Rangeland Resources Assessment with Satellite Imagery: An Operational Tool for National Planning in Namibia

Article in Geocarto International · September 2005

DOI: 10.1080/10106040508542353

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Rangeland resources assessment with satellite imagery: an operational tool for national planning in Namibia

(Accepted for publication in **GeoCarto International** for 2005)

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Abstract

The Namibian authorities endeavour to implement a rangeland resources management policy at national level. The first line of action is the allocation of livestock marketing priorities to the most drought-affected areas. Another potential application is the estimation of land value in terms of grazing capacity, as a base for land purchase and redistribution for private land taxation. Accurate and up-to-date information on the resources, which are extremely variable in time and space, is indispensable for rational and efficient decision-making. In this regard, low-resolution satellite imagery appears to be a practical and suitable source of data for non-biased and reasonably accurate estimation of forage production over the whole country. Using 17 years of AVHRR and VEGETATION satellite data over Namibia, seasonal biomass production estimates were obtained with a simple but operational vegetation production model. The accuracy of such products was assessed by comparison to field measurements carried out between 1999 and 2001, showing a residual error of approximately 25%. Long-term averages of biomass production from all available satellite data (17 growing seasons) give an indication of the "normal" potential of the land in terms of grazing. This can be used for marketing priority allocations, the comparison of the production of the current season to the long-term average allowing to identify the most problematic zones and to quantify the severity of a crisis. The long-term average is also a good base for land value assessment, although complementary processing is required. The products are integrated in a GIS

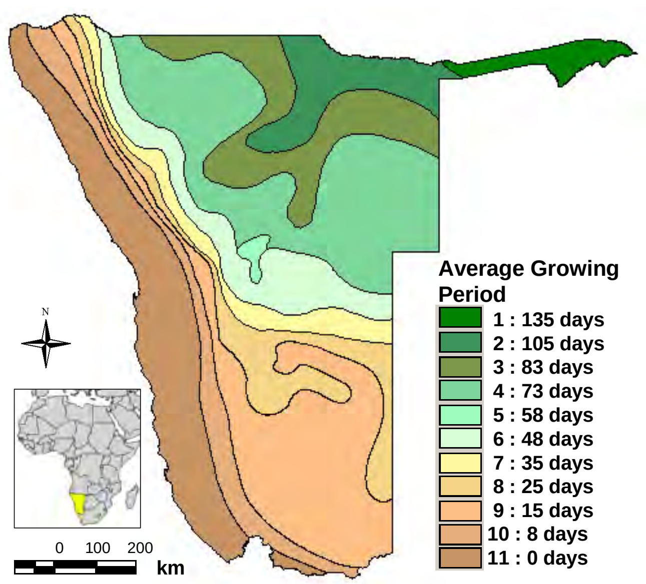
environment to be used with complementary geographic information. The potential of such a system for decision making within the Namibian range resources management policy is discussed.

Key words : Forage resources, Rangeland management, Remote sensing, Namibia.

1. Introduction

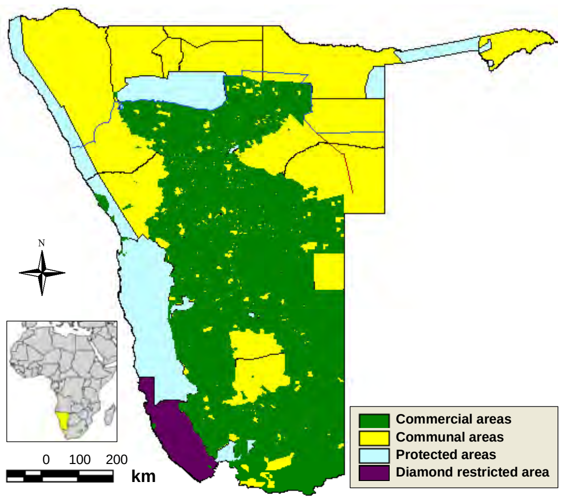
The Republic of Namibia is a large country, covering 824 269 square kilometres. As a result of a very arid, sometimes hyper-arid climate, its human population is very low (1.8 million inhabitants approximately) with an average density of 1.7 inhabitants per square kilometre, in relation to the limited agricultural potential (Moyo ***et al.,*** 1993).

Only the northern fringe of the country (10% of the surface, see **figure 1**) benefits from agro-climatic conditions compatible with arable agriculture, the largest proportion being desert or arid land utilised as pastures for livestock raising. Animal production contributes 75% to the agricultural Gross Domestic Product of Namibia (MAWRD, 2000). The livestock production of Namibia is well known for its quality and represents a substantial income through meat export, especially to Europe, which reaches 15% of the total exports of Namibia (Werner, 2000).



<u>Figure 1</u> : Growing period zones of Namibia

Namibian rangelands are clearly separated into two types of land uses. The communal areas (38% of the country), are exploited by subsistence farmers and grazed a traditional way. The commercial areas (45.5% of total area) are occupied by large fenced individually owned farms managed for profitable production, mainly of meat for export (Moyo ***et al.,*** 1993, figures updated in 1998 thanks to the NARIS[1] data set). The remainder of the surface is represented by national parks and other protected areas (13.9%), and by the “diamond” mining restricted area (2.6%). At present, the information available on rangelands is mostly concentrated on commercial areas, while the communal areas, which host 65.3% of the total human population, are less well known and mapped (Census Office, 2001).



<u>Figure 2</u> : Main land use types in Namibia

As all arid lands, the Namibian rangelands are subjected to a very variable climate, with rainfalls that can be extremely different from one growing season to the next. The distribution of the rains within a growing season is equally erratic and unpredictable (Olszewski, 1997; Du Pisani, 1999). This climatic variability explains the recurrent droughts which can have a disastrous result, not only because of their immediate socio-economic effect, but also because of the degradation of vulnerable resources they can induce (Matanyaire, 1995). In such irregular climatic conditions, the forage resources can at times be highly insufficient to sustain the livestock present, resulting in overgrazing (Prince and Tucker, 1986; Rothauge, 2001). This has an especially severe impact in the communal farming areas because of a combination of socio-economic factors, traditional farming methods, and a degraded natural resources base (Seely et Al., 1995).

The Government of Namibia, and especially the Ministry of Agriculture, Water and Rural Development (MAWRD), has clear objectives in terms of management of the

[1] **NARIS** : Namibian Agricultural Resources Information System, produced by the Agro-Ecological Zoning (AEZ) programme of the Ministry of Agriculture, Water and Rural Development (MAWRD) of Namibia.

rangeland resources and resulting livestock production in the country (MAWRD, 1995). Within recent policy orientations, priority is given to crisis (drought) mitigation and to land reform. These lines of action involve decisions made at national level which can be of great benefit to the vulnerable rural communities as well as to the commercial farmers as long as there are rational. In this regard, the decisions must be based on unbiased and up-to-date information on the forage resources over the entire country. The Government is therefore in need for both real-time information on the agro-meteorological situation of the ongoing season for crisis assessment and mitigation, and general information on the productivity of the different parts of Namibia for fair and efficient land reform.

Unfortunately, little accurate information is available, not to mention in the course of the growing season for early warning purposes. The last carrying capacity[2] surveys were carried out in the nineteen-seventies, mostly through visual estimates, and included only the commercial areas. No recently updated maps of the carrying capacity compiled from conventional methods (visual estimates or herbaceous samples from the field) are available (Strohbach, 2000).

Satellite imagery happens to provide a very practical alternative source of data to fill this gap, as it will be explained hereafter. A technical project was therefore initiated by the French Co-operation services in Namibia, hosted by the Agro-Eocological Zoning (AEZ) programme of the MAWRD, with technical support from GDTA[3], a subsidiary of the French National Space Agency (CNES). This project, conducted between 1998 and 2002, resulted in the implementation of operational satellite image processing tools for range resources monitoring within the AEZ programme.

This article describes how remote sensing and GIS can efficiently help in the national level decision making process for rational range resources management in Namibia. It shows how quantitative biomass production estimates, derived form low-resolution satellite imagery and integrated in a GIS environment, can be the base for adapted decision making products. The potential of such information is discussed for two essential aspects of range resources management at national level in Namibia: early

[2] **Carrying Capacity** : the number of herbivores than can be sustained per area unit on a rangeland. The carrying capacity is expressed in units of animal load per area unit; often used are the Tropical Livestock Units (TLU) per hectare, or Kilograms of live weight per hectare.

[3] GDTA : Groupement pour le Développement de la Télédétection Aérospatiale (Group for the Development of Aerospace Remote Sensing)

allocation of livestock marketing priorities, and land valuation for taxation and land reclamation.

2. Materials and methods

The base for an evaluation of the rangeland resources is an assessment of the seasonal biomass production. In arid and semi-arid climates, it is mostly related to rainfalls and is therefore extremely variable in time and space. It can be measured in the field or estimated from rainfall data, but the results are inaccurate and based on sample measurements and are therefore often not representative in space and in time (Prince and Tucker, 1986). Especially field measurements, unless applied regularly and involving great effort, expenditure, and time, mainly give an indication of the standing biomass, not of the production of the ongoing season. Satellite imagery proves to be a practical and efficient alternate source of data for the purpose.

2.1. Satellite data for range resources assessment

Low resolution (also called “wide field”) satellite sensors, with acquisitions almost every day and with a complete geographic coverage of large areas, appear to be very suitable for vegetation monitoring and production assessment at national level. Even though the spatial resolution is limited, the data remain suitable because the temporal resolution (or revisit capability) is the most important element for the evaluation of fast changing seasonal vegetation conditions (Prince and Tucker, 1986). Nevertheless, the spatial resolution of commonly available low-resolution sensors (for example NOAA/AVHRR, SPOT/VEGETATION, SeaWiFS, MODIS, MERIS[4]…), ranging between 250 and 1100 meters, remains compatible with the extensive natural vegetation ecosystems that characterise the arid and semi-arid lands in Namibia.

Low-resolution satellite systems are normally equipped with Red (R) and Near-Infra-Red (NIR) sensors. The corresponding bands allow the computation of vegetation indices, the value of which is related to the “greenness” of the vegetation cover. The

[4] **AVHRR** : Advanced Very High Resolution Radiometer of the National Oceanographic and Atmospheric Administration (NOAA), USA
VEGETATION : instrument onboard satellites SPOT4 and SPOT5, CNES, France
SeaWiFS : Sea Wide Field Spectro-radiometer, onboard satellite ORBVIEW2, Orbimage, USA
MODIS : MODerate resolution Imaging Spectro-radiometer onboard EOS “Terra” and “Aqua”, NASA, USA
MERIS : MEdium Resolution Imaging Spectro-radiometer, onboard ENVISAT, European Space Agency

most applied index is the "Normalised Difference Vegetation Index" (NDVI), a simple but robust index well adapted for arid and semi-arid vegetation monitoring (Diallo et Al., 1987; Prince, 1991; Wylie et Al., 1991). It is generally used as "10-day composites" computed with the Maximum Value Compositing (MVC) method (Holben, 1986). This process reduces cloud cover and optimises the quality of the data by selecting the pixels with the minimum atmospheric, lighting and viewing conditions disturbances in the compositing period.

For the present work, all products were based on 10-day composite NDVI data from 2 satellite sensors, covering a period of 17 years: NOAA/AVHRR (1985-2000) and SPOT/VEGETATION (1998-2002). **Figure 3** shows the seasonal evolution of the vegetation index over Namibia for the 1998-1999 and 1999-2000 growing seasons (SPOT/VEGETATION data).

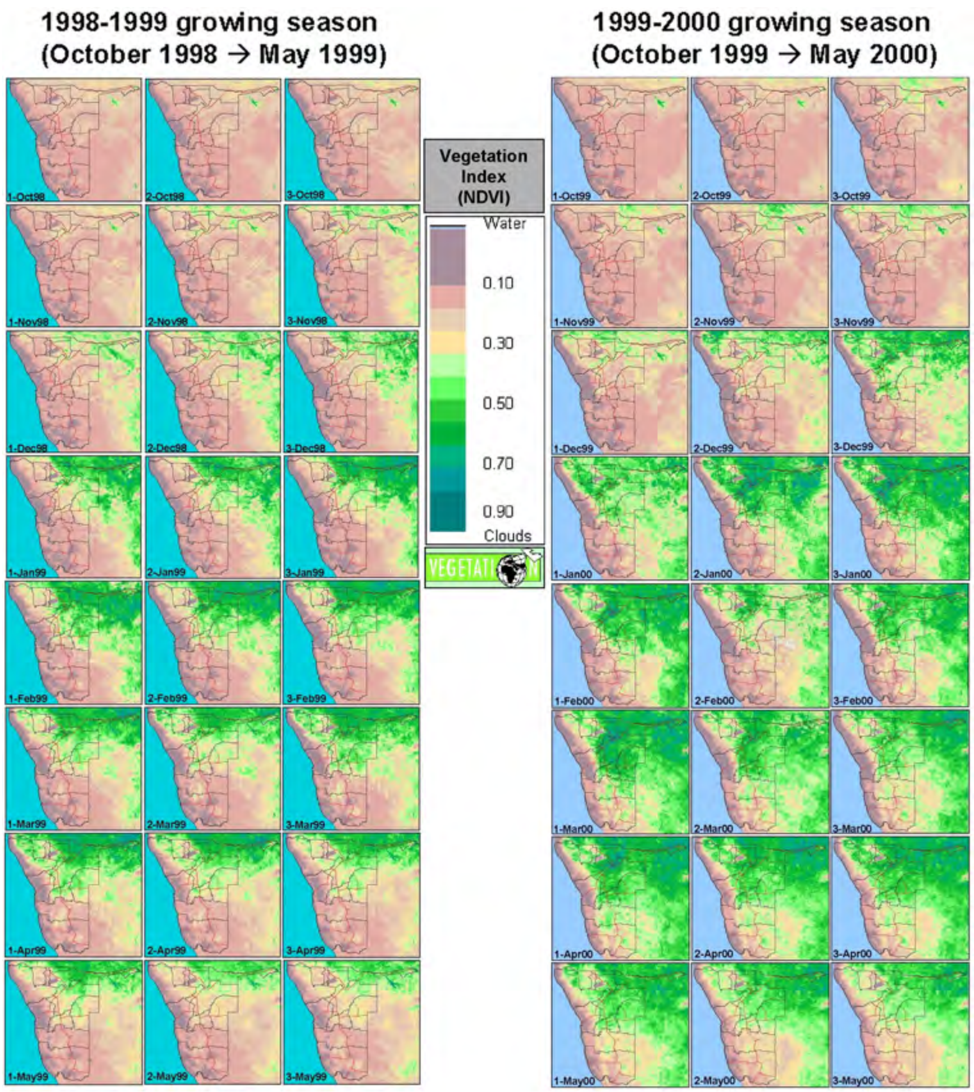


Figure 3 : 10 day synthesis of vegetation index over Namibia

This type of product is only of limited interest for rangeland resources management, the vegetation index only giving an instantaneous indication of the greenness of the vegetation. Nevertheless, when considered over the entire season, the vegetation index indicates the amount of vegetation biomass produced during the corresponding period. One can for example intuitively interpret from **figure 3**, that the second season was more productive than the first. This integration of the vegetation index over time can be the base for the elaboration of biomass production estimates, information which is more suitable for our purpose because it provides a quantitative assessment of the forage resources.

2.2. Seasonal Biomass Production Estimation (SBPE)

The above ground **seasonal biomass production** can be considered as the amount of forage which is produced during a "growing season", which is suitable basic information, for example, for the estimation of the carrying capacity. It represents the renewable resources necessary for animal production, not to be confused with the "standing biomass". For savannah types present in southern Africa, with a significant woody cover and a grass layer dominated by perennial species (Tainton, 1999), the standing biomass can be significantly higher than the production due to the part of the biomass carried over from previous seasons.

A simple and practical approach to estimate biomass production with remote sensing can rely on the fact that the vegetation index, related to the green cover, is linked to the photosynthetic activity and therefore to plant production. It is widely accepted (although still discussed) that plant production is related to the Absorbed Photo-synthetically Active Radiation (APAR), and that satellite Vegetation Indices are a good indicator of the APAR (Ruimy ***et al***., 1994, Hanan ***et al***., 1995, Prince, 1991b). In other words, an "integration" of the vegetation index over the entire season gives a direct indicator of the production, taking into account both the **greenness** and the **duration** of the vegetation activity.

In the present work, biomass production estimations were computed according to this approach, applying a method know as the ***Monteith model*** which simulates the photosynthetic process of use of solar radiation as a source of energy for vegetation growth and production (Monteith, 1972; Kumar and Monteith, 1981), as described hereafter.

2.3. The simplified Monteith model

The Monteith model is often referred to as an "efficiency" model. It states that the biomass produced during an interval of time is related to the solar radiation intercepted and absorbed by green plants to be converted into chemical energy in the form of biomass. The fractional biomass productions can then be summed up to represent the entire season. The model has been applied extensively and is described in detail with its parameters (or "efficiencies") in several documents (see for example Prince, 1991b; Ruimy ***et al.,*** 1994; Hanan ***et al.***, 1995; Loudjani, 1993; Ouaidrari, 1994; Nouvellon ***et al.,*** 2000). It can be summarised as follows :

$$\mathbf{BP}_{season} = \sum_{season} (\varepsilon_i \,.\, \varepsilon_b \,.\, PAR\, \Delta t)$$

with $\mathbf{BP}_{season}$: seasonal Biomass Production;

ε_i : efficiency of interception of solar radiation by active vegetation;

ε_b : efficiency of conversion of solar energy into biomass;

PAR : Photo-synthetically Active fraction of the solar Radiation;

Δt : time step.

The **efficiency of interception** of the solar radiation appears to be the main parameter of the model, explaining most of the variability of biomass production, and the entry point of remotely sensed data in the model. Its value can be estimated accurately from remotely sensed data using canopy radiative transfer models (Hanan ***et al.,*** 1995), which is fairly complex. In the present work, it has been estimated using a simple linear relationship between ε_i and the vegetation index (see for example Loudjani, 1993), which represents the main data input of the model. The NDVI of a bare soil (interception negligible) and the NDVI of a full green cover (100% interception) are retrieved from the images by photo-interpretation on known targets (deserts, fully developed crops). From these two reference values, one can define the linear relationship between NDVI and efficiency, which then allows the computation of the efficiency for each pixel at any time.

The PAR corresponds to a fraction of the **incoming solar radiation** on which little information is available in real-time. Estimations of the global radiation can nevertheless be computed on a monthly basis from meteorological satellite imagery, which provides a practical approximation in an image format (Dedieu et Al., 1987). This approximation is acceptable because the variations in illumination are mostly related to the season (Loudjani, 1993; Ouaidrari 1994). Moreover, the variability of the production is determined predominantly by the variability in the interception of the light, not in the solar energy available (Prince 1991a). A slight inaccuracy in the values of the global radiation is therefore acceptable.

The **efficiency of conversion** of light into chemical energy (organic molecules, biomass) is the most difficult model parameter to estimate. It is quite complex and varies according to the growth stage of the plants (Ruimy ***et al.,*** 1994; Nouvellon, 2000). But it appears to be conservative (Prince, 1991) and can therefore be used on different growing seasons. It is usually taken as a seasonal average, which in the literature ranges between 0.35 and 2.5 $g.MJ^{-1}$. For the aerial parts of tropical grasses, the value 0.81 $g.MJ^{-1}$ can be found in Hanan(1995), when Ruimy ***et al.*** (1994) propose a higher value of 1.26. Woody plants have been found to be less efficient with values as low as 0.35 $g.MJ^{-1}$ (Nouvellon, 2000).

2.4. Operational implementation of the Monteith Model

In its simplified format, the Monteith model is easily applicable, with only easily available data as inputs and simple multiplication operations. The actual processing nevertheless requires choices of data sources, values for the parameters and simplifying hypotheses which, within this exercise, were the following :

- The **10 day composited vegetation indices** used as the main input of the model came from 2 sources of low resolution images : SPOT/VEGETATION and for NOAA/AVHRR. The time step for the computations was therefore fixed to 10 days.
- The **efficiency of interception** of the solar radiation was deduced from the values of the NDVI according to the “linear” method presented above, with specific NDVI reference values for VEGETATION and for AVHRR data.
- The **Photo-synthetically Active Radiation** (PAR) was calculated as **48%** of the global radiation received by the canopy (Ruimy et Al., 1995), based on the

monthly global radiation averages extracted from the "Africa and Global Change" database (MEDIAS FRANCE, 1997).

- The **conversion efficiency** was given a fixed value of **0.8 g.MJ^{-1}**, constant throughout the season, by simplification. In the literature, this value corresponds to the efficiency of tropical herbaceous covers; it is applied here to all types of canopies, as if the woody cover had little effect. This approximation is indispensable for the model to be applied a simple and operational way, and we will see in paragraph 3.2 that it is acceptable under certain conditions.

3. Results and accuracy assessment

3.1. Results

Figure 4 shows the results of biomass production estimations on 12 years extracted from the complete 17-year data set described above. The productions were obtained on a period of time ranging from the beginning of October to the end of May of the following year, period covering the normal growing season in Namibia.

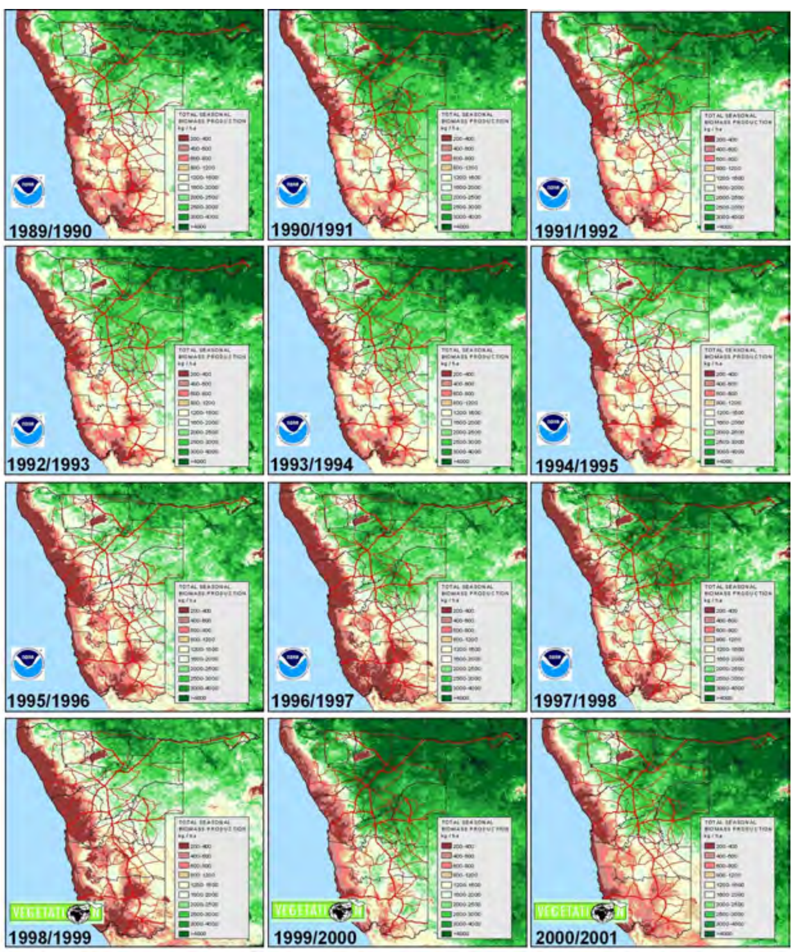
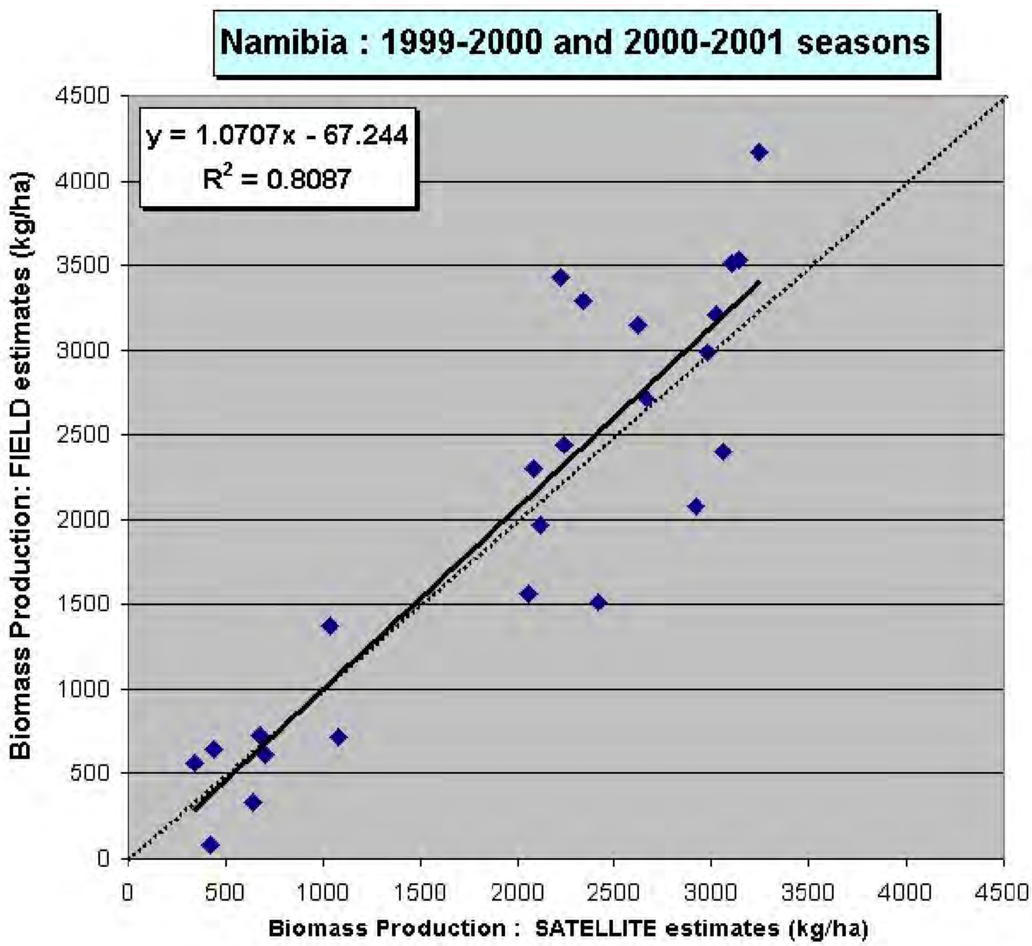


Figure 4 : Results of biomass production estimation for 12 growing seasons

3.2. Accuracy assessment

Field measurements of standing biomass were achieved throughout the country during 2 growing seasons, 1999-2000 and 2000-2001. Using selected plots referenced by GPS (satellite Global Positioning System), biomass was clipped from 1 m^2 quadrats, dried and weighed every 10 days throughout the season. The production of the season was deduced from the sum of biomass increases (Rothauge ***et al.*** ,2003).

Figure 5 presents the comparison between field and satellite derived biomass productions, all data compiled for the two seasons[5]. The statistical correlation between the field and satellite estimates was **0.899,** showing a good correspondence between data sets.



<u>Figure 5</u> – Comparison of the field measured and satellite estimated Biomass Productions over 2 growing seasons (1999-2000 and 2000-2001) for 6 sampling stations in Namibia

A linear regression between field and calculated values gave a **Y = 1.07 X - 67** equation (almost a Y = X line), with a coefficient of determination R^2 of **0.808**, and a residual error of **25.6%**. This shows that the method is applicable with the approximations and simplifications in the model implementation. The fixed value of **0.8 $g.MJ^{-1}$** of the conversion efficiency is acceptable for sites where the woody cover is limited and the use of monthly satellite derived data for the Global Radiation appears sufficient.

3.3. Comparison of results for data from different satellite sensors

For two growing seasons (1998-1999 and 1999-2000), NOAA/AVHRR and SPOT/VEGETATION vegetation index data were available simultaneously. Biomass production estimates were computed with both data types to test the similarity of the results obtained from both types of images. This was achieved by extracting a set of pixel values on the same locations from each source and for both seasons. The correlation between the AVHRR and VEGETATION based results was **0.964**, and linear regression yielded an almost Y = X equation, showing that the results are very comparable

4. Application to national level range resources policy in Namibia

Satellite derived biomass production estimates can be of great help for range resources management at national level. The Namibian authorities utilise them for livestock marketing priorities allocation and investigate their possible use within the agricultural land reform policy.

4.1. Livestock marketing priorities

The Government of Namibia endeavours to promote a rational policy of meat and animal products marketing. This is mainly under the responsibility of a “para-statal” entity, the Meat Board of Namibia (Rawlinson, 1994), which applies one essential mode of action to implement this policy : livestock marketing priority allocation according to the agro-climatic situation. Following this principle, the farmers who have experienced the worst climatic conditions compared to normal are allowed to sell their animals first. This simple decision can have a significant economical and

[5] highly abnormal data and measurements from stations with a very high woody cover were not included.

ecological impact, the beneficiary being the farmer, whether communal or commercial.

From the **economical** point of view, the marketing priority enables farmers to sell their animals in fairly good condition (before they start loosing too much weight by lack of forage). Especially in critical situations, their income is maintained to the best possible level if the priority is allocated a fair and rational way. From the resources or **ecological** point of view, this also has an impact in the long run by reducing the potential degradation by over-utilisation. With accurate priority allocations, the rangelands with the less favourable seasonal conditions hold their livestock for a shorter time.

Remote sensing can be of great help for this purpose of early decision making for early action. As we have seen previously, satellite derived seasonal biomass production estimates (SBPE) prove to be a handy and acceptably accurate source of information on the forage resources. They can be used to quickly assess the current agro-climatic situation, delimit critical areas and evaluate the severity of a crisis, information from which priority allocations can be decided on a good base.

In order to reach these results, the satellite data must be processed to a further stage. It is not the quantity of forage available which is the most relevant in this case, but its comparison to a “normal” situation. In other words, the assessment can only be done efficiently by comparing the current situation to a reference. When using SBPE as the source of information, this reference can be materialised by the average biomass production over a long period. **Figure 6** presents the average SBPE over Namibia for 17 growing seasons, between 1985-1986 and 2001-2002. Being based on a fairly long period, this average can be assumed to integrate the inter-seasonal variability and to represent the “normal” rangeland resources.

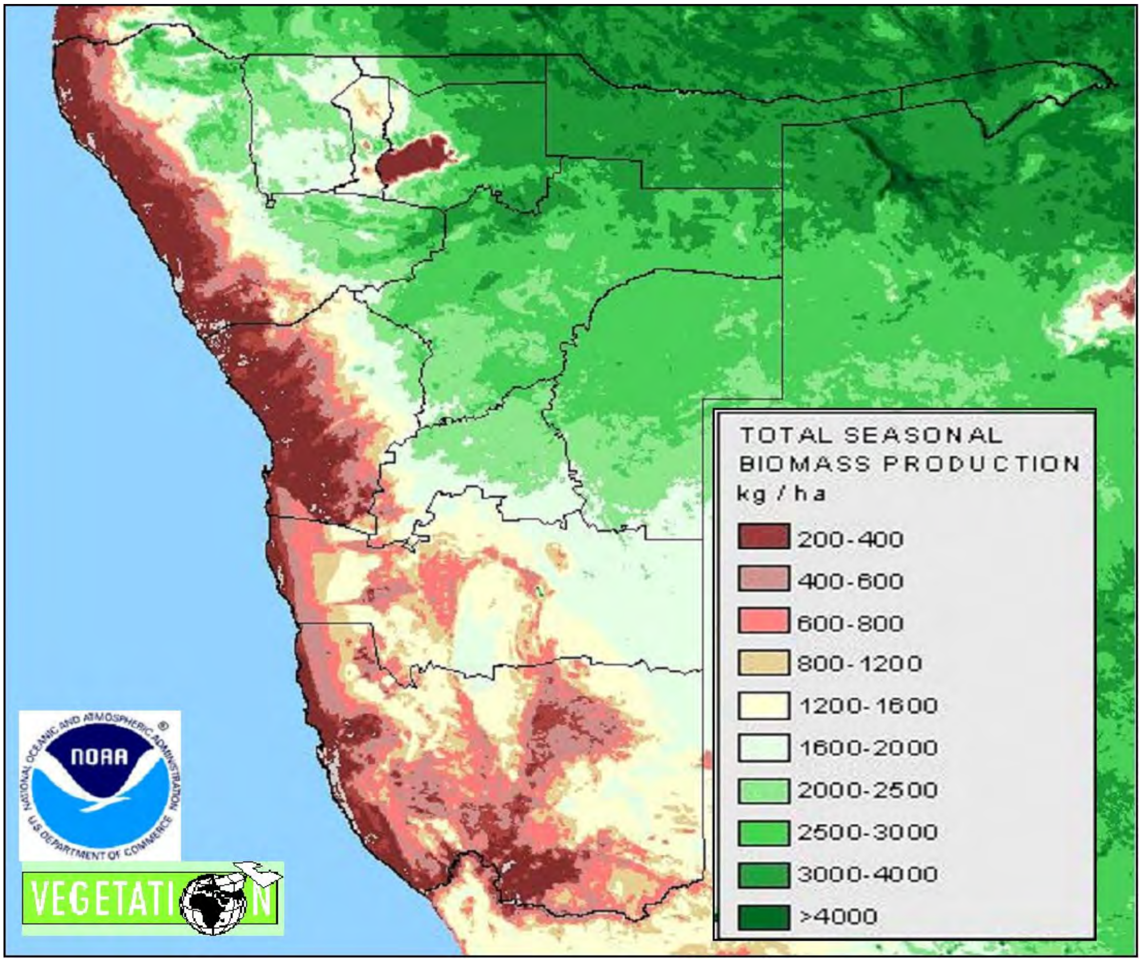
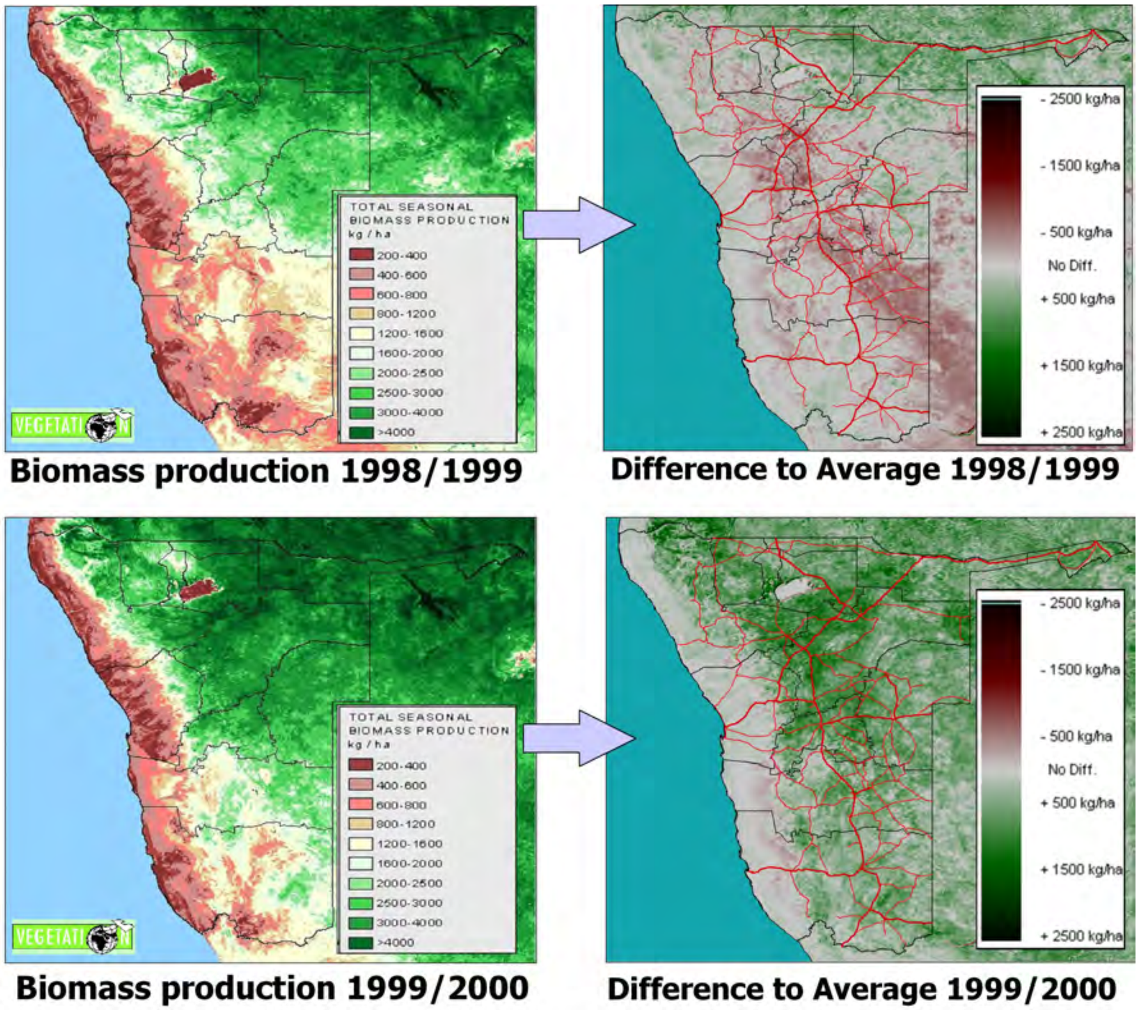


Figure 6 : Average Biomass Production 1985–2002 from NOAA/AVHRR and SPOT/VEGETATION satellite data

The reference being available, the satellite derived information can be processed according to a "multi-temporal" approach which consists of subtracting the current value of the seasonal biomass production to the average. **Figure 7** shows an example of result of this type of process on two different seasons with the 1985-2002 average. The images clearly show that the 1999-2000 season was more productive than the previous and the "difference products" indicate the areas where the production was above average (in green) or below average (in red). This allows to accurately identify and delimit drought stricken areas and to clearly locate the most severe ones, marked by a large difference to average. This last information is particularly useful as a base for priority allocation decisions to the most severely affected areas.



<u>Figure 7</u> : Agro-climatic situation assessment and early detection of critical areas for 2 growing seasons

This type of product based on the difference to the average is already computed an operational way at the end of each growing season (end of may) by the AEZ programme of the Ministry of Agriculture, for delivery to the Meat Board.

4.2. <u>Farms valuation for purchase and taxation</u>

The land reform policy of the Government of Namibia includes (among others) two lines of action which are of concern here : the purchase of land from private owners for reallocation to communal farmers and the implementation of a taxation system for private land. The problem lies in being able to assign a fair value to the land in order for the Government to purchase private farms at the right price and apply fair taxation levels according to the income of the farmers. In both cases, the natural productivity of the land is a key factor[6]. The Government is therefore in great demand for information on the value of the land in terms of grazing.

This resource-related value can be summarised in a very practical range management parameter : the "carrying capacity[7]", which describes a rangeland "in general". In this sense, is not easy to evaluate in the variable climatic conditions that characterise arid lands. The forage is never available in the same quantities from season to season and the carrying capacity, strictly speaking, should be different each season (Behnke and Scoones, 1993). Nevertheless, a value is required, which satellite derived biomass production estimates can help to obtain. When compiled on many different seasons as a long term average, as shown previously on **figure 6**, they allow the estimation of a carrying capacity value which is, in a way, representative in time. Averaging on a long period is a way of taking into account the variability of the resources in time, thus providing a fair indication of the "general" animal production potential.

The specific use of the information for private farm land valuation can be illustrated by a simple case study example, in which data are integrated in a GIS environment. This allows to overlay the commercial farm boundaries, extracted from the NARIS database, to the 17-year average biomass production, as shown on **figure 8**. For the two farms selected in this example, the average biomass production over 17 years is averaged over the whole area of the farm. In other words, the average over time is extracted by spatial analysis for all the pixels included in the farm boundaries and averaged in space to represent the whole farm. The values extracted were **1848 kg/ha** for farm number 58 and of **928 kg/ha** for farm number 104. The example suggests that farm number 58 has a carrying capacity approximately double of that of farm 104.

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[6] although for purchase value the improvements made by the owner (farm houses, fences, etc…) are also taken into consideration.
[7] The **Carrying Capacity** is defined as the number of animals which can be sustained by a surface unit of rangeland. It highly depends on the forage productivity.

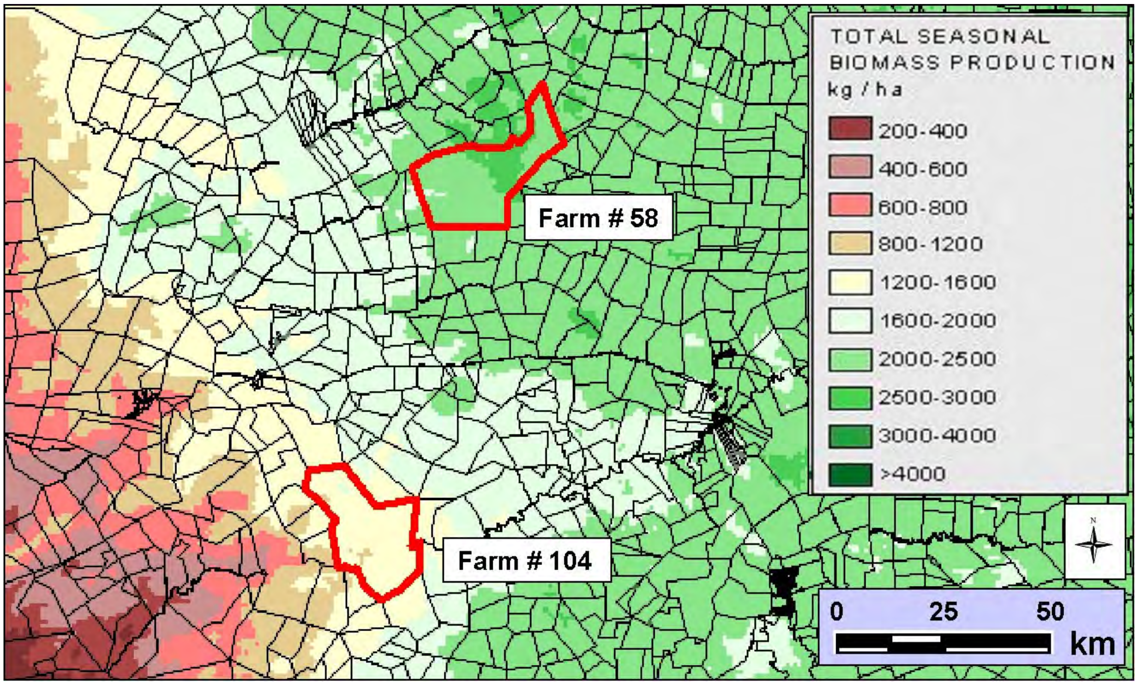

Figure 8 : Overlay of Farm boundaries and long term average biomass production

The method seems to have great potential as an answer to the Government request of baseline information on the carrying capacity. It shows the "normal" value of the land, but must, at this stage, only be considered as an indication and be handled with great care, as we will see in the following discussion.

5. Conclusion and discussion

The present work clearly shows that low resolution satellite imagery can contribute more efficiently than any other source of data to rangeland resources management at national level. Their geographic coverage already is an important asset, but it is the high time resolution and the availability of data on long periods which are mostly responsible for their superiority. Thanks to these last two aspects, the products can be not only quantitative, with obvious the practical aspect, but also multi-temporal, which we have seen allows a great deal more in terms of processing and information elaboration.

The method presented here, based on seasonal biomass production estimations, also has significant assets. It appears to be simple enough to be **really operational**, mainly because only easily available remote sensing data are necessary as inputs for the simplified production model. It also shows to be **versatile** and **adaptable** to any low resolution vegetation index data. Whatever the sensor used, biomass productions are expressed in the same unit, the kilogram of dry matter per hectare. The values being very similar when different satellite data are used, biomasss production estimates from different sources are compatible and can be used in conjunction, for example to be averaged in time. Thus, using BPE as the main indicator solves one of the difficulties inherent to low resolution remote sensing : the inter-calibration of different sensors. For this specific application, the greatest advantage nevertheless remains the **fair and objective** (unbiased) aspect of the satellite data, essential for central institutions to make nationwide rational decisions.

However, satellite based information has its limits. The **accuracy** of the biomass production estimates has proven to be acceptable, but tests were carried out only on field stations with little woody cover. The production model was applied as if the vegetation was entirely herbaceous, which is far from being the reality in the Namibian rangelands where the woody component can be substantial. In fact, trees and shrubs tend to reduce grass production[8] by competition for water and nutrients (Scholes, 1993), except in very arid conditions where the shading and fertilising effect of leguminous species can have a positive effect on grass production (Belsky, 1994). Also, from the satellite point of view, they contribute to the greenness of the canopy but are about half as efficient as grasses for biomass production, which leads to inaccurate (overestimated) results when the woody cover proportion is large.

Accuracy matters are therefore limiting, but not for all applications. For the allocation of **marketing priorities**, the crucial information, is the **relative value** (the assessed situation compared to normal), not the actual value of the biomass production. In this case, “raw” biomass production estimates already provide suitable information as such because the multi-temporal approach leaves aside the effect of the woody cover. For **land valuation,** conversely, the figure required is an **absolute value** of the production, indicating the actual carrying capacity, the livestock production potential of the land. In this case, accuracy becomes an issue and makes things

[8] Grass production, as opposed to the leaves from trees and shrubs, is most of the time considered as the main provision of forage for livestock.

more complex. The carrying capacity is determined by the part of the biomass which is really accessible to the herbivores. This can be significantly different from the total biomass produced, especially in places where the woody proportion is high, where bush encroachment or range degradation factors cannot be ignored. In this case, the value of the "raw" biomass productions are a good information base but must be further processed to take into account local conditions.

Fortunately, GIS based methods exist that allow to take into account the differences in vegetation types. This way, one can take into account the proportion of trees and shrubs in the canopy, but also the quality and accessibility of the forage. The difficulty in the process resides in the necessity of an accurate baseline map with delimitation of the different vegetation types and description of woody cover, accessibility and palatability for each. This type of process was tested successfully on a small protected area in Kenya (Ganzin and Mulama, 2002). It can, theoretically, be applied to larger areas such as the whole of Namibia, provided an equivalent baseline map is available, which is unfortunately not the case. Preliminary tests have nevertheless been carried out using the Agro-Ecological Zones map of the NARIS data base for rough zones delimitation, with very rough estimates of woody cover, accessibility and palatability gathered from a committee of local experts[9]. The results are limited by the accuracy of the baseline information, but very promising, showing that the method can work. In this regard, possibilities are actively investigated and since the issues of land taxation and reallocation are controversial and matters of national priority, the perspective of a nationwide data acquisition effort involving intensive field work campaigns was discussed at the MAWRD in late 2003.

Of course, one should always bear in mind that the information may not always be applicable in the real world. For example, the priority of livestock marketing may not be easily applicable in the communal lands where farmers traditionally tend to sell their livestock in the best possible physical shape. This generates a double risk of having the animals lose condition and face health problems after crossing a long period of reduced forage availability and of environmental degradations by over-grazing in the long run. Still, in such a situation, satellite products may be useful, if not as central decision making tools, maybe as clear and simple information to educate and convince farmers. Many look at satellite products as useful to promote a

[9] The figures were estimated using the field knowledge of rangeland experts, mainly from the Ministry of Agriculture and from the Botanical Institute of Namibia

better management of the land through a different perception, to progress towards a use of the resources more compatible with the actual capacity of the land. Whatever it may be, the use of remote sensing seems to efficiently contribute in providing service or assistance to the most important beneficiary and actual manager of the rangelands : the livestock farmer.

Acknowledgements

The authors wish to acknowledge the French Co-operation in Namibia and the NOLIDEP project (NOrthern regions LIvestock DEvelopment Project) for their technical and financial support, enabling to achieve the collaborative work that lead to the results presented in this paper.

Many thanks to the Etosha Ecological Institute, to the Namibian Meteorological Service, and to the Institute for Soil Climate and Water (ISCW) of South Africa for the provision of valuable archives of satellite data.

The authors also would like to thank the field collaborators for their valuable work in sampling biomass at the agricultural colleges of Neudamm and Ogongo, at the Agricultural research stations or extension offices of Sandveld, Asap, Omatjenne, Gellap Ost, Sonop, and in the Okarumatero private farm.

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