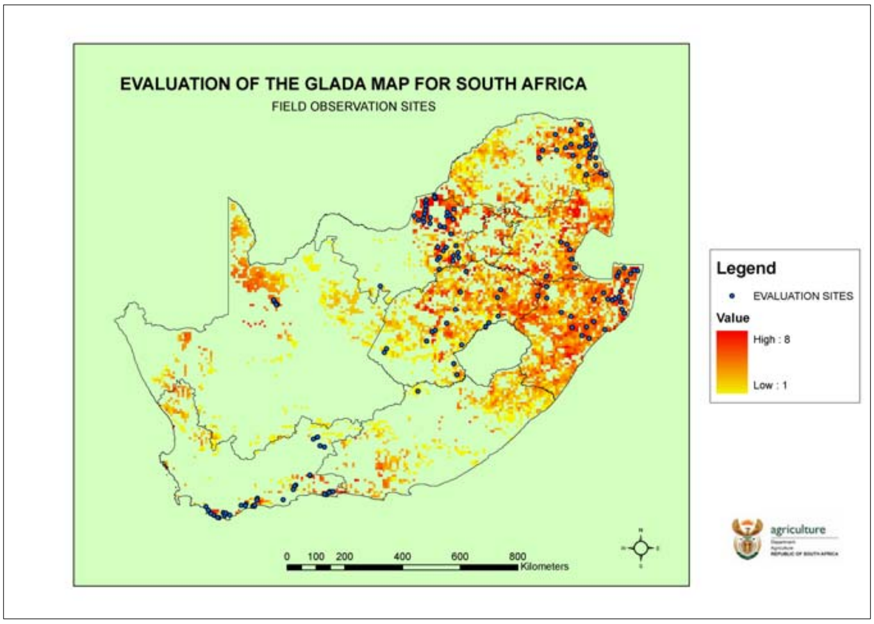


Figure 2. Position of field observation sites on the GLADA negative trend map.

The field/SPOT 5 data were compared with the GLADA results by means of a GIS zonal statistics procedure (extract raster data values). The negative trend value was extracted at the exact field observation point as well as for an 8 kilometer buffered area around the point – here the majority value was compared with the observed degradation status (Figure 3).

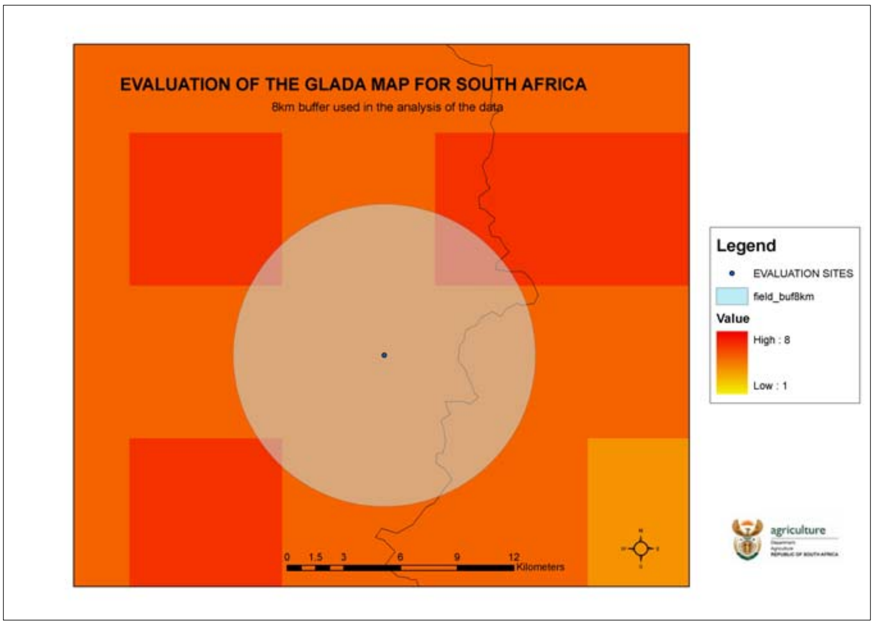


Figure 3. GLADA results were extracted for point as well as an 8km buffered area.

3. RESULTS

As indicated earlier the focus of the evaluation was not to perform a comprehensive verification of the spatial data produced in the report but to try and identify major problem areas that will need further investigation.

The zonal statistics analysis (165 sites analysed) indicated a 33% and 48% correlation between the observation and negative trend GLADA data for the point and 8km buffered areas (majority values). At this stage it is difficult to debate which figure is statistically the most acceptable. Due to the fact that there are always errors in the spatial geo-referencing of satellite data the buffered values could be more reliable.

From an analysis of the results of the 8km buffer zonal statistics data the following main problems with the GLADA data were identified:

3.1 Plantations

During the first field visit with officials from ISRIC, FAO and the CDE in October 2007 in the Mpumalanga Province it was pointed out that areas under plantations came out as highly degraded on the GLADA negative trend map. During follow-up visits in Mpumalanga and KwaZulu/Natal the same problems were identified. Some of the reasons for these errors might be the clearing of trees and plantation fires. The areas that were however identified as degraded are too large to be influence by the above factors. Very little obvious degradation could be observed during the field investigations. Examples of plantation areas that are classified as highly degraded are presented in Figures 4 and 5 (zoomed in).

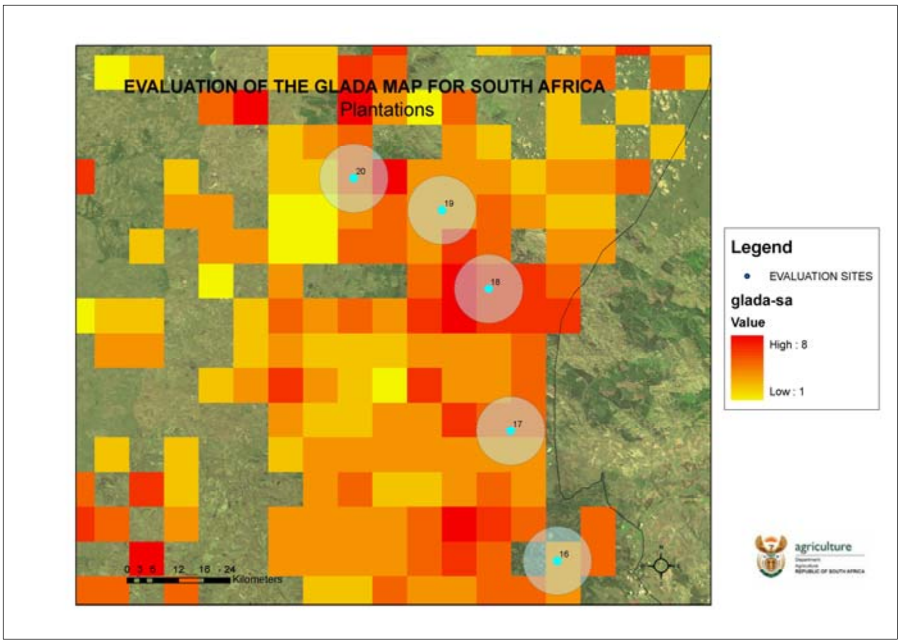


Figure 4. Plantation areas in the Mpumalanga Province classified as highly degraded on the GLADA negative trend map.

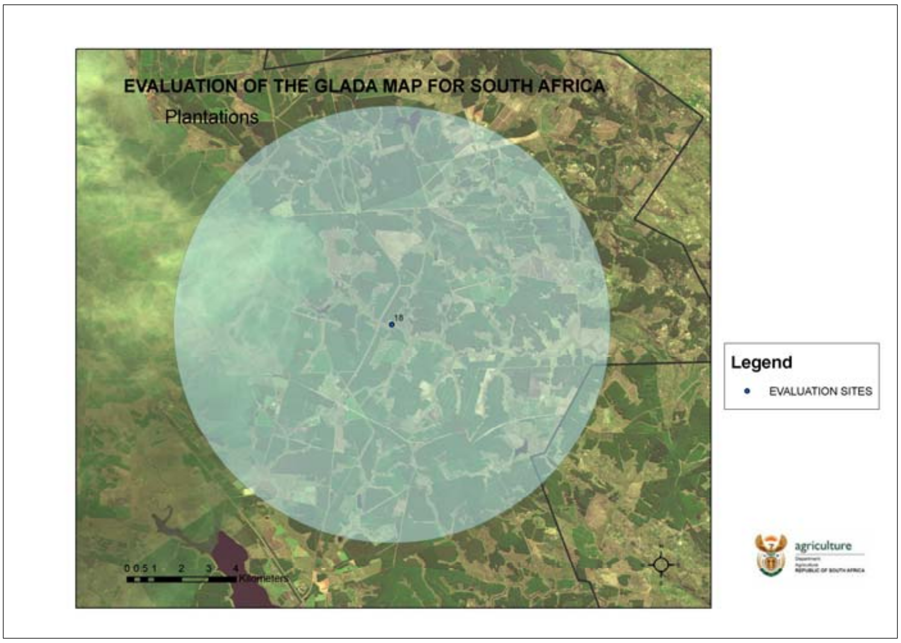


Figure 5. Example of plantations classified as highly degraded on the GLADA negative trend map (zoomed in – SPOT5 data only).

3.2 Conservation areas (Kruger Park)

During the first field visit in 2007 in the Mpumalanga Province the southern part of the Kruger National Park, also classified as highly degraded, was visited. Although some isolated overgrazing on duplex soil do occur in this region it can not be classified as highly degraded. On the GLADA negative trend map this area is even more degraded than the previous Self Governing Territory of Kangwane, bordering the park on the west (Figure 6).

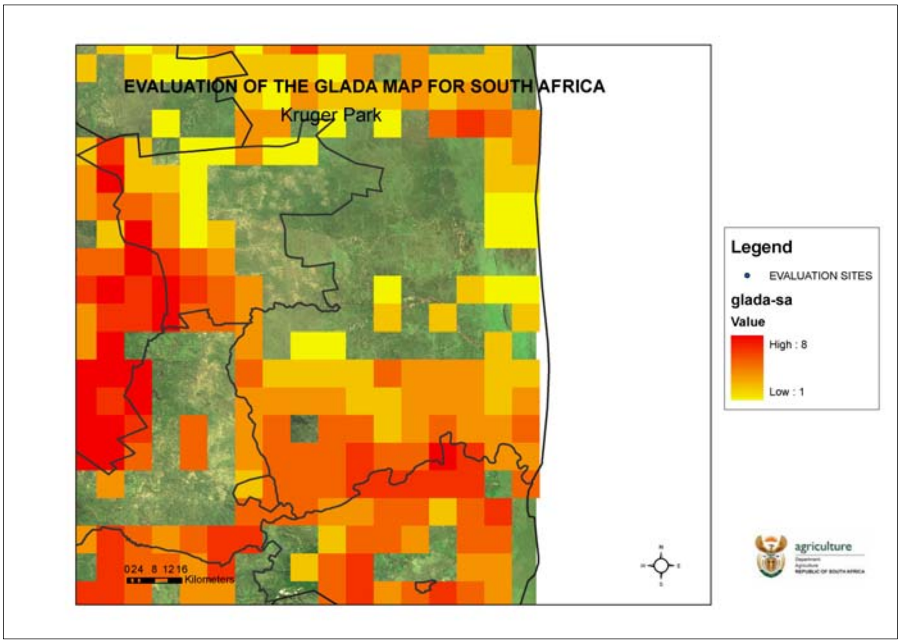
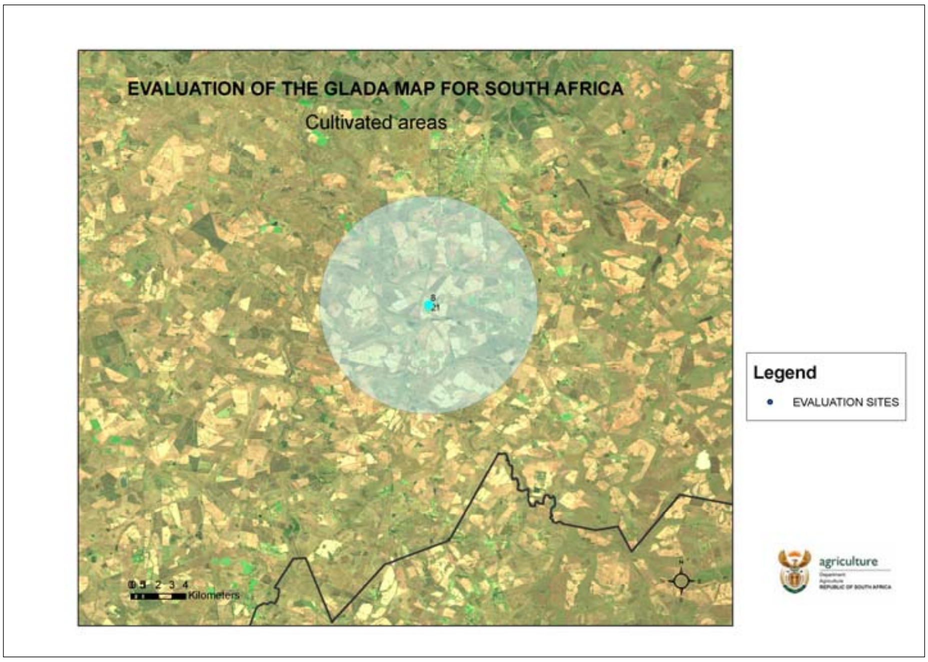
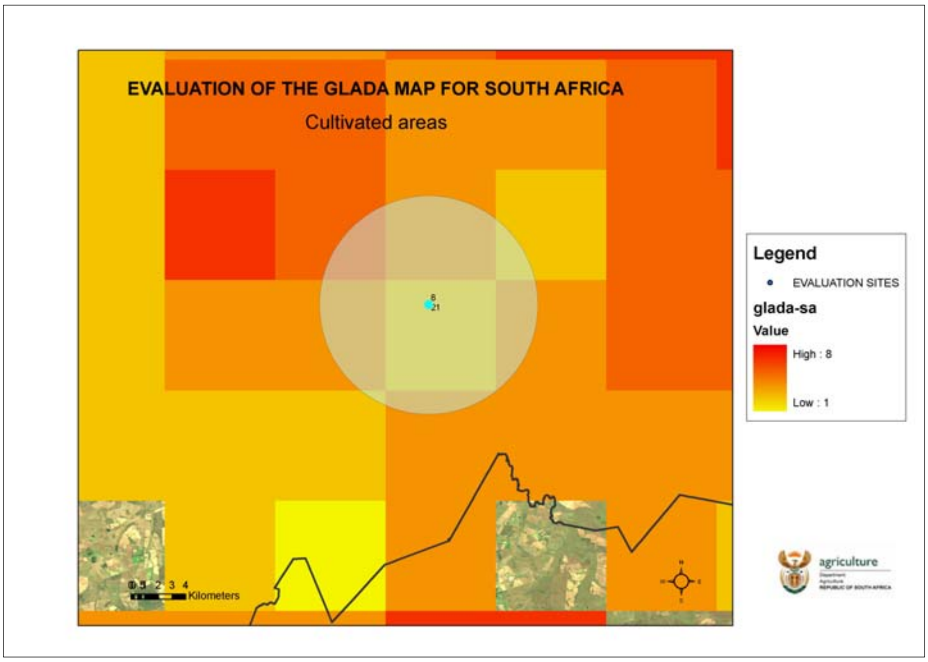


Figure 6. Southern part of the Kruger National Park that is classified as highly degraded on the GLADA map.

3.3 Cultivated areas

One of the major concerns regarding the GLADA results is the fact that large areas under cultivation are classified as highly degraded (Figures 7 and 8). These areas are in general the high potential cropping areas in South Africa where conservation management practices, like contouring, grass strips and waterways, are generally in place. The application of fertilizer and lime where needed is also a standard practice. The yield on these areas are however influenced to a large extend by rainfall. This is however true for vegetation in the entire South Africa. Reasons for the negative trend in NPP and RUE could only be explained by rainfall variability, crop rotation and the fallow fields.





Figures 7 and 8. Cultivated areas classified as degraded on the GLADA map.

3.4 Degraded arid areas

Another big concern is the positive and low negative trends in NPP and RUE in the central, drier parts of South Africa (Figures 9 and 10). Large parts of these areas are dominated by Karoo Sediments (mudstones and shales) and subsequently soils with a very high erodability. The only reasons why these misclassifications occurred could be due to the lack of vegetation or again the influence of rainfall. Some of the most serious overgrazing and erosion occur in these areas.

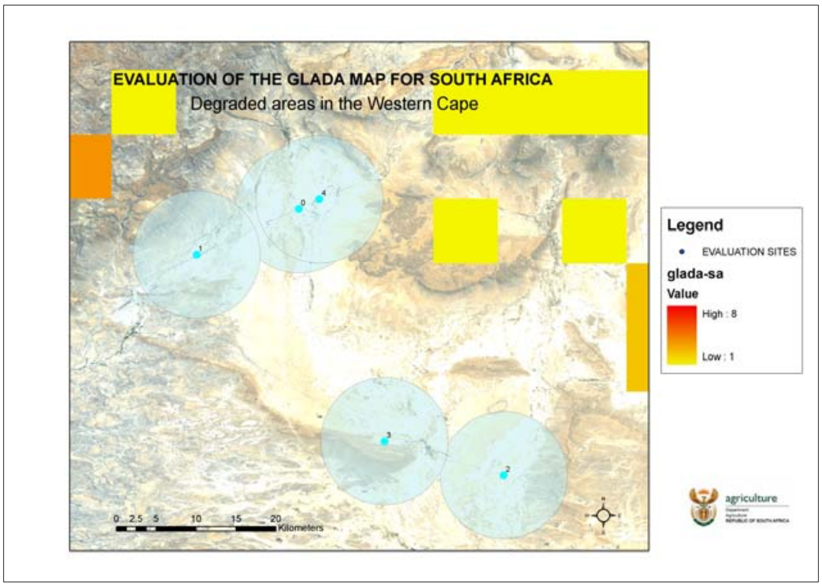


Figure 9. Degraded areas in the Western Cape not classified as degraded on the GLADA map.

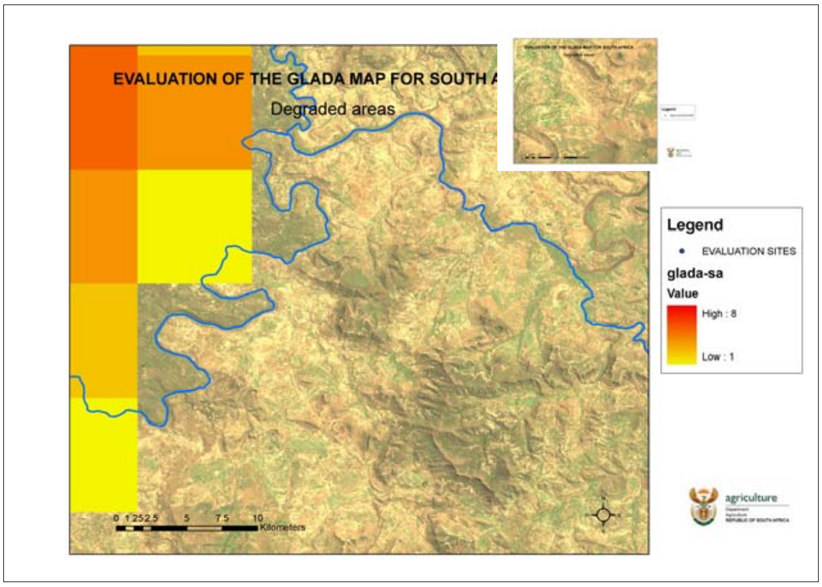


Figure 10. Degradation in the Sterkspruit area (known for its high degradation status) not classified as degraded on the GLADA map.

3.5 Kalahari Dune Veld

A special effort was also made to verify some of the negative NPP and RUE trends in the north western part of South Africa – Kalahari Dune Veld. Although some overgrazing and bush encroachment do occur in some areas the classification of vast areas as degraded on the GLADA map is very strange (Figure 11). During field visits to some of the sites in this area no obvious degradation could be identified. The area between Noenieput, Askham and Pearsons Hunt is, according Dr. Herman Fouche from the Agricultural Research Council (personal communication), not degraded to the extent as indicated on the GLADA map. It must however be noted that this area reacts vigorously to rainfall/droughts – possible cause for misclassification. More dedicated fieldwork is however necessary to verify these vast areas.

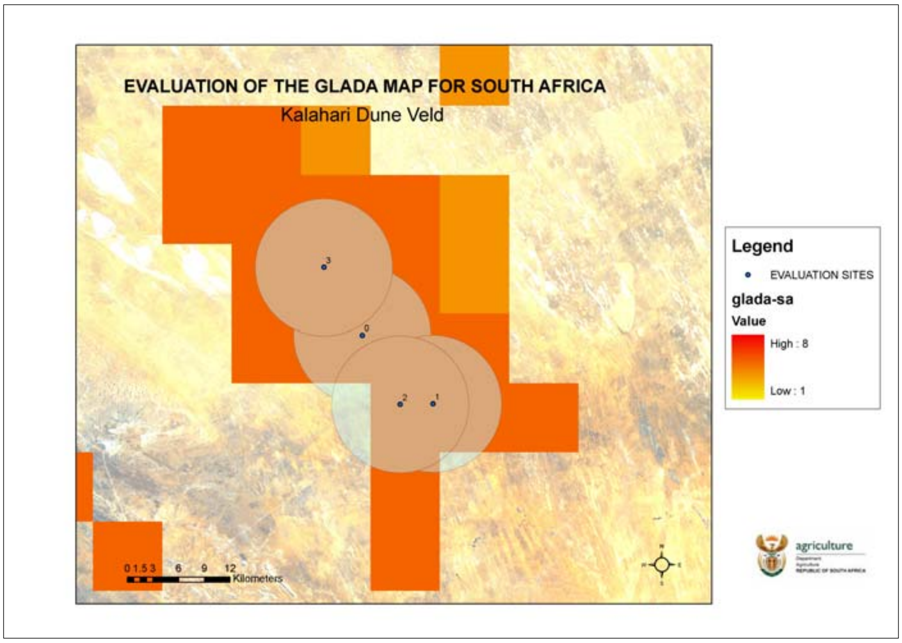


Figure 11. Areas in the Kalahari Dune Veld classified as degraded on the GLADA map.

4. CONCLUSIONS AND RECOMMENDATIONS

In the light of the above discussions it is evident that the GLADA land degradation and improvement mapping methodology used to produce the negative and positive trends maps for South Africa needs serious rethinking. Major problems on the negative NPP and RUE trend map were prominent in the following areas:

- Plantations in most parts of the country
- Conservation areas – focus on the Kruger National Park
- Cultivated areas
- Degraded arid areas
- Kalahari Dune Veld

The main reasons for the problems could be rainfall related. In recent discussions with Dr. Konrad Wessels he stated that even his RESTREND model contains some serious limitations. It seems to be a fact that a method to map and monitor degradation at a global level at an acceptable level of accuracy has yet to be developed. Other reasons for the inaccuracies could be:

- Arid and semi-arid areas with a low vegetation cover in general react more vigorously to rainfall than humid areas. Degradation in these areas should rely more on GIS based prediction models with soil type, rainfall intensity, slope and management practices as variables.
- The NPP and RUE for plantations are also open for discussion. In general one would expect rainfall to have a very little effect on NPP values for plantations. Due to calibration differences in the NOAA-AVHRR data the RUE trends in plantations could be misleading. It is suggested that plantations should be masked out in the final degradation map.
- Degraded areas with little to no vegetation cover could definitely not be included in the NPP and RUE analysis – no vegetation (destruction of the seed beds and removal of topsoil) in these areas could lead to serious misinterpretations. Degradation information regarding these areas could be mapped from Landsat or even MODIS satellite data – the GIS prediction approach could also be followed.
- It is suggested that cultivated areas also be excluded from the NPP and RUE analysis. Factors like intercropping, rainfall variability and fallow fields definitely contribute to the classification errors in these areas.

It is also recommended that a multidisciplinary approach be followed to produce a global land degradation and improvement map. Different techniques should be used to determine the status of different land cover/use classes. If this approach is not possible the global assessment should again be based on expert opinions, as the case with the national assessments.

To conclude the National Department of Agriculture doesn’t approve any publications of the Degradation and Improvement report for South Africa as an indication of the current state of the natural resources. Serious errors are contained in the NPP and RUE trend maps. Although some correlations do exist between the maps and field investigations at selected sites there are also major discrepancies.

Comments and recommendations in this report must be viewed in a positive light. The commitment from ISRIC’s side on the assessment must not be underestimated. It is however also the commitment of DoA and others in South Africa to assist with the refinement of a global methodology to map/monitor degradation and improvement.

5. ACKNOWLEDGEMENTS

The following contributions are acknowledged:

Prof. M C Laker and Dr. K J Wessels for their evaluation of the report.

Mr. M Samadi for project coordination and review of draft report.
Personnel from DoA who assisted with fieldwork.
Mr. H J Lindemann for advice and support.

GLADA: SOUTH AFRICA

RESPONSE TO THE DRAFT DOCUMENT BY Z.G. BAI & D.L.DENT (2007) TITLED *“LAND DEGRADATION AND IMPROVEMENT IN SOUTH AFRICA. 1. IDENTIFICATION BY REMOTE SENSING”*

By Professor MC Laker

1. TERMS OF REFERENCE

The terms of reference given to the compiler of this response were (e-mail from M. Samadi, ARC-ISCW, March 10, 2008):

> *GLADA Map of South Africa: negative trend in both NPP and RUE between 1981 and 2003 (ISRIC product): Evaluate the map using your field knowledge. The Bai & Dent report of Nov. 2007 "Land Degradation and Improvement in South Africa" can be used as a background information.*

2. PROCEDURE

As requested in the terms of reference, the author drew comprehensively on his extensive field knowledge of various types of soil degradation throughout South Africa. He also drew comprehensively on existing published and unpublished data on soil degradation in South Africa with which he is well-acquainted, *inter alia* due to being involved in the compilation of review papers and reports on existing knowledge on soil degradation in the country. The most recent ones include unpublished comprehensive reviews of existing knowledge on soil erosion and physical soil degradation respectively, which he compiled for the National Department of Agriculture in 2007. The author also obtained additional information specifically for evaluation of the mentioned GLADA map and report of Bai & Dent.

It is not possible to comment on the map on negative trends in NPP and RUE combined (which can also be called the map on land degradation trends) in isolation. In order to present a logical response, it is necessary to also comment on various aspects of the report itself and other maps and graphs in the report.

3. INTRODUCTION TO THE BAI & DENT REPORT

Bai & Dent (1st page, 2nd paragraph) state that GLADA *“assesses the state and trends of land degradation and identifies areas suffering severe constraints, or at severe risk, and areas where degradation has been arrested or reversed. In the parent programme Land Degradation Assessment in Drylands, areas identified by this first screening will be further characterised in the field by national teams.”*

Bai & Dent make it clear that their report is not aimed at identifying types (kinds) of degradation, state (degree and extent) of degradation or causes of degradation. It only looks at recent (1981-2003) trends in degradation. In this regard it differs from previous studies on land degradation. The GLASOD survey, for example, looked at type, degree, extent, rate and causes of degradation as one package. (The author contributed the GLASOD inputs for South Africa, Lesotho and Namibia.)

Bai & Dent explain the rationale of the GLADA approach as follows (p.26, last bullet): *"The data from a defined, recent period enable us to distinguish between the legacy of historical land degradation from land degradation that is taking place now. For many purposes, it is more important to address present-day land degradation."*

Bai & Dent make use of an indirect method, viz. trends in "greenness" (NDVI) – as indicator of NPP – to derive trends in land degradation over the chosen period. This is why the eventual answer of this "first stage" analysis is an amorphous "faceless" one that does not give any information on type, degree, extent or cause of degradation. It must be kept in mind, however, that this first stage analysis by Bai & Dent is simply meant to identify actively badly degrading areas (hot spots) and improving areas (bright spots). They point out that patterns identified on the basis of NDVI indices, derived from remote sensing, must then be followed up by field investigation of identified areas, undertaken by national teams within the LADA programme, to determine the actual situations.

In view of the previous paragraph it is clear that the primary objective of this evaluation should be to determine whether the Bai & Dent map depicting the trend in NPP and RUE combined (i.e. depicting the trend in land degradation) is a correct, appropriate, suitable basis for the identification of areas for follow-up fieldwork.

4. EVALUATION OF THE BAI & DENT REPORT – WITH EMPHASIS ON EVALUATION OF FIGURE 10, DEPICTING THE NEGATIVE TREND IN COMBINED INDEX OF NPP AND RUE 1981-2003

Methodology used by Bai & Dent

As indicated in Section 3, Bai & Dent used trends in NDVI to determine trends in land degradation and land improvement in South Africa during the period 1981-2003. They describe NDVI as a satellite measurement using the difference between reflected near- infrared and visible wavebands divided by the sum of these two wavebands, or greenness index (Page 1, 3rd paragraph).

NDVI is then "translated" to net primary productivity (NPP), i.e. biomass productivity (Page 6, Point 3). According to Bai & Dent: *"Mean annual sum of NDVI representing the aggregate of greenness over the whole year is chosen as standard surrogate for mean annual biomass productivity."*

Bai & Dent correctly state that: *"A negative trend in NDVI/NPP does not necessarily indicate land degradation; nor does a positive trend necessarily mean land improvent."* They relate this to the fact that NPP depends on several variables, of which they mention fluctuations in rainfall, sunshine and length of the growing season, as well as land use – and that *"NPP trend may be interpreted as land degradation or improvement only when these factors are accounted for"*.

Comment: There is a major basic error and problem in using NDVI as indirect method for assessing trends in land degradation or improvement: It cannot distinguish between canopy cover and basal cover. Dense basal cover is the only effective protection against soil erosion , and even soil crusting. Canopy cover without basal cover cannot achieve this. Bush encroachment into grasslands and bush densification in savannah and encroached grassland are major, and very serious, forms of land degradation. With "bush encroachment" and "bush densification" is here meant encroachment and densification (increased tree numbers per unit area) of ***indigenous*** trees or shrubs. These are widespread problems in various sub-humid to semi-arid areas of South Africa. An extremely serious consequence is that growth of grasses is seriously reduced – often completely eliminated – once the trees reach a certain density. Thus the basal cover is seriously reduced and often completely eliminated, leaving the soil surface exposed to water erosion. Water erosion is usually very severe in such situations, but the satellite cannot pick it up. What it "sees" is usually even a much greener surface, due to the dense canopy growth, and identifies it as a positive trend. In more arid areas the encroachment is by short shrubs and scrub into grassland, with the same consequence for erosion as above.

Bai & Dent accounted for rainfall variability by introducing the concept of rain use efficiency (RUE), which is the ratio of NDVI to rainfall. They state that: *"For South Africa, RUE was calculated as the ratio between annual aggregated NDVI and station-observed annual rainfall on a yearly time-step."*

Comments:

1. Because NDVI is a component of it, RUE has the same inherent error as described in the comment above.
2. Using total annual rainfall is very simplistic and is not really related to reality. A year with very high rainfall can be very unproductive, because a lot of the rain might have come in a very short space of time. By far the biggest proportion of it can be lost due to runoff and often causes severe flood damage, the scars of which would then be observed as a negative outcome of the rain. It may have negative impacts on NDVI for many years afterwards. Conversely, a year with quite moderate rainfall can be highly productive if the rains are well-distributed and come at the right time of the season. Specific cases in South Africa during the period 1981-2003 will be discussed later.

Annual rainfall

Bai & Dent spatially aggregated annual rainfall for the period 1981-**2002** (Figure 6, Page 11). It should be noted that these represent aggregation of annual rainfall for diverse rainfall regions, from winter rainfall in the south to summer rainfall in the north and from a hyper arid area in the west (with a long-term average annual rainfall of less than 50 mm) to humid areas in the east (with long-term average rainfall in excess of 1 000 mm).

Aggregating annual rainfall for the country as a whole, masks the year-to-year variations for individual areas. These usually differ widely between different areas in a specific year, having important practical implications. If required, several examples could be provided for the period covered by Bai & Dent. Map 1, which gives rainfall for 2003 as percentage of the long term average rainfall for South Africa, could serve as an illustration: While almost the whole country received less rain than the long term average (most areas less than 75% and substantial areas less than 50%), a small area in the southeastern part of the Western Cape province received up to five times the long term average. These aspects will be discussed in more detail in later sections, especially where RUE is discussed.

An interesting point, which will be elaborated upon again further later, in Figure 6 of Bai & Dent (p. 11) is that the total rainfall figures for the four “peak” wet periods during the study period (1981, 1988, 1996 and 2000) were very similar.

Making conclusions about rainfall trends in areas with such cyclical rainfall variations as is the case in especially the summer rainfall areas of South Africa is fraught with problems. Simply moving a study period a few years earlier or later, can give a completely different conclusion. For the eastern part of the Northwest Province (a major maize production area) rainfall has increased by an average of between 4 and 6 mm per year according to Figure 5c of Bai & Dent (p. 10). Taking it as 5 mm per year means an increase of 110 mm over the 22 years (1981-2002) for which rainfall are given in Figures 5 and 6 of Bai & Dent. Moving the study period just three years earlier (1978-1999) would have given a trend that was virtually the opposite. The starting period (1978-1981) formed the last four years of a nine year period (1973-1981) of abnormally high rainfall in this area. It would end in 1999 with an exceptionally dry year. With 1996 being a somewhat above average rainfall year, but not nearly having such a dramatic peak as for the country as a whole (Figure 6 of Bai & Dent) it is clear what the trend would be.

It is not clear why Bai & Dent did not include the rainfall data for 2003 in their study. The author tried (via M. Samadi) to obtain the point for 2003 for Figure 6 from Bai & Dent, but at the time of writing this report no reply had been received from them. As second best option the author obtained Map 1 of this report for 2003 from the Agro-meteorology section of the ARC-ISCW. It shows that 2003 was a very dry year when averaged for the country. The author believes that a point for 2003 on Figure 6 of Bai & Dent would be almost as low as the one for 1992. Some of the few individual rainfall stations which the author checked, showed dramatic reductions in rainfall from 2000 or 2001 to 2003 – in some cases virtually linear decreases over the 3-4 years. Using the points for 2000, 2001 and 2002 from Figure 4 of Bai & Dent and the NDVI for 2003 from Figure 2 of their report, Figure 1 of this report has been constructed to simulate a rainfall point for 2003. This is very important with a view to an evaluation of certain important conclusions by Bai & Dent.

Another important point in regard to the interpretation of rainfall (and related) trends in areas with cyclical rainfall patterns is its implications for comparisons of different areas on a continental scale. It has been pointed out that the summer rainfall Highveld areas of the Northwest and Mpumalanga provinces of South Africa had an abnormally long above normal rainfall period from 1973 to 1981. That was the period when the Sahel region had its very long devastating drought. When the author visited the central plateau of Burkina Faso in 1995 he remarked on excellent plant growth on areas of good soils. The comment from the local scientists was that this was because this area, with a long term average annual rainfall of about 650 mm, received an average of about 950 mm per annum during the previous three years (1992-1994). Figure 6 of Bai & Dent and individual stations in the summer rainfall areas of South Africa show that on average 1992-1994 was a very dry period in this country. It seems as if synchronized latitudenal movement of rainfall belts causes reversed high and low rainfall periods for the Sahel and the summer rainfall areas of South Africa.

National mean temporal NDVI patterns and trends

As pointed out by Bai & Dent, NDVI more-or less fluctuated according to rainfall cycles, but that averaged over the country there has been basically no difference between the NDVI situation at the beginning and the end of the study period. The very low NDVI for 2003 (Figure 2 of Bai & Dent), the lowest in the whole 23 year study period, obviously contributed to this scenario. If NDVI data for only up to 2002 were used (as Bai & Dent did for rainfall) the end situation (and the trend) would have been somewhat different.

In terms of NDVI the study period started with two relatively good years (1981 and 1982) and ended with two bad years (2002 and especially 2003). It was a start that could hardly be improved on in the long term thereafter. In contrast, by 1981 huge areas of the Sahel were completely barren and devoid of any vegetation. The value of even something small divided by zero is infinite. Thus any improvement in vegetative cover amounts to very high increases on a percentage basis.

With a view to later evaluation of conclusions by Bai & Dent there are a few aspects to note from trends in NDVI at national scale (Figure 2 of Bai & Dent):

1. There is a clear-cut linear upward trend in peak high NDVI values (in years 1981, 1989, 1991, 1996 and 2000) over the study period (Figure 2 of this report). Since the lowest NDVI points did not increase during the study period, it means increased recovery in NDVI during peak years over the study period. This indicates increased resilience (recovery potential). Increased resilience is an important positive parameter in regard to land degradation/improvement.

2. Most striking in regard to the above is the huge increase in NDVI in the high rainfall year 2000 from the very low level in 1999.

3. There may be questions why NDVI did not peak in the very high rainfall year 1988, but peaked only later. It was due to a combination of factors. Firstly, the aggregate high rainfall in 1988 was due to exceptionally high rainfall within a very short time only over the central parts of the country. Most of this rain was lost unproductively as runoff. Secondly, it was not a particularly high rainfall year in the most productive areas to the north of this. In parts of the Mpumalanga Highveld it was, in fact, an exceptionally dry year. Thirdly, it followed on an extended sequence of dry years.

4. Also the peak rainfall year 1996 had lower NDVI than would be expected. This was simply because it followed upon an extended (four year) period of low NDVI from which it had to recover. This is in contrast to 2000, which had to recover from only one year of low NDVI (see Point 2 above).

5. In contrast 1982 had much higher NDVI than would have been expected considering its low rainfall. This low rainfall included all the main production areas. Again, two reasons provide straightforward explanations: Firstly, it followed on the extended period of nine years with above normal rainfall, especially in the main summer rainfall areas. In the rangelands this would have produced a dense productive grass sward. Secondly, the first part of the year (the last half of the 1981/82 summer season) would have benefitted greatly from the good rains during the last few months of 1981 (the first part of the 1981/82 summer season).

Spatial NDVI patterns and trends

It is physically impossible to give temporal (annual) data for spatial patterns. Thus Bai & Dent give only the overall mean annual sum NDVI spatial patterns averaged over the whole study period in their Figure 3a and the spatial trends in NDVI for the whole study period (amounting to comparisons of the beginning and end situations) in their Figures 3 b and 3c.

The spatial distribution of mean NDVI values for the period (Figure 3a) basically follows the same patterns as the mean annual rainfall for the period (Figure 5a), as one would expect. High NDVI values conspicuously fall east of the 600 mm rainfall line from about Mafikeng in the north to Port Elizabeth in the south. From Port Elizabeth the high values follow a narrow westward strip in the high rainfall area between the mountains and the coast, before becoming a broad area again in the southwestern Cape coastal area. Low NDVI values occur in the dry semi-arid to arid interior plateau areas to the west of the 600 mm rainfall line.

The trends and changes in annual sum NDVI between 1981 and 2003 (Figures 3b and 3c) show remarkable patterns, such as:

1. Probably 70-80% of the country's most highly productive areas east from the 600 mm rainfall line (the area with high sum annual NDVI) have (according to these maps) suffered severe decreases in NDVI between 1981 and 2003 in terms of both trend and change. These are the areas with high mean NDVI for the study period (Figure 3a). In these cases (trend and change) the the lines between decreases to the east of it and increases to the west of it do not follow the 600 mm rainfall line all the way from Mafikeng in the north to Port Elizabeth in the south as for mean sum annual NDVI. It stops at about Queenstown. From there a line running more-or-less east-northeast (ENE) towards approximately Port St. Johns separates the area with decreased NDVI to the north of it from an area with increased NDVI to the south of the line. **NB:** The high rainfall and high mean NDVI areas south of the Queenstown-Port St. Johns line that had **increases** in NDVI during the period 1981 to 2003 are the very badly degraded southwestern part of the former Transkei homeland and the former Ciskei homeland. The areas with decreased NDVI immediately north of the line are commercial farming areas and the high potential stable northeastern parts of the former Transkei. Very noteworthy is the strip with decreased NDVI running from northwest to southwest through

the area with increased NDVI. This is the commercial farming "corridor" that ran between the Transkei and Ciskei during the homeland era.

2. In the southern and southwestern Cape areas with decreases in NDVI between 1981 and 2003 follow the narrow higher rainfall coastal strips and the high rainfall mountains of the Boland. In contrast the grain producing areas of the Rûens and Swartland, with low rainfall and very poor quality soils, had increases in NDVI between 1981 and 2003, according to the Bai & Dent report. The long term average annual rainfall of both the Rûens and Swartland is between 400 and 420 mm.

3. In contrast to the decreases in NDVI in the higher rainfall areas during the study period, the low rainfall areas of the interior plateau (west of the 600 mm rainfall line) with low mean sum NDVI (Figure 3a), had increases in NDVI over the study period. The areas with the biggest increases include some of the lowest rainfall areas in country and some of the most degraded areas in South Africa. Areas with increased NDVI also include the only former homeland areas that were in low rainfall areas, viz. the western areas of the former Bophuthatswana.

4. A strange picture is that according to Bai & Dent the whole Kruger National Park, the famous big conservation area for more than a century, had high mean annual sum NDVI, but most of it (probably more than 80%) suffered substantial decreases in NDVI over the study period. Ironically the small area that they indicate as having had an increase in NDVI is an area about which the author is seriously concerned because he noticed serious degradation there during recent visits.

5. In the vicinity of Zeerust and Dwaalboom there is a striking phenomenon in the Figure 3 maps of Bai & Dent that accentuates the above discussions: A circular area of high mean annual some NDVI surrounds a core with lower NDVI (Figure 3a). **But**: The circle of high NDVI has suffered a substantial decrease in NDVI during the study period, while the core with lower mean NDVI experienced a substantial increase in NDVI during the study period (Figures 3b and 3c).

Summary: The above five points all support each other in a very strange scenario emanating from the Bai & Dent report, viz.

- High rainfall = High mean annual sum NDVI = **Decreasing** NDVI, except in badly degraded areas, like homelands (where NDVI increases)
- Low rainfall = Low mean annual sum NDVI = **Increasing** NDVI, especially in badly degraded areas

This is in direct contradiction to actual South African research findings (e.g reviewed by Laker, 2004), which can be summarized as

- High rainfall = Stable vegetative cover + More stable soils (due to more advanced pedogenesis) = Higher stability against land degradation
- Low rainfall = Unstable vegetative cover + Less stable soils = Higher susceptibility to land degradation

Rain-use efficiency

It should be noted that rain-use efficiency (RUE) is given only for the period 1981 to 2002 (Figure 7 of Bai & Dent), and that 2003 is not included. In the next Section this will become an important issue.

As stated earlier, RUE was calculated simply as the ratio between annual aggregated NDVI and station-observed annual rainfall on a yearly time-step.

There is a superficial general tendency for mean annual RUE to ***decrease*** with increasing mean annual rainfall and increasing mean annual sum NDVI (Figures 7a, 5a and 3a of Bai & Dent). They found by far the highest mean annual RUE in the hyper arid corner on the west coast at the Namibian border, where the long term mean annual rainfall is less than 50 mm.

Comparison of Figures 7b and 5b reveals a strong negative relationship between the trend in RUE and the trend in annual rainfall. Where annual rainfall increased, RUE decreased. This is most clearly seen (i) in the corner east of the Namibian border and north of the Orange river and (ii) in northeastern KwaZulu-Natal. More conspicuously are the increases in RUE where rainfall decreased in arid to hyper arid areas in the southern half of the country. The bigger the decrease in rainfall, the bigger was the increase in RUE – according to these Bai & Dent data. Ironically these include some of the most severely degraded areas in the country.

A trend of decreasing “RUE” with increasing rainfall (and increasing NDVI) is also found in Figure 4 of Bai & Dent. The slope of the regression line is such that the ratio of NDVI over rainfall decreases with increasing rainfall and NDVI. The author just calculated the values for NDVI divided by rainfall for the lowest and highest points of the given regression line. The respective “RUE” ratios are 1.09 for the lowest point and 0.80 for the highest point, i.e. a decrease of about 27% in “RUE” from the lowest rainfall year to the highest rainfall year in the study period.

It is a pity that Bai & Dent do not give a figure depicting mean RUE for the country on an annual basis for the study period – similar to their Figures 2 and 6 for NDVI and rainfall respectively. From the foregoing it can be predicted that the pattern in such RUE figure would be the inverse of Figures 2 and 6 – especially Figure 6.

Land degradation and land improvement

Critical question that has to be answered by Bai & Dent: *According to Bai & Dent, land degradation for the period 1981 to 200**3** was identified by declines in **both** NPP and RUE. Likewise, land improvement for the period 1981 to 200**3** was identified by increases in **both** NPP and RUE. It is also indicated as such in the titles of both Figures 10 and 11. **However**, according to their data and previous figures RUE was determined only for the period 1981 to 200**2**. **So, how could they determine land degradation or land improvement for the period 1981 to 2003?***

Evaluation and comments:

This is the key section in this report, since the terms of reference were basically to evaluate and respond to this part of the Bai & Dent report. The previous sections of the present report were compiled to provide necessary background for this section.

Bai & Dent define **land gegradation** as *"a long term decline in both NPP and RUE"* (p. 16). Elsewhere they emphasise that it must be **both**. They scaled both criteria 1 to 8 and weighted them equally to create a single *"semi-quantitative"* index. Since the single semi-quantitative is obviously also scaled 1 to 8 (looking at the legend of Figure 10 of Bai & Dent) it **seems** that the procedure that they followed to derive it, must have been as follows:

Step 1: Identify all the areas in which both NPP and RUE declined during the study period. Delineate these as areas where land degradation occurred during the study period. Exclude all areas where only one of them declined and the other one did not and all areas where none of them declined.

Step 2: Assign a scaled value between 1 and 8 for NPP and a value between 1 and 8 for RUE for each pixel identified as an area which degraded during the study period.

Step 3: For each pixel add up the value assigned for NPP and the value assigned for RUE and divide the total by 2 to give a value between 1 and 8 for the single combined semi-quantitative land degradation index for that pixel. Mathematically it can be expressed as

$$LDIsv = (NPPsv + RUEsv)/2$$

Where: LDI = Land degradation index
sv = Scaled value

Similarly, Bai & Dent identified **land improvement** as positive changes in both NPP and RUE, again with the emphasis on "both". Again, both criteria are scaled 1 to 8 and weighted equally to give a single combined index. The same three steps as outlined above had to be followed. In each case "declined" must just be substituted with "increased" and "land degradation index" (LDI) replaced with "land improvement index" (LII).

There is, of course a third category of land, that would not fall into either the category showing land degradation or the category showing land improvement. These would be areas where either NPP or RUE declined during the study period and the other one increased or areas where none of them changed significantly. These can range from extremely severely degraded areas beyond recovery to very stable, highly productive areas. Bai & Dent (Last bullet, p. 26) correctly state that *"severely degraded areas are not distinguished by this analysis if there has been no further change over recent years; the same applies to long-improved areas that are now maintained in a stable condition."* One must add that the same applies to stable areas that had never suffered degradation. Land falling in this third category will be blank areas on both the land degradation and land improvement maps (Maps 10 and 11 of Bai & Dent).

Bai & Dent correctly also point out that various kinds of land degradation and improvement are not distinguished in their analysis.

4.6.1 Land degradation

As could be expected when looking at the maps for trends in NDVI and RUE, by far the most of the degrading areas (particularly the severely degrading ones) are in the higher rainfall northeastern parts of the country (Map 10, p. 16 of Bai & Dent). Notable exceptions are Gauteng, the northeastern corner of the Northwest province, huge areas running north-south through the centre of Limpopo province and the central parts of the Mpumalanga Highveld.

According to Bai & Dent degrading areas in the east of the country are *"most conspicuously in the former homelands."* It is well-known that the former homelands are extremely severely degraded, both in terms of degradation of the vegetative cover and soil erosion (water erosion). This is, however, **not** shown by the results of the study by Bai & Dent in their Figure 10. This is clear from Map 2 of this report, showing the boundaries of the former homelands overlaid over Figure 10 of Bai & Dent. A large proportion of the central parts of Limpopo province showing little or no land degradation according to Bai & Dent are within very highly degraded areas of the former Lebowa homeland. Next to the southwestern corner of the Kruger National Park (KNP) is a former KaNgwane area that is extremely highly eroded. On Landsat images it stands out as a barren area, with good vegetative cover in the KNP on the other side of the fence. On Map 10 this area of the KNP is severely degraded, but the KaNgwane area is stable. Various other examples could be mentioned in these northern areas.

In the discussion on NDVI it was pointed out that the highly degraded former Ciskei and southwestern parts of the former Transkei are indicated by Bai & Dent as areas where NDVI increased during the study period. Not surprisingly their Figure10 indicates these areas as having no degradation (or only little spots). In fact, in their Figure 11 these come out as areas with major (not just slight) land improvement during the study period. Most conspicuously the **Sterkspruit/Herschel** (Glen Grey) area of the former Transkei (the little triangle between the Free State and Lesotho borders) is according to their Figure 10 not suffering any degradation. Parts of it are, in fact, indicated as having land improvement in their Figure 11. **The Sterkspruit/Herschel area** is known as possibly the most barren and most highly eroded area in South Africa. There is still a lot of erosion continuing in these former Eastern Cape homelands. One only needs to look visually at the sediment loads in the rivers after rains.

It is impossible to point out or discuss all anomalies regarding areas in the northern parts of South Africa that are indicated on Figure 10 as not having degraded during the study period, but are known problem areas undergoing degradation. Two of these are dealt with here, because they are very important:

1. The central parts of Limpopo province which are not in the former Lebowa homeland areas mentioned above, are subject to very serious bush (tree) densification. Bush densification in itself is a very serious form of land

degradation. In these areas it is, in addition, accompanied by very serious soil erosion – that cannot be "seen" from the skies.

2. During the study period there has been major expansion of open-cast coal mining in the Witbank-Middelburg-Hendrina area. This is of great concern to South Africa's soil scientists, because it is accompanied by exceptionally severe land degradation – mainly soil compaction and soil acidification. According to Figure 10 this is also an area where land degradation has not taken place during the study period.

In contrast there are various areas in the northeastern parts of the country that have not been subject to serious land degradation, that are indicated as having suffered serious (not just slight) degradation during the study period. A few of these are:

1. The biggest part of the Kruger National Park.
2. Several citrus and sub-tropical fruit producing areas in Mpumalanga and Limpopo.
3. Most forest areas – including both indigenous forests and exotic plantations.

Bai & Dent indicate that manual investigation of Landsat images should/will be the second step in this process, following this evaluation by them. Manual investigation of Landsat has over the years been done. In several known cases in the northeastern parts of the country, amongst those discussed above, it is known that these images give exactly the opposite picture as Figure 10 of Bai & Dent. The best known example is the area in and around the southern part of the Kruger National Park. The former KaNgwane area west from the southern tip of the park is seen as a bleak, barren area. In contrast, the area immediately south of the KNP is (correctly) clearly seen as a very densely vegetated area on Landsat images.

According to Figure 10 there has been major land degradation in the maize producing areas of Northwest province, an area that normally produces about one third of the country's maize. There is an important factor that possibly caused the observed decline in NDVI and RUE in this area: The area planted to maize in South Africa declined steadily from 4.1 million hectares in 1987 to an average of only 2.9 million ha by 2003, with a minimum of 2.7 million ha in 2001 (Newby & Paterson, 2005). According to Newby & Paterson (2005) the decrease in area planted was mainly in the drier parts of the crop production areas. Since the Northwest province is the driest part of the maize quadrangle much of the decrease in area plated to maize would have been here. When cropland is abandoned and left to revert to rangeland, biomass production on it remains low for at least a number of years. Where maize lands are converted to, for example, sunflower production – as is often done – the conversion is to less biomass and furthermore a sunflower field in full bloom looks yellow to observations from the air and not green. The author saw examples of both the above while traveling through a small part of Northwest province a few weeks before writing this report.

In the **arid** parts of the country a very small number of areas are indicated in Figure 10 as having suffered moderate to serious land degradation during the study period. Only one of these will be highlighted, because it is a very special case, viz. the area in the corner between the Namibian and Botswana borders, then east of the Namibian border down to Noenieput, from there north of a line running southeast to just east of Upington and west of a line from Upington to Van Zylsrus. The boundaries of this area closely fit the boundaries of the area covered by a unique (within a South African context) geomorphological phenomenon, viz. the area known as the so-called "Duineveld" in Afrikaans. ("Duine" = dunes and "veld" = rangeland.) It is not found anywhere else in South Africa. The whole area is characterised by very long seif dunes running parallel to each other, with narrow valleys – called "strate" in Afrikaans – between them. ("Straat" = street.) Their direction is from north-northeast to south-southwest. Under the present climate the dunes are stable and do not shift. About 95% of the soils in the area are red sandy soils with 2-8 % clay. The vegetation of the area is predominantly very open "parkland" (very open savannah), i.e. grassland with sparsely distributed tress. Some areas of pure open grassland also occur. The vegetation of the area is described as extremely vulnerable to overgrazing, especially during droughts. The perennial grasses disappear and after rains only pioneer plants then appear. Figure 10 of Bai & Dent shows that degradation occurred both in commercial farming rangelands and in the Kgalagadi transfrontier national game reserve. Recent South African studies of satellite images revealed similar results for this particular area to those of Bai & Dent. From a scientific/academic point this would be an interesting case to follow up at national level. It may not be a priority, however, since it represents such a very specific scenario in a low potential area that results from it cannot be extrapolated. It even differs completely from the large areas around it with similar sandy soils but without dunes.

4.6.2 Land improvement

According to Figure 11 of Bai & Dent there has been virtually no land improvement in the higher rainfall, more productive areas of South Africa, like KwaZulu-Natal, the maize quadrangle of the Highveld (in Mpumalanga, Gauteng, northern Free State and eastern Northwest province), the citrus and subtropical fruit production areas, sugar cane areas and afforested areas.

Areas identified by Bai & Dent as having experienced land improvement during the study period include, *inter alia*:

1. Land improvement in some much less productive areas of the Limpopo province (compared with the above) , including areas that are known land degradation problem areas – as discussed under Section 4.6.1.
2. They indicate a large area of substantial "land improvement" in the western part of Northwest province just south of the Botswana border. This is, in fact, one of the most notorious areas in South Africa in regard to land degradation. The problem is invasion and densification of black thorn (*Acacia mellifera*) and sand yellowwood (*Terminalia sericea*). Invasion and densification of black thorn is especially an extremely severe form of land degradation where it occurs. (as is the case in large areas of Namibia also). It should be noted that here we deal with a case of extreme degradation of the vegetative cover only. Because this is a flat area with deep sandy soils, the bush densification is not accompanied by water erosion (as is the case in Limpopo province). Thus, this area was in GLASOD indicated as a stable area, since GLASOD dealt only with **soil** degradation, not with other aspects of land degradation. Of course, a

NDVI analysis would just see the dense canopy cover of the black thorn and sand yellowwood trees and interpret this as an improved situation.

3. According to Bai & Dent, most of the Karoo, the semi-desert area on the interior plateau between the Orange river in the north and the half moon escarpment around it in the west, south and east, showed land improvement during the study period. Apart from being very dry, this area is dominated by very shallow, poor quality soils. Large areas have undergone very severe land degradation, both in regard to degradation of the vegetative cover and soil erosion. Just wo of the areas which are indicated as having had **high** levels of land improvement will be highlighted:
    a. The area immediately south of the Orange river just below the confluence of the Orange and Vaal rivers. This area was described as follows by Department of Water Affairs (1986): *"A marked decrease in sediment in the middle reaches of the Orange River is attributed to a progressive change in the amount of erodible material available. Enhanced erosion attributable to the influence of man has been so severe that the recent decrease in sediment yield can be ascribed to the reduced availability of erodible material as a result of the washing away of alluvial valleys and the stripping of topsoil from sensitive soil profiles."* While driving through some of these areas several times during recent years, the author has noticed so-called "bitter Karoo" shrubs still each standing on its own little pedestal of soil and the whole topsoil (which in many cases is the whole soil profile) inbetween gone. This means that often over more than 80% of the area there is no topsoil (even no soil) left.
    b. An area in the southwestern corner of the Karoo. This area has been described by Acocks as having a *"black, moonlike landscape"*. In 1986 it was found that in the Ceres Karoo 78% of the area consisted of absolutely bare soil, with the rest being covered by sparse vegetation of which only 4% were edible species (Roux, 1990).

4. Reference has already been made to the fact that according to Bai & Dent substantial land improvement occurred during the study period in the biggest problem parts of the former Eastern Cape homelands, viz. the Ciskei, southwestern part of Transkei and the Sterkspruit/Herschel area of Transkei.
    a. As indicated earlier, the Sterkspruit/Herschel area of Transkei is probably one of the worst degraded areas in the world. Plate 1 of this report is a photograph taken in this area in 2000. There are various other similar recent photographs from the area. Yet, according to Bai & Dent parts of the area even showed land improvement during the study period.
    b. In the southwestern part of Transkei the areas with the highest land improvement, according to Bai & Dent are in the western parts, which are the worst degraded parts, as depicted in Plate 2 of this report – taken in 1984. There is obviously basically no possibility for such area to recover within several decades (or even a century).
    c. In the former Ciskei many areas that were demarcated by planners during the 1960s/early 1970s to be cultivated under the "betterment

> schemes" were brought under cultivation (as proven by the still visible contour bunds). By the late 1970s most of these were abandoned due to severe land degradation, consisting of gully erosion and severe soil crusting over the rest of the area. Plates 3 and 4 of this report, taken of a specific abandoned area in 1987 and 1997 respectively show that there was some new vegetative growth in the areas next to the gully about 10 and 20 years respectively after the area was abandoned. In the Bai & Dent report these will obviously show up as land improvement from a zero vegetation start. Before the area was cultivated it carried some of the highest potential grassland in the world (see the grass in the foreground of the photos), but it will probably not be able to recover to that condition again within more than a century.

It would seem that the Bai & Dent procedure indentify only very badly degraded areas as having positive land improvement, and specifically areas with poor quality resources and low agricultural potential.

4.6.3 Follow-up work required and the suitability of the Bai & Dent report as basis for the follow-up work

According to Bai & Dent the next stages of the GLADA project will be (p. 6 of the report):

1. *"At the next stage, areas of land degradation and improvement, identified on the basis of NDVI indices, will be characterised manually using 30m-resolution Landsat data, to identify the probable kinds of land degradation."*
2. *"Finally, field identification of the identified areas of degradation and improvement will be undertaken by national teams within the wider LADA programme."*

Manual investigation of Landsat data

The author is not an expert on the topic, but it is not clear to him how ***kinds*** (types) of land degradation can be identified by means of manual studies of Landsat data. The author has done some manual analyses of Landsat images and has found it excellent for identification of badly degraded barren areas caused by severe removal of vegetation and/or soil erosion on the one hand and well-vegetated areas on the other hand. This is probably all that one can identify by this method. Even then it is not possible to distinguish between different types of water erosion (sheet, rill, gully).

It must be kept in mind that there are at least two main groups of land degradation, viz. degradation of the vegetative cover and soil degradation. Degradation of the vegetative cover includes types of degradation like, *inter alia*

- Reduction in the density of stand of plants and plant cover.
- Reduction in bio-diversity of plant species.
- Reduction in the nutritional quality and palatability of the plant cover due to favourable species being pushed out by inferior species.

- Bush encroachment and bush densification into grassland and open savannah.

Soil degradation includes, *inter alia*

- Different types of water erosion (sheet, rill, gully).
- Wind erosion.
- Physical soil degradation (compaction, crusting, waterlogging).
- Chemical soil degradation (salinisation, sodification, acidification, pollution).
- Reduction in mineral soil fertility/ plant nutrient levels.
- Biological soil degradation (reduction in soil organic matter levels; effects on soil microbial composition and organisms like earthworms).

It is a question why manual evaluation of Landsat images should be used, with a methodology like the "bare soil index" (BSI) of Pretorius available. This methodology is based on manipulation of ratios between two spectral bands from satellite imagery.

Bai & Dent do not make clear whose responsibility it will be to do the manual studies of satellite imagery – a central unit like ISRIC or the national teams.

Field work

In 2007 the FAO document *"GLADA Stratification – Inputs, Preprocessing, Outputs: South Africa"* was evaluated in terms of the (a) correctness of the data in the document and (b) the appropriateness of procedures outlined in the document for use at national level. It was indicated the final step in the GLADA/LADA programme would be field investigations in selected "hot spots" and "bright spots" in each pilot country by national teams.

Although it is not spelled out explicitly, it is clear that the primary objective of the Bai & Dent report and maps for South Africa is to serve as basis for the identification of a few appropriate, representative hot spot and bright spot pilot areas in which to conduct these field studies. ***Based on the evaluation of the Bai & Dent report up to this point, it is clear that the report and maps do* NOT *provide an appropriate and suitable basis for the selection of appropriate hot spots and bright spots.*** There is something radically wrong if basically only very badly degraded areas qualify for consideration as "bright spots" (good areas) and only high potential stable areas as "hot spots" (bad areas). ***A different approach and methodology will have to be found for the identification of hot spots and bright spots.***

4.7 Other factors

Bai & Dent considered a series of other factors (in addition to NDVI and RUE) that could possibly affect land degradation and land improvement and essentially concluded that none of these had any effect. All these factors were also discussed in the FAO document *"GLADA Stratification – Inputs, Pre-processing, Outputs: South Africa"*. A comprehensive South African response was written on that document, pointing out major shortcomings and errors in it. Unfortunately the Bai & Dent report has exactly the same shortcomings and errors in regard to these. It is clear that either the FAO did not make that South African response document available to Bai & Dent or Bai & Dent decided to ignore the report.

The whole response to the 2007 FAO document could be copied and pasted in here as response to the relevant points in the Bai & Dent document, but the author does not deem it the way to go. The original document is available in the GLADA documentation and it could simply be consulted. The author does wish to highlight two aspects again, however:

1. The land cover map in the report of Bai & Dent (Figure 1, p. 5) is largely the same greatly incorrect map that was used in the 2007 FAO report, apparently with some additional errors. The errors were pointed out in detail in the response to that report. It is a very great pity that the necessary corrections were not made to that map. ***The biggest error is that there is still no provision for grassland, but that grasslands are still included in shrub mapping units.*** Invasion and densification of shrubs and scrub into grassland is, in fact, one of the most widespread and serious forms of land degradation and also leads to serious soil erosion, as has been pointed out. Invasion of short Karoo scrub into grassland in the northeastern areas of the Karoo is often regarded as the main form of desertification in South Africa. As pointed out before, the grasslands are very important, both in regard to protecting soil against erosion and as feed in extensive rangeland agriculture. The grassland biome covers 26% of South Africa, mainly in the eastern summer rainfall areas (Department of Environment Affairs, 1992).
2. Soil type and geology have been shown to be ***extremely*** important factors related to soil degradation in South Africa – both physical degradation and soil erosion. In small-scale global maps these may "disappear", but at country level they need to be taken into account.

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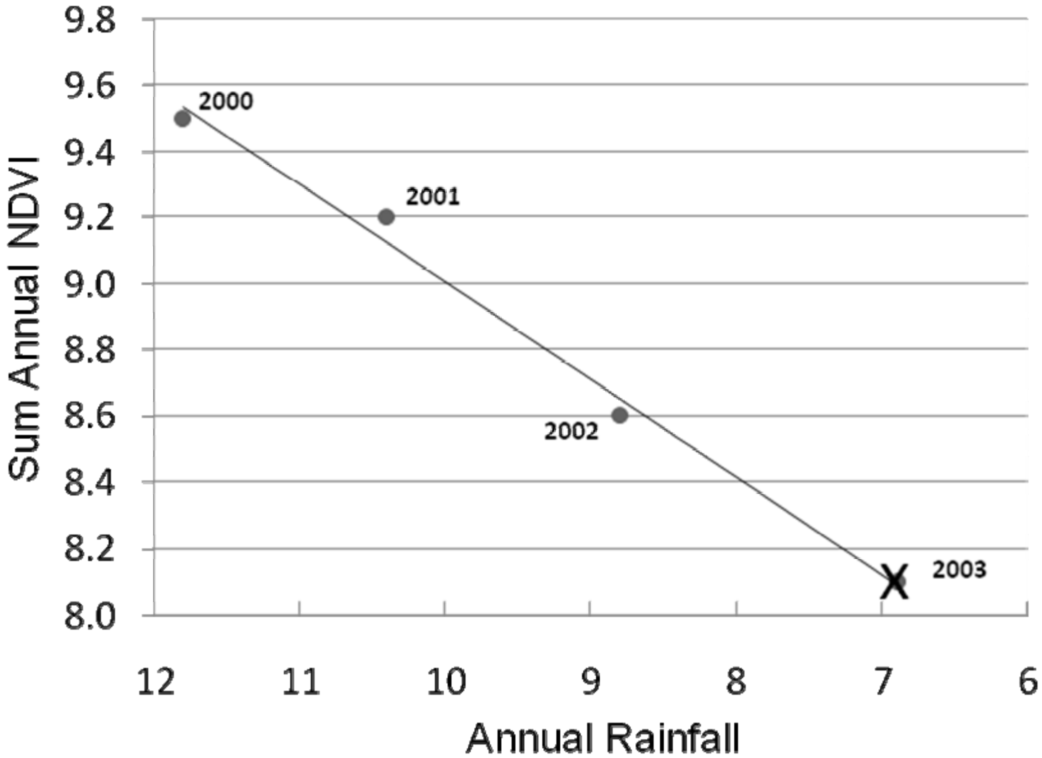


FIG.1 – NDVI vs. Annual Rainfall for 2000-2003

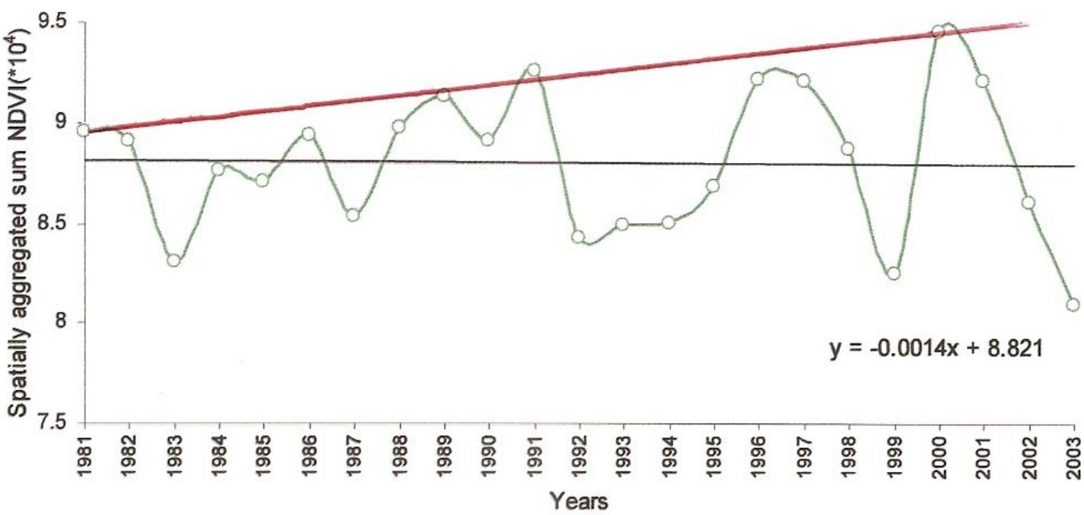
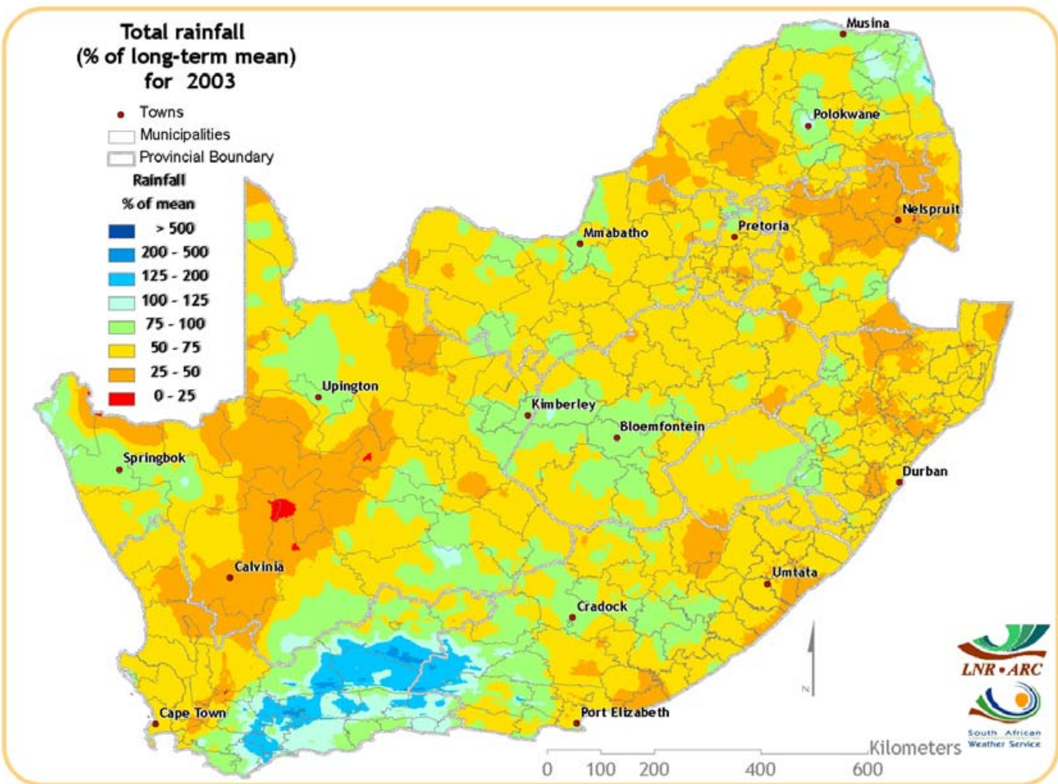
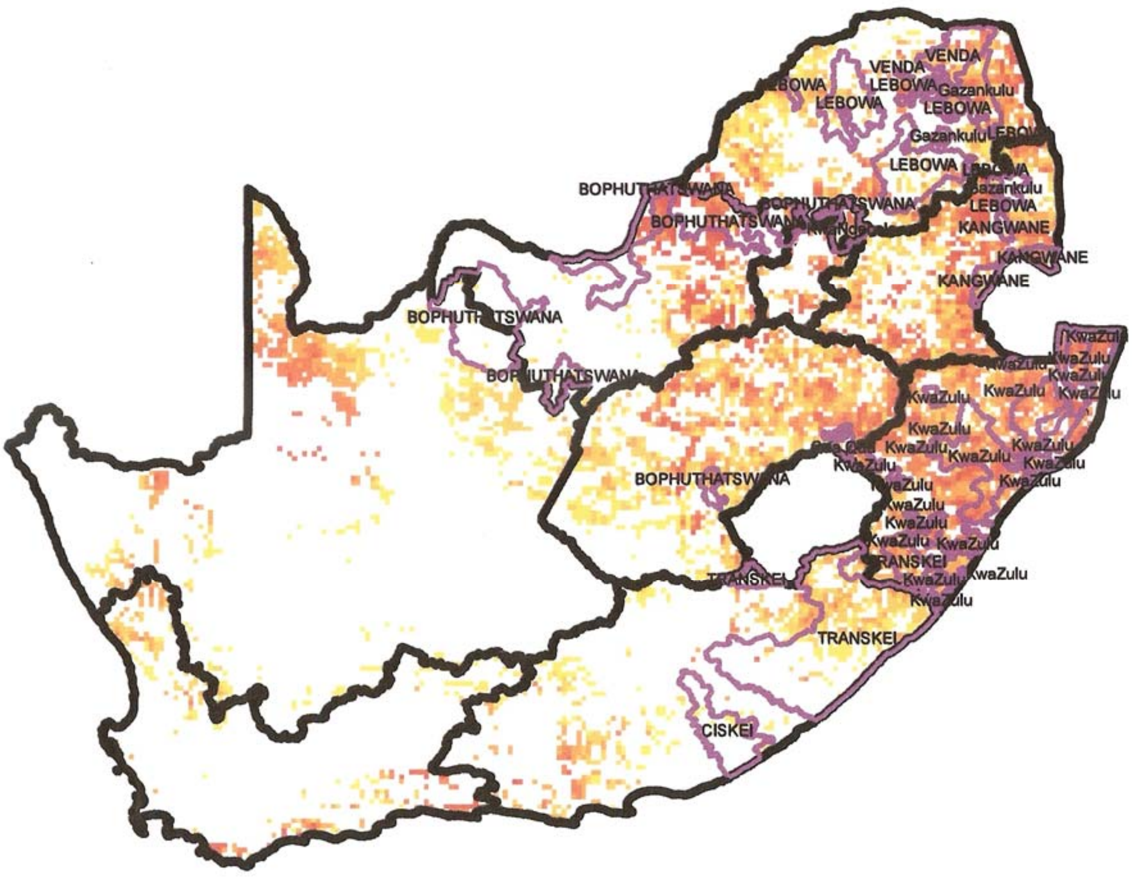


Figure 2. Spatially aggregated annual sum NDVI 1981-2003, $p<0.01$

(Red line indicates increasing recovery during high rainfall years.)



Map 1 – Rainfall for 2003 as percentage of long-term mean



Map 2 – Land degradation map (Figure 10) of Bai & Dent with former homelands super-imposed (purple lines)

Plate 1 – Gully erosion, Herschel, Eastern Cape (Photo: N.N. Mswana)

Plate 2 – Rill/gully erosion in abandoned betterment cultivated area, Lubisi dam catchment, Glen Grey/Lady Frere, Eastern Cape (From: Tracor, 1984)

Plate 3 – Betterment cultivated area abandoned due to gully erosion, near Alice, Eastern Cape, ca 1987 (Photo: J.L.H. Williams). Compare with Plate 4.

Plate 4 – Betterment cultivated area abandoned due to gully erosion, near Alice, Eastern Cape, ca 1997 (Photo: J.L.H. Williams). Compare with Plate 3.

Comments on Land Degradation and Improvement in South Africa 1. Identification by remote sensing (Nov 2007).

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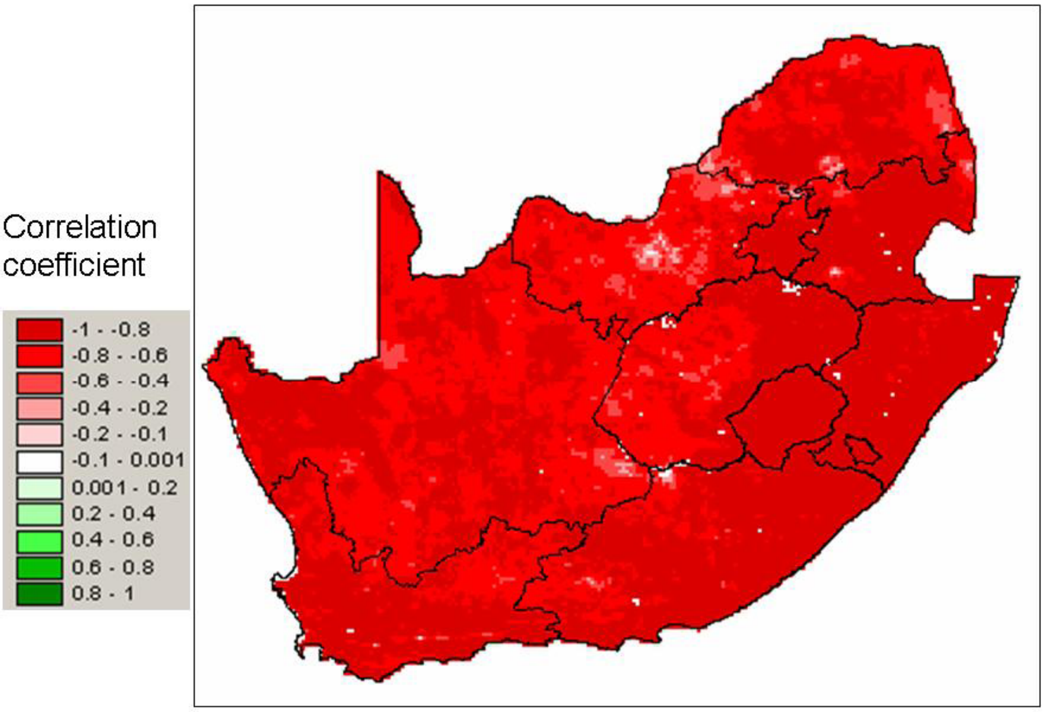
Background:
The National Department of Agriculture of South Africa (DoA, Directorate??) has been funding research into the remote sensing of land degradation since 1997. In 2001 the author (K.J. Wessels) affiliated with ARC-Institute for Soil, Climate and Water was contracted to investigate the use of remotely sensed Rain-Use Efficiency (RUE) for monitoring land degradation in SA. This work formed the basis of the author's PhD studies at the University of Maryland and is referenced in the LADA report. Most of the comments given here are based on this DoA-funded research and is therefore highly relevant to the LADA study. Research into monitoring land degradation is ongoing at the CSIR and is a central theme in at least three current projects. The author was approached by ARC-ISCW and DoA to provide comments on the LADA country report.

Specific comments:
1. Main points. The statement is made that "Thirty per cent of the degrading area is cropland – almost half of all cultivated areas". Is this reduction supported by data on crop statistics / food production?
2. Page 1: The statement is made that:" NPP trend may be interpreted as land degradation or improvement only when these other factors are accounted for. Variability of rainfall is accounted by rain use efficiency: the ratio of NPP to rainfall." However, the correlation between annual RUE and annual rainfall needs to be tested. If these are highly correlated, calculating the RUE ratio DOES NOT account for or control for variability in rainfall. This correlation between RUE and rainfall was calculated per pixel for SA using AVHRR NPP and rainfall (Sum Oct to April) (fig below). There was a very strong negative correlation (average r = -0.8) across SA and thus RUE is not independent of rainfall. Trends in RUE through time thus largely indicate trends in rainfall and not land degradation / improvement.
3. Annual sum NDVI and rainfall. As SA is in the southern hemisphere, growth seasons span across 2 calendar years and thus NDVI or rainfall should not be summer annually as doing so will mix the tail end of the first season and the beginning of a second season together. As there is a lag of about 1 month between rainfall and peak vegetation response (NDVI), using annual relations between rainfall and NDVI severely distorts the picture. I have personally done this and got very misleading results. I suggest that the global analysis be split along the equator and "hydrological" years used in the southern hemisphere. The results of the northern and southern can then be spliced together along the equator. This is a major weakness of this LADA study in SA and needs to be addressed.



Correlation RUE vs. Rainfall

4. Page 14, Predicting NPP from AVHRR NDVI using MODIS NPP: The average annual sum AVHRR (2000-3) and corresponding MODIS NPP average was regressed using > 21 000 pixels distributed throughout SA. The regression of AVHRR NDVI vs. MODIS NPP was therefore derived "through space" across massive rainfall gradients. Such regression through space are always strong, but does not necessarily indicate a strong relationship between AVHRR NDVI and MODIS NPP "through time" on a per-pixel basis. The latter relation should actually be used for this regression, but since only 4 years of data are available, it can not be done. I am nevertheless not convinced that the NPP estimate applied in the LADA report is correct.
5. RUE of cultivated areas: Applying this method to identify degradation in cultivated areas, is highly questionable as NPP of crops is influenced by so many management practices, e.g. crop type, crop rotation planting date, fertilization ect. The methods are only applicable to natural vegetation / rangeland.

Conclusions:
The use of global remote sensing dataset to monitor land degradation is definitely a step in the right direction and a vast improvement on previous efforts which were only based on expert opinions. However, I am concerned about the correct interpretation of these products primarily because the simple RUE ratio is highly correlated with rainfall and thus trends in RUE merely reflect trends in rainfall. I would suggest that Residual Trends (RESTREND) method (Wessels et al. 2007), which avoids these correlations between RUE and rainfall be tested on this data. On the other hand, the outputs of the RESTREND method have also not yet been sufficiently validated and thus there is no guarantee that it will provide more reliable results.

As the RUE trend products stand now they should not be used to drive any policies or interventions. The products should be subjected to rigorous validation efforts involving high resolution data and field work.