# Diversity II – Preliminary Dryland Products

# Booklet for Test Site 12 Southern Africa


## *Team*

***European Space Agency***

Project requirement definition; user interface; EO data provision; project control

***Brockmann Consult GmbH, Germany***

Prime contractor; project management; algorithms for preprocessing including atmospheric correction over land and lakes; software and production

***GeoVille, Austria***

Drylands requirements analysis; algorithms for drylands; software and production

***Brockmann Geomatics AB, Sweden***

Biodiversity and user interface; algorithms for in-water retrieval and lake indicators; website, web GIS, communication and outreach

***Research Centre in Biodiversity and Genetic Resources CIBIO, Portugal***

Requirements engineering, validation

***Consultants***

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# Table of Content

## Introduction

With the Diversity II project (http://www.diversity2.info/) ESA aims at contributing with EO based methods to the strategic goals of the Convention on Biological Diversity (CBD), especially the supportive goal E: Enhance implementation through participatory planning, knowledge management and capacity building. Besides the CBD and other interested parties, also the UN Convention to Combat Desertification (UNCCD) is a major relevant and interested stakeholder and participating in the User Requirement compilations. The specific aim of this project is to set up an EO-based monitoring scheme for assessment of status, changes and trends of biodiversity and ecosystem NPP (Net Primary Production) in global drylands using moderate resolution EO data. The project is based on Envisat MERIS data and comprises a period of analysis from 2002-2012. Figure 1 gives an overview of the dry land sites which have been selected in the Diversity II project.

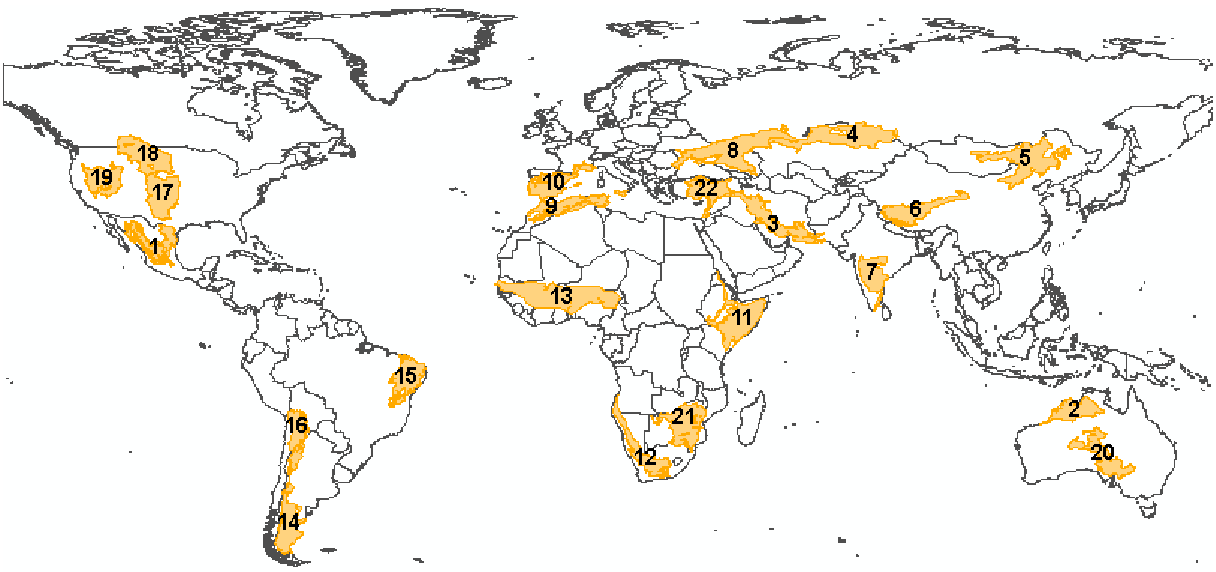



**Figure 1: Distribution of global Diversity II dry land sites**

## Scope of the Preliminary Booklet

This booklet presents NPP proxy and Rain Use Efficiency (RUE) status, change and trend maps for study site 10, Southern Europe along with some basic background information. The booklet is in a preliminary stage and may be changed upon user request to include further or different results of the analyses. The booklets can be downloaded on http://www.diversity2.info/testsites/ppd/.

However, the focus of the booklet is on the most significant and important results of the studies, while complete documentations of methods, techniques and all results will be subject of the project reports. The presented maps can be downloaded via FTP (see page 10 for FTP access).

Up to now, only so-called “Level one” products are shown, i.e. descriptive maps of status and trends of NPP proxies and RUE. They will be supplemented with level-two products, which are currently under development and aim to present the results in more abstract and synthesised ways.

The booklet serves not only to present methods and results in a compact way to users, but also to elicit user feedback. At the end of the booklet (page 30), a short questionnaire is included, aiming at structuring the feedback along some general lines. However, for convenience we recommend to use the on-line questionnaire on http://www.diversity2.info/testsites/ppd/uq/.

## Overview of Test Site

The map in Figure 2 presents an overview of the study site 12 in the South Western part of Africa. The map on the left-hand side shows the GlobCover v. 2.3 2009 data, which were derived (http://due.esrin.esa.int/globcover/ ) based on ENVISAT MERIS FR (300m) reflectance data. The GlobCover map shows rather dense vegetation in the northern part of the test site mainly consisting of grassland mixing with open deciduous forest. Towards the south the vegetation density follows a decline in water availability becoming more and more sparser.

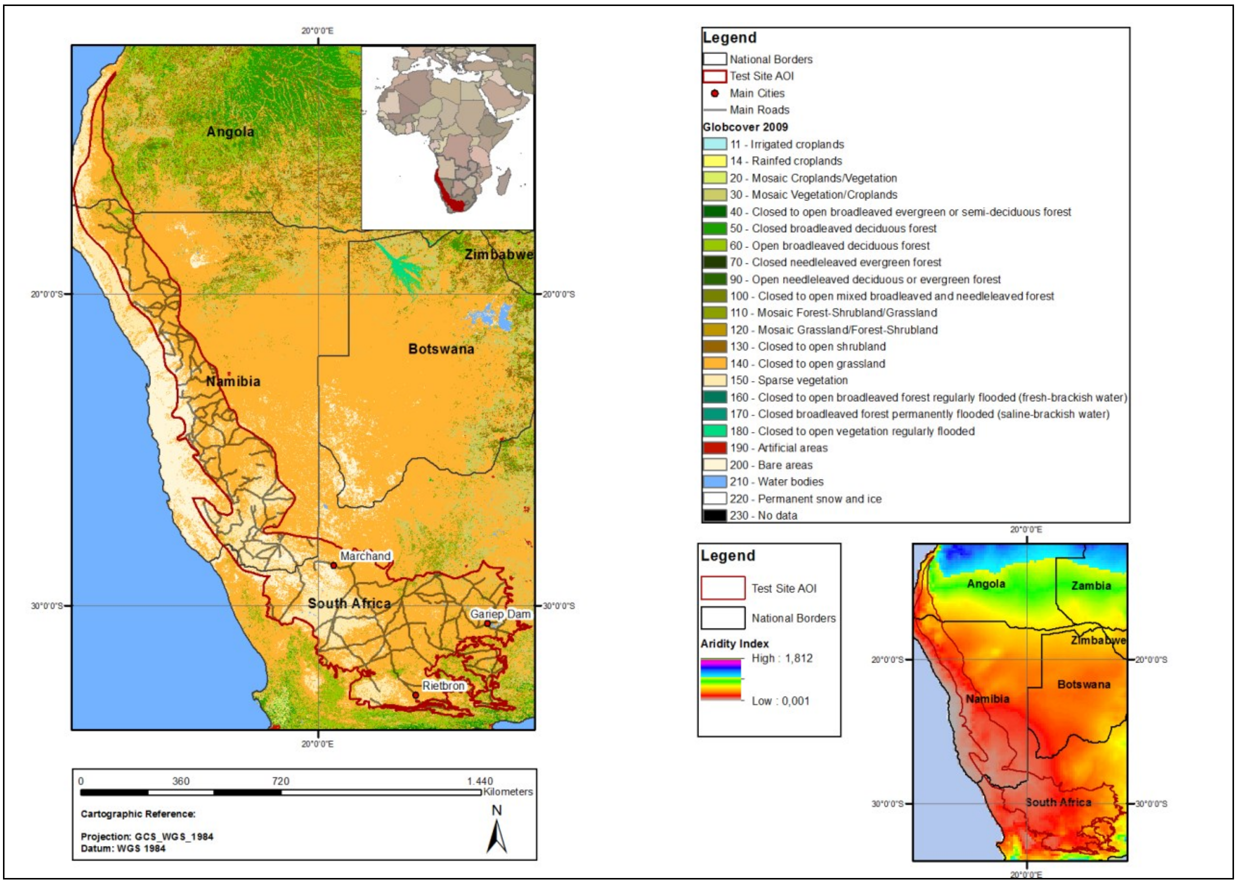



**Figure 2: Overview of test site 12, Southern Africa, showing land cover from the GlobCover 2009 data set on the left-hand side and an aridity index map on the right-hand side derived from the CGIAR-CSI global aridity data base**

Towards the South-East a contrasting gradient can be observed with again increasing vegetation density towards grassland mixed with deciduous forest. This pattern is clearly following the aridity index derived from the CGIAR-CSI global aridity data base (Zomer et. al, 2007, Zomer et. al, 2008) which is depicted on the right-hand side of Figure 2. The CGIAR-CSI global aridity index is computed as ratio of mean annual precipitation and mean annual potential evapotranspiration. Note that declining values indicate increasing aridity. The southern African test site comprises aridity values between 0,025 – 0,584 with the majority ranging between 0,025 and 0,15 (following the CGIAR-CSI classification scheme this corresponds to Arid-Hyperarid).

Figure 3 shows a two climographs of Northern and Southern Namibia, respectively. Both climographs exhibit a similar seasonal behavior, but also represent the by far higher humidity of the climate in the North, compared to the South.

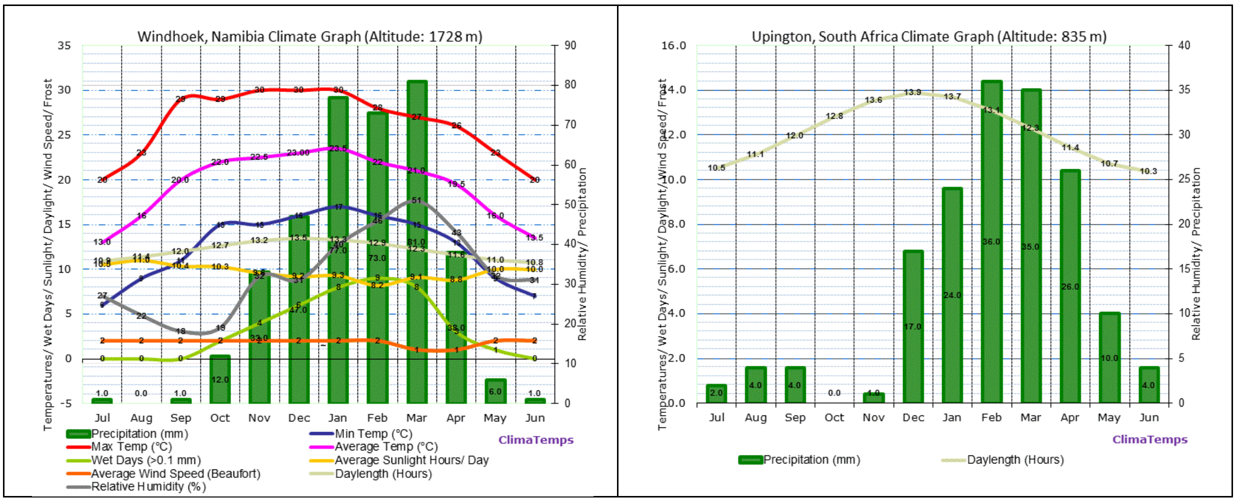



**Figure 3: Climographs of Windhoek (Northern Namibia) and Upington (Southern South Africa), sources: http://www.windhoek.climatemps.com/graph.php, http://www.upington.climatemps.com/graph.php**

## Vegetation and Biophysical Time Series

The seasonal behaviour of the vegetation greenness and important water related parameters are shown in Figure 5. Figure 4 presents the locations of the time series data in all diagrams derived for test site 12, of which time series for location 2 and 4 are presented in Figure 5.

As NPP proxy the NOAA AVHRR GIMMS NDVI (http://gcmd.nasa.gov/records/GCMD_GLCF_GIMMS.html)were used, along with the corresponding rainfall (http://disc.sci.gsfc.nasa.gov/precipitation/documentation/TRMM_README/TRMM_3B42_readme.shtml), CCI soil moisture (http://www.esa-soilmoisture-cci.org/) and MODIS evapotranspiration (http://modis.gsfc.nasa.gov/data/dataprod/dataproducts.php?MOD_NUMBER=16) time series data. All these global data sets are available on the internet free of charge.

The two diagrams shown give an impression of both the spatial and the temporal variability of rainfall and subsequently of soil moisture and vegetation. MODIS evapotranspiration follows this temporal pattern especially at location 4 that is much drier than location 2 further up in the North.

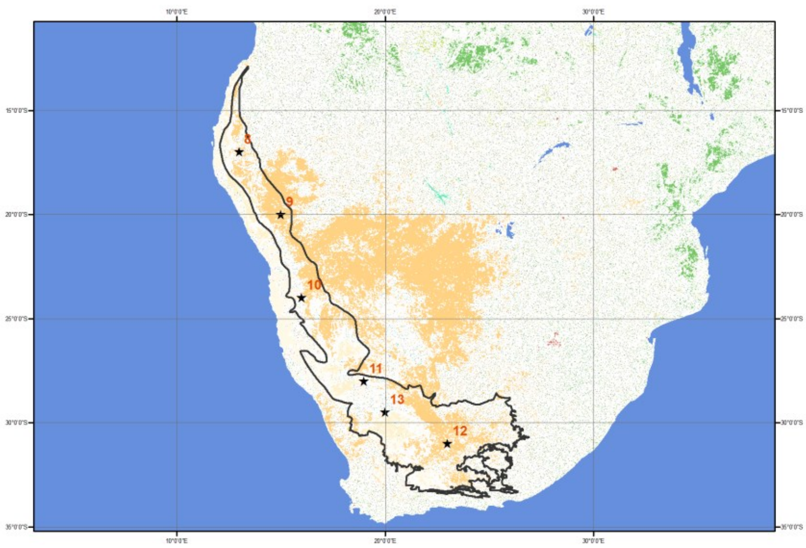
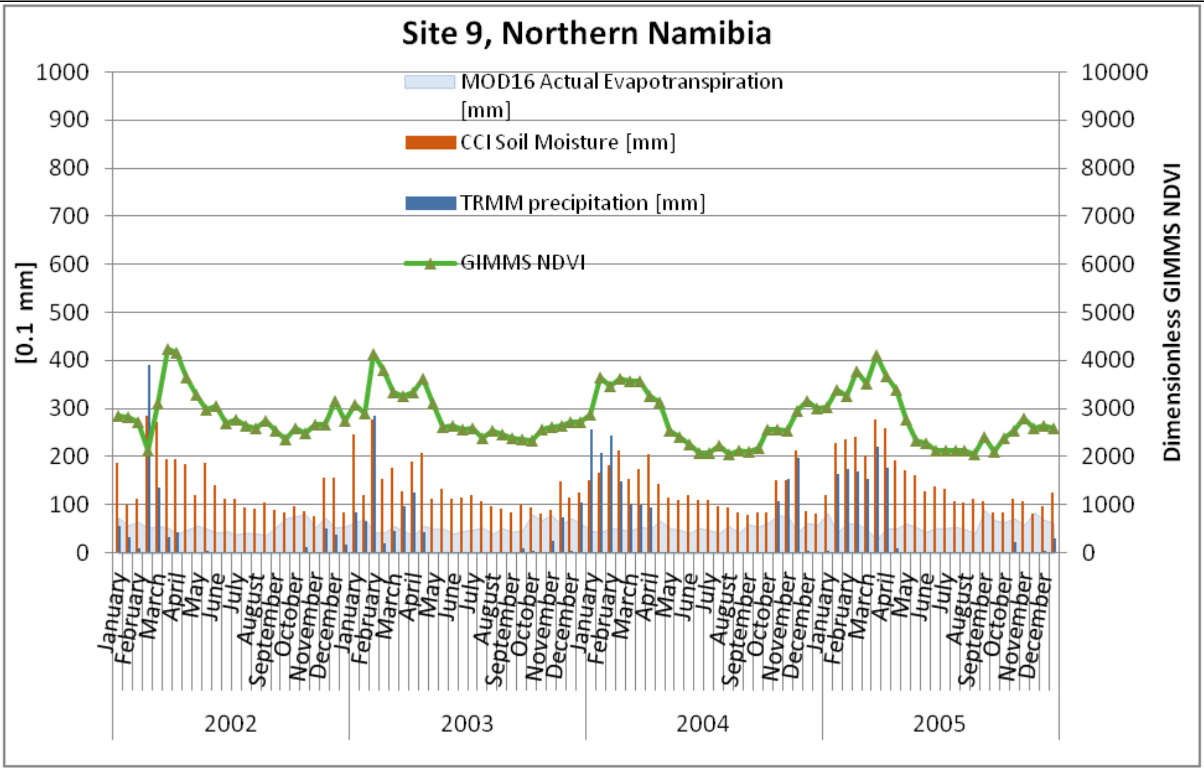



**Figure 4: Locations of derived time series diagrams**



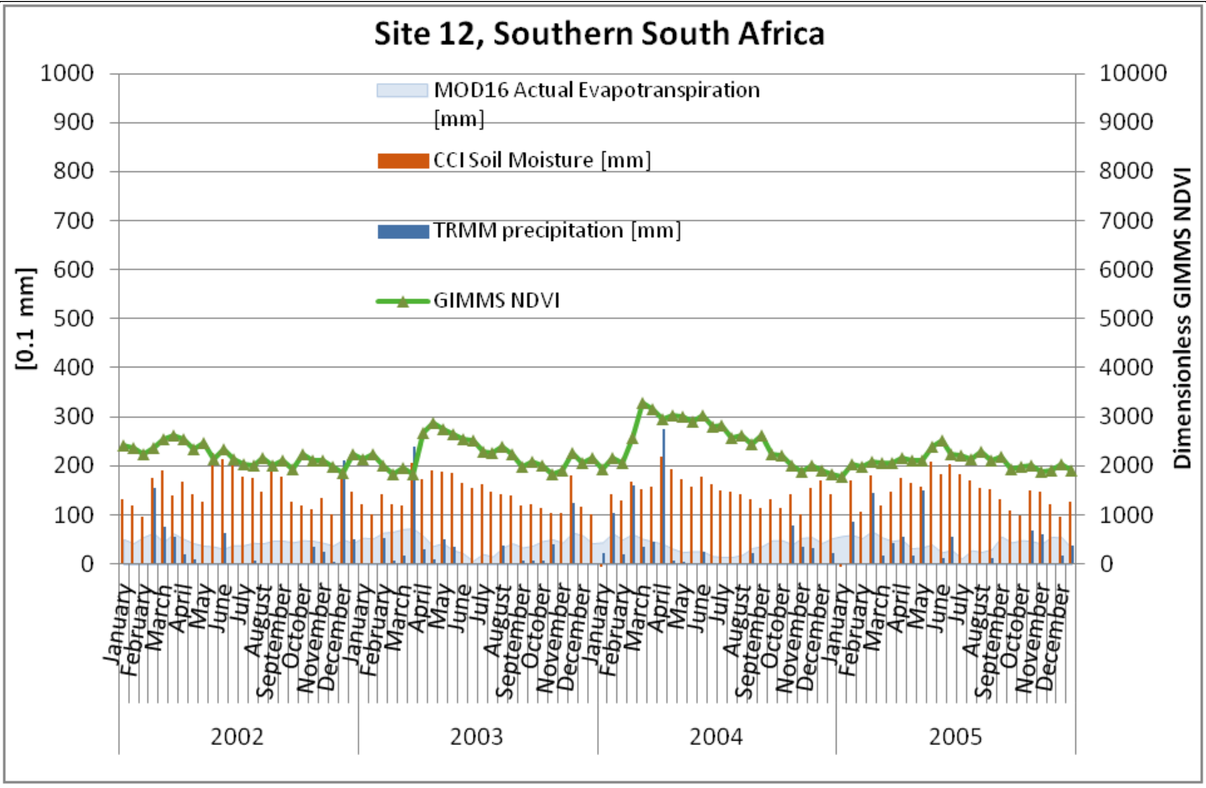




**Figure 5: Time series diagrams for locations 9 and 12 in Figure 4**

## Underlying Data of the Generated Indicators

Based on ENVISAT MERIS FR (Full Resolution) data with a ground resolution of 300m, all NPP proxies presented here and the indicators derived therefrom originate from the fraction of absorbed photosynthetically active radiation (fAPAR) computed according to Gobron et al. 1999. The fAPAR values are compiled on a bi-weekly basis, resulting in time series data with 24 values per calendar year. In addition, TRMM 3b42 rainfall data were used to relate the productivity data to precipitation.

## Generation of NPP-Proxies

In a first step, phenological descriptors and periods are derived individually for each year, as shown in Figure 6. The diagram in Figure 6 shows the temporal course of the NPP proxy data (here NOAA GIMMS NDVI) during a 3-years periods and the subdivision into different seasonal periods. The vegetation year includes the full yearly vegetation cycle starting at the end of the preceding dry season and ending at the end of the following dry season – or in case of several green seasons during a year – at or before the begin of the (statistically) dominant green season. The vegetation year length of a given year varies with possible shifts of the green season start time.

The ***vegetation year*** can be subdivided into different periods, limited by defined starting and ending points in time. The ***growing season*** includes ascending (green segment of the curve) and descending parts (brown part) and starts once a selected greenness threshold is surpassed on the way from the start of the vegetation year to the green peak. The brown part of the curve demarcates the ***senescence period***, which ends again once a defined lower fAPAR threshold is passed. The thresholds depend on the ranges between the fAPAR minima before and after the green peak, respectively, and the peak fAPAR value. Here, 10 percent of these ranges added to the respective minima define the thresholds. The ochre part of the vegetation curve constitutes the "***dry season***".

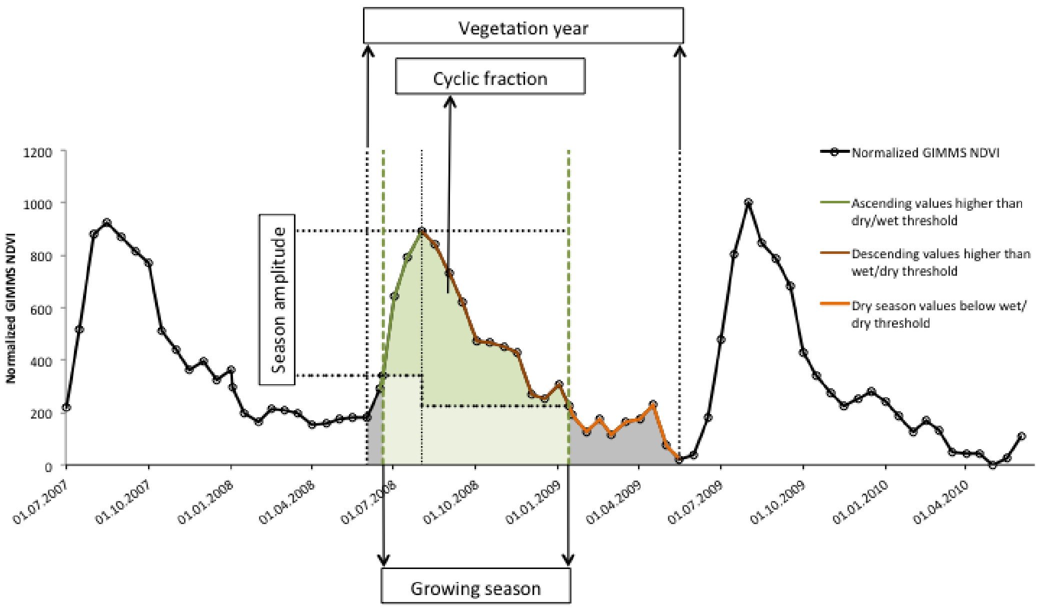



**Figure 6: Scheme of the extracted phenological descriptors and periods . Note: the actual NPP proxies are derived based on MERIS fAPAR**

For the above described phenological periods, the MERIS fAPAR values have been temporally integrated to either sum or average values, or in case of the season amplitude (figure 4), the difference between the fAPAR at the start of the growing season and the peak fAPAR is taken. The results are called "***NPP proxies***", and constitute yearly (one value per vegetation year) values. The indicator maps presented in this preliminary version of the booklet are based on the following NPP proxies:

- ***Average vegetation year fAPAR:*** Mean value of all fAPAR values within one full vegetation cycle, constituting a proxy for the annual NPP.

- ***Cyclic fraction fAPAR:*** The cyclic fraction of the vegetation comprises summed fAPAR values of the green peak(s) during a vegetation year, subtracting the non-cyclic base levels. The cyclic fraction fAPAR can be interpreted as the amount of NPP that is directly related to the annual cycle of the climatic vegetation growth factors, especially rainfall.

- ***Average dry season fAPAR:*** For the dry season the low fAPAR values after the green peak are taken, defined by a 10% amplitude threshold. The dry season greenness values reflect the portion of plants that remain green after senescence of the annual vegetation or grow new green leaves during the dry period. High dry season levels indicate the presence of shrubs, bushes and trees.

## From Proxies to Indicators

By analyzing the annual NPP proxies and rainfall through time, a set of indicators for vegetation/ecosystem condition and change is derived. The indicators shown so far can be divided into status and trend type. Given the MERIS data period from June 2002 to March 2012 and the globally varying vegetation cycles, NPP proxy and Rain Use Efficiency indicators for a total of eight vegetation years could be extracted, starting in 2003/(2002) and ending in 2011/(2012).

Hence, the status and trend indicators cover worldwide eight vegetation years. Status indicators for this period include 8-year averages and the coefficients of variation. In addition, the 8-year period was subdivided into two epochs covering four vegetation years each. The corresponding epochal status maps and epochal difference maps are not shown in this booklet.

For the trend indicators, absolute and relative trends are shown. They were derived with the non parametric Theil Sen trend slope estimator (Theil 1950, Sen 1968) and limited with the Mann Kendall significance test (Kendall 1962) to trends with a probability greater than 0.95.

All indicator maps show distinct ranges of the original continuous values, using the same class intervals and colour scheme worldwide.

## Maps of Indicators

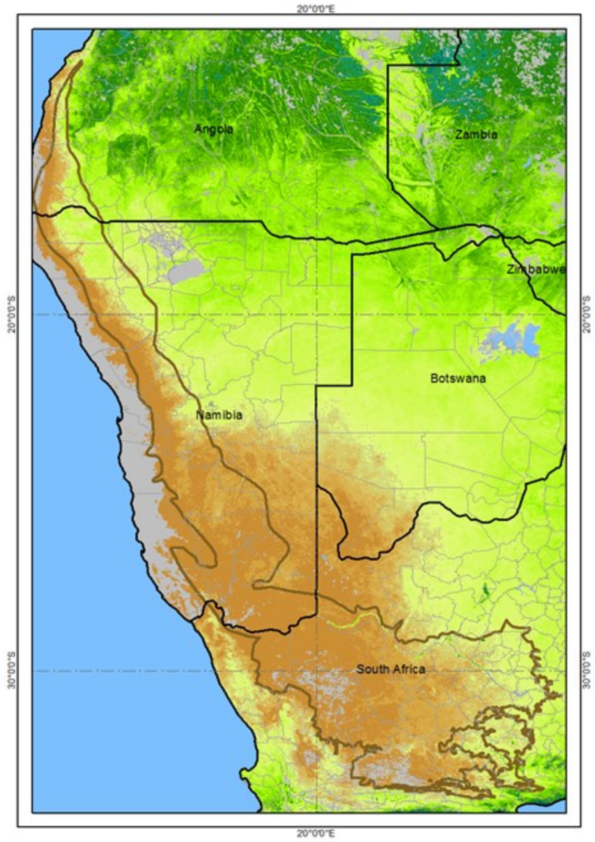
The following section contains maps for the entire test site and surrounding regions for each indicator product. The first two maps of each item depict status and variability maps while the third and fourth map show absolute and relative trends maps, respectively. An exception is the rainfall maps, where instead of the relative trend the difference between the two epochs (2002 – 2006 and 2007 – 2011, respectively) is shown. The maps are described with short product specifications.

They can be downloaded from:

**Domain**: ftp.brockmann-consult.de

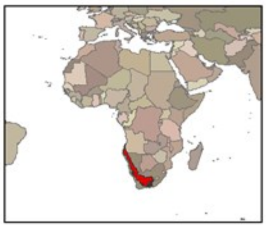
**Username**: diversity-pub
**Password**: dl&iw-usr

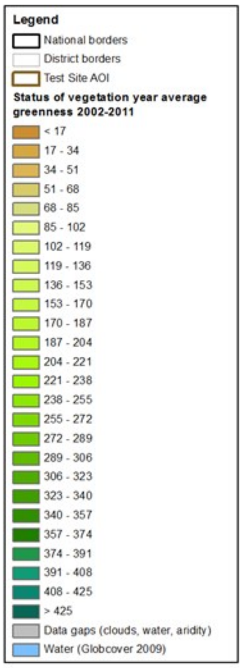
## Average Vegetation Year Greenness

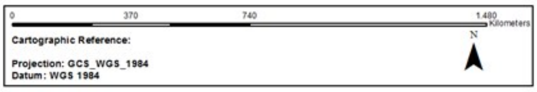



Description:

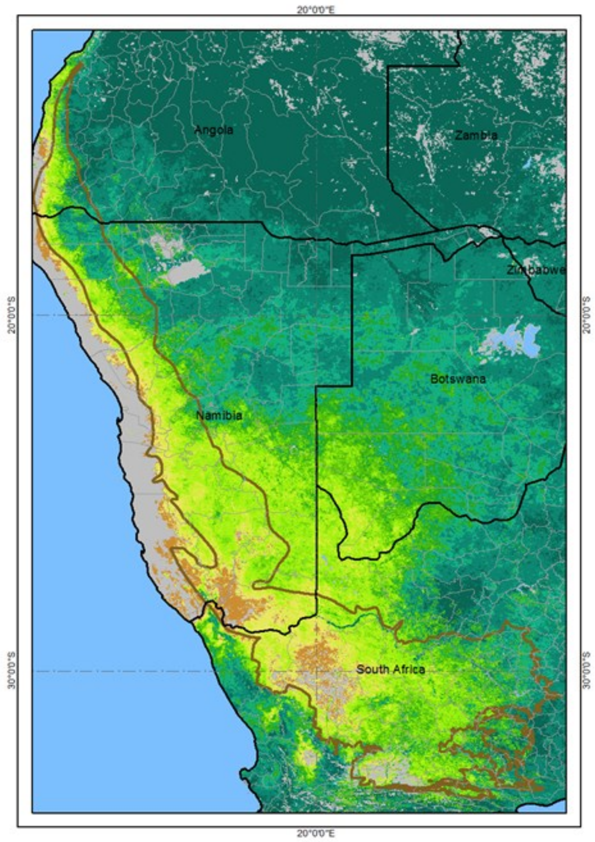
Status of ENVISAT MERIS fAPAR average vegetation year greenness, calculated as mean value for the period 2002-2011 in test site southern Africa. One vegetation year comprises one full phenological cycle of the vegetation.





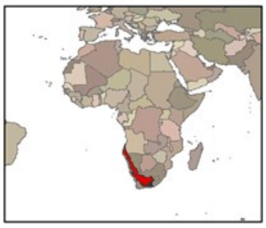



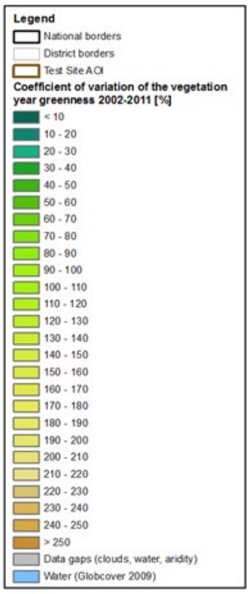

## Vegetation Year Variability

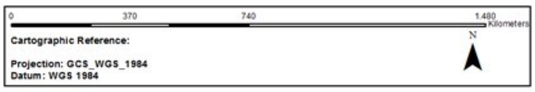



Description:

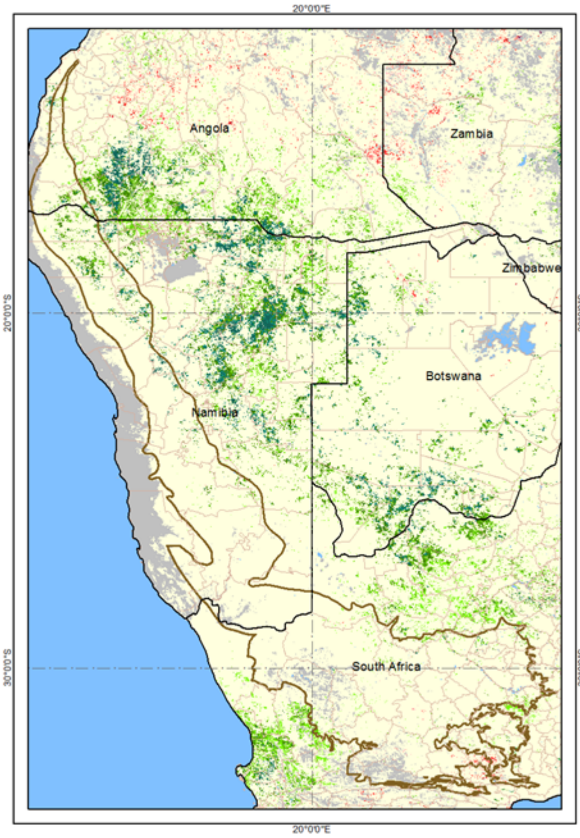
Variability of ENVISAT MERIS fAPAR vegetation year greenness expressed by the coefficient of variation for the period 2002-2011 in test site southern Africa. One vegetation year comprises one full phenologic cycle of the vegetation.





## Vegetation Year Greenness Trend (abs.)




Description:

Slopes of absolute trends of ENVISAT MERIS fAPAR vegetation year averages in test site southern Africa throughout the period 2002-2011. One vegetation year comprises one full phenological cycle of the vegetation and hence constitutes a proxy for the overall annual NPP. The vegetation year is defined to start at the onset of vegetation greening following first rainfalls and last until the end of the dry season. The actual start of each vegetation year is individually determined for each year.

Trends are calculated using the median trend estimator after Theil (1950) and Sen (1968). Only significant trends (p 0.05) are depicted based on the trend test on significance according to Mann (1945) and Kendall (1975).

Trend values indicate average change per year. Original fAPAR values reach from 0 to 1 and have been stretched from 0 to 1000.

Data gaps in the time series resulting from cloud cover, a too pronounced aridity or water bodies have been masked out.

**Legend**

- National borders
- District borders
- Test Site AOI

**Absolute trend slopes of vegetation year average greenness 2002 – 2011**

- yearly decrease > 15
- yearly decrease 12 - 15
- yearly decrease 9 - 12
- yearly decrease 6 - 9
- yearly decrease 3 - 6
- yearly decrease 1 - 3
- yearly increase 1 - 3
- yearly increase 3 - 6
- yearly increase 6 - 9
- yearly increase 9 - 12
- yearly increase 12 - 15
- yearly increase > 15
- Insignificant or trend < 1
- Data gaps (clouds, water, aridity)
- Water (Globcover 2009)

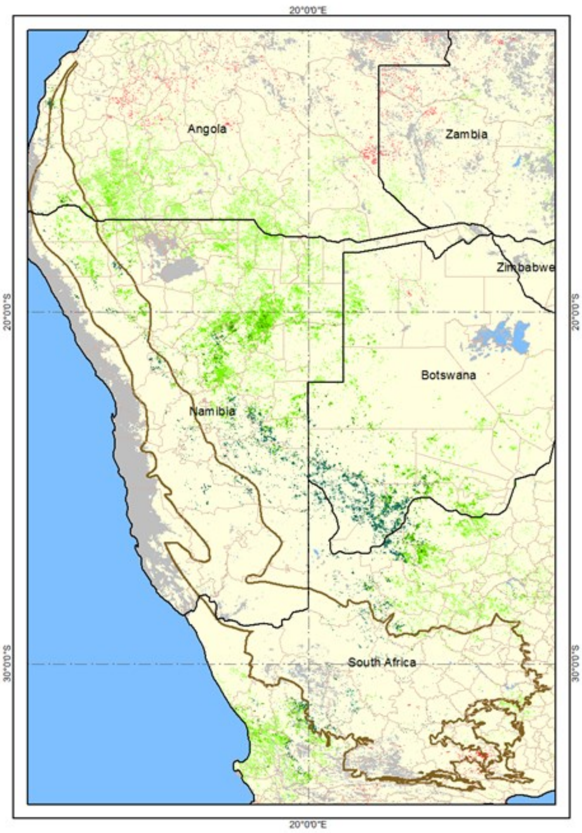
0 355 710 1.420 Kilometers

N

**Cartographic Reference:**

**Projection: GCS_WGS_1984**
**Datum: WGS 1984**

## Vegetation Year Greenness Trend (rel.)




Description:

Relative yearly changes of ENVISAT MERIS fAPAR vegetation year averages in test site southern Africa throughout the period 2002-2011. One vegetation year comprises one full phenological cycle of the vegetation and hence constitutes a proxy for the overall annual NPP. The vegetation year is defined to start at the onset of vegetation greening following first rainfalls and last until the end of the dry season. The actual start of each vegetation year is individually determined for each year.

Trends are calculated using the median trend estimator after Theil (1950) and Sen (1968). Only significant trends (p 0.05) are depicted based on the trend test on significance according to Mann (1945) and Kendall (1975).

Data gaps in the time series resulting from cloud cover, a too pronounced aridity or water bodies have been masked out from the analysis.

**Legend**

- National borders
- District borders
- Test Site AOI

**Relative trend of vegetation year average greenness 2002 – 2011**

- yearly decrease > 15%
- yearly decrease 10 - 15 %
- yearly decrease 5 - 10 %
- yearly decrease < 5 %
- yearly increase < 10 %
- yearly increase 10 - 20 %
- yearly increase 20 - 30 %
- yearly increase 30 - 40 %
- yearly increase 40 - 50 %
- yearly increase 50 - 60 %
- yearly increase 60 - 80 %
- yearly increase > 80 %
- Insignificant or abs. trend < 0.5
- Data gaps (clouds, water, aridity)
- Water (Globcover 2009)

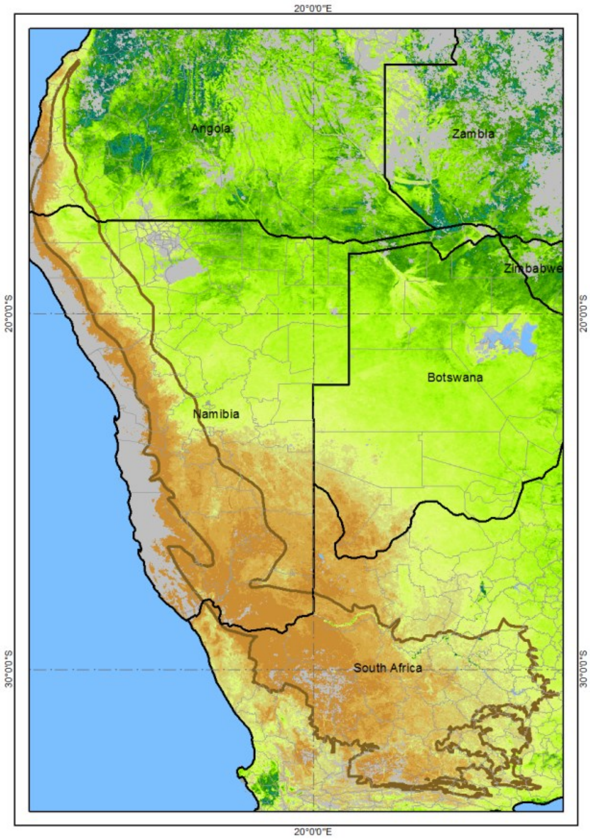
0 375 750 1.500 Kilometers

N

**Cartographic Reference:**

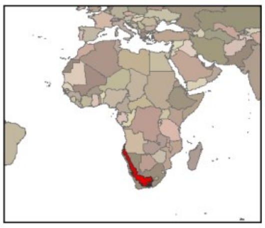
**Projection: GCS_WGS_1984**
**Datum: WGS 1984**

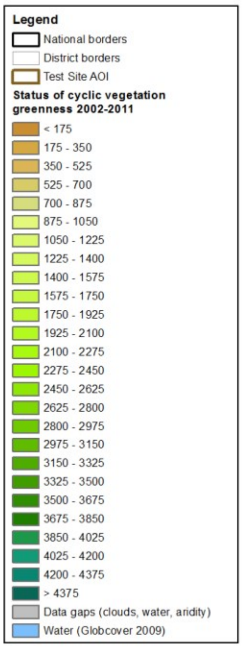
## Cyclic Vegetation Greenness

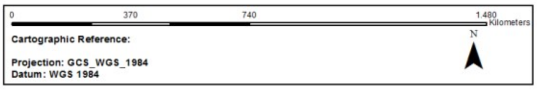



Description:

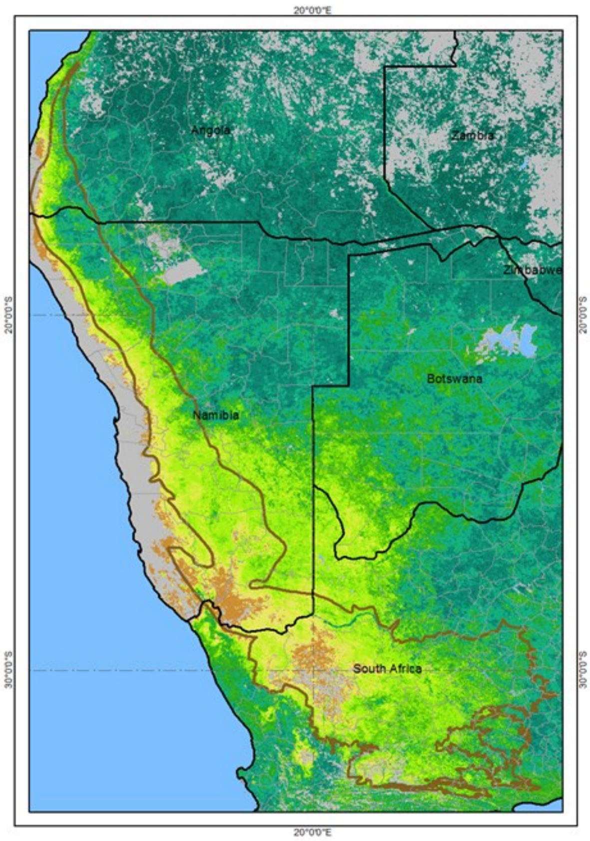
Status of ENVISAT MERIS fAPAR cyclic vegetation greenness calculated as mean value for the period 2002-2011 in test site southern Africa. The cyclic fraction of the vegetation comprises summed fAPAR values of the green peak(s) during a vegetation year, subtracting the non-cyclic base levels.





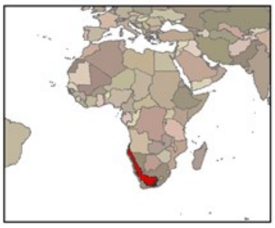



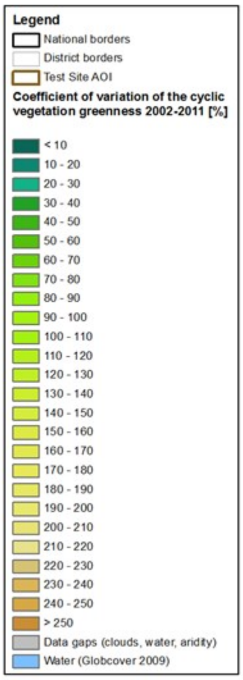

## Cyclic Vegetation Variability

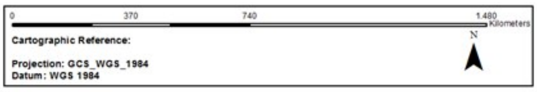



Description:,

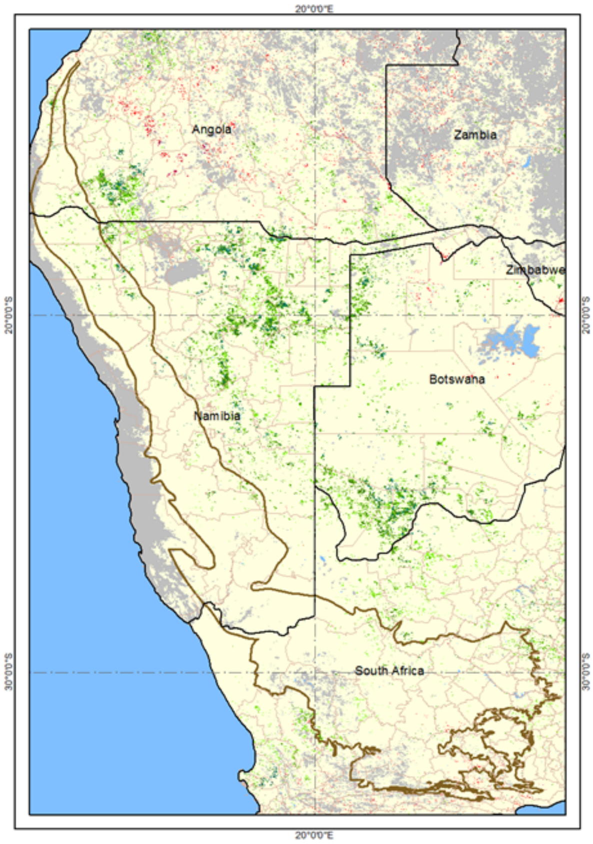
Variability of ENVISAT MERIS fAPAR cyclic vegetation greenness expressed by the coefficient of variation for the period 2002-2011 in test site southern Africa. The cyclic fraction of the vegetation comprises summed fAPAR values of the green peak(s) during a vegetation year, subtracting the non-cyclic base levels.





## Cyclic Vegetation Greenness Trend (abs.)




Description:

Slopes of absolute trends of ENVISAT MERIS fAPAR "cyclic fraction" values in test site southern Africa throughout the period 2002-2011. The cyclic fraction of the vegetation comprises summed fAPAR values of the green peak(s) during a vegetation year, subtracting the non-cyclic base levels. The cyclic fraction fAPAR can be interpreted as the amount of NPP being directly related to the annual cycle of the climatic vegetation growth factors, especially rainfall.

Trends are calculated using the median trend estimator after Theil (1950) and Sen (1968). Only significant trends (p 0.05) are depicted based on the trend test on significance according to Mann (1945) and Kendall (1975).

Trend values indicate average change per year. Original fAPAR values reach from 0 to 1 and have been stretched from 0 to 1000.

Data gaps in the time series resulting from cloud cover, a too pronounced aridity or water bodies have been masked out from the analysis.

**Legend**

- National borders
- District borders
- Test Site AOI

**Absolute trend slopes of cyclic vegetation greenness 2002 – 2011**

- yearly decrease > 250
- yearly decrease 200 - 250
- yearly decrease 150 - 200
- yearly decrease 100 - 150
- yearly decrease 50 - 100
- yearly decrease 10 - 50
- yearly increase 10 - 50
- yearly increase 50 - 100
- yearly increase 100 - 150
- yearly increase 150 - 200
- yearly increase 200 - 250
- yearly increase > 250
- Insignificant or trend < 10
- Data gaps (clouds, water, aridity)
- Water (Globcover 2009)

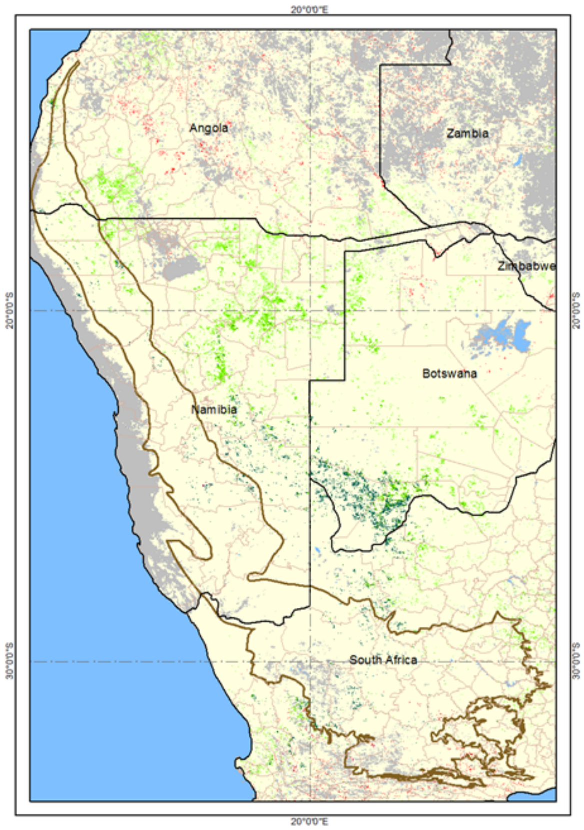
0 370 740 1.480 Kilometers

N

**Cartographic Reference:**

**Projection: GCS_WGS_1984**
**Datum: WGS 1984**

## Cyclic Vegetation Greenness Trend (rel.)




Description:

Relative yearly changes of ENVISAT MERIS fAPAR "cyclic fraction" values in test site southern Africa throughout the period 2002-2011. The cyclic fraction of the vegetation comprises summed fAPAR values of the green peak(s) during a vegetation year, subtracting the non-cyclic base levels. The cyclic fraction fAPAR can be interpreted as the amount of NPP being directly related to the annual cycle of the climatic vegetation growth factors, especially rainfall.

Trends are calculated using the median trend estimator after Theil (1950) and Sen (1968). Only significant trends (p 0.05) are depicted based on the trend test on significance according to Mann (1945) and Kendall (1975).

Data gaps in the time series resulting from cloud cover, a too pronounced aridity or water bodies have been masked out from the analysis.

**Legend**

- National borders
- District borders
- Test Site AOI

**Relative trend of cyclic vegetation greenness 2002 – 2011**

- yearly decrease > 15%
- yearly decrease 10 - 15 %
- yearly decrease 5 - 10 %
- yearly decrease < 5 %
- yearly increase < 10 %
- yearly increase 10 - 20 %
- yearly increase 20 - 30 %
- yearly increase 30 - 40 %
- yearly increase 40 - 50 %
- yearly increase 50 - 60 %
- yearly increase 60 - 80 %
- yearly increase > 80 %
- Insignificant or abs. trend < 10
- Data gaps (clouds, water, aridity)
- Water (Globcover 2009)

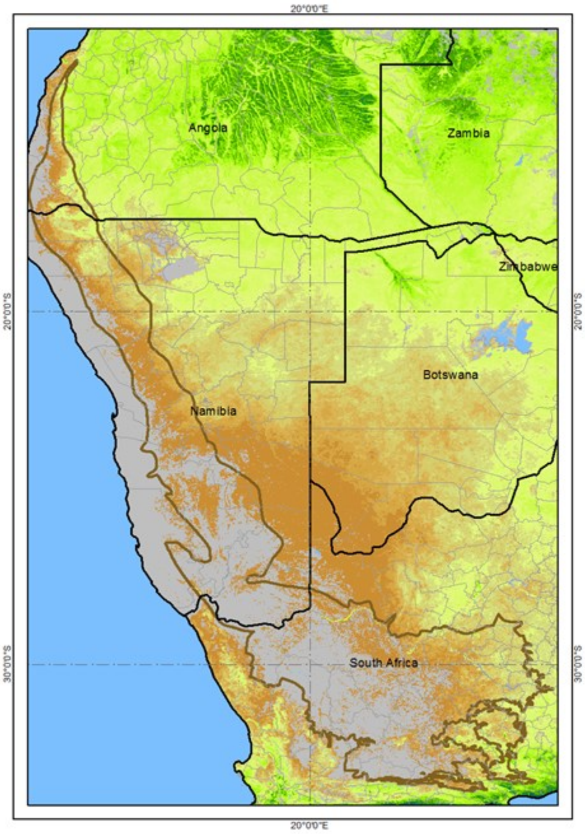
0 375 750 1.500 Kilometers

N

**Cartographic Reference:**

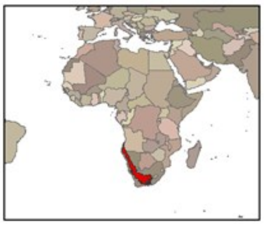
**Projection: GCS_WGS_1984**
**Datum: WGS 1984**

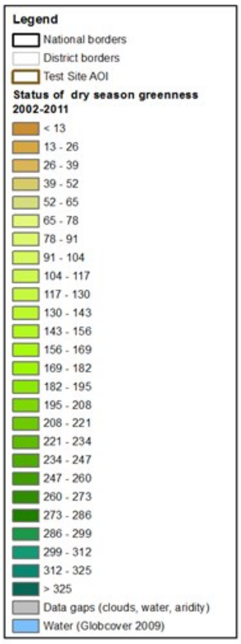
## Dry Season Greenness

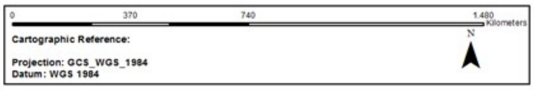



Description:

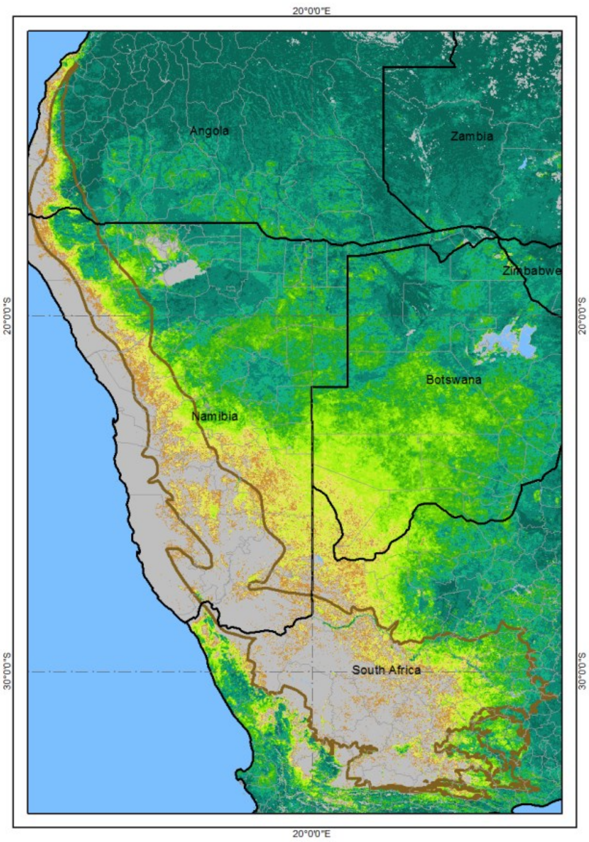
Status of ENVISAT MERIS fAPAR dry season greenness calculated as mean value for the period 2002-2011 in test site southern Africa. The dry season greenness values reflect the portion of plants that remain green after senescence of the annual vegetation or grow new green leaves during the dry period.





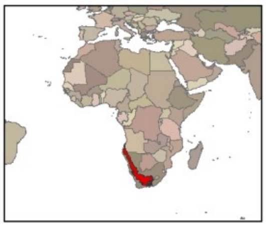



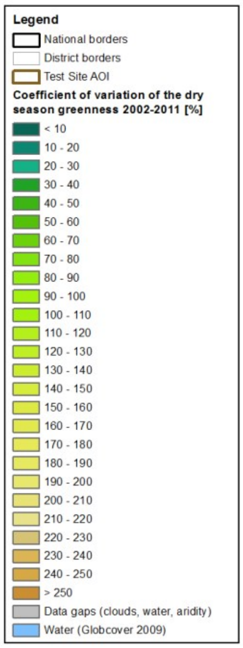

## Dry Season Variability

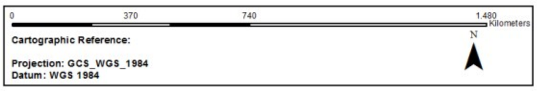



Description:

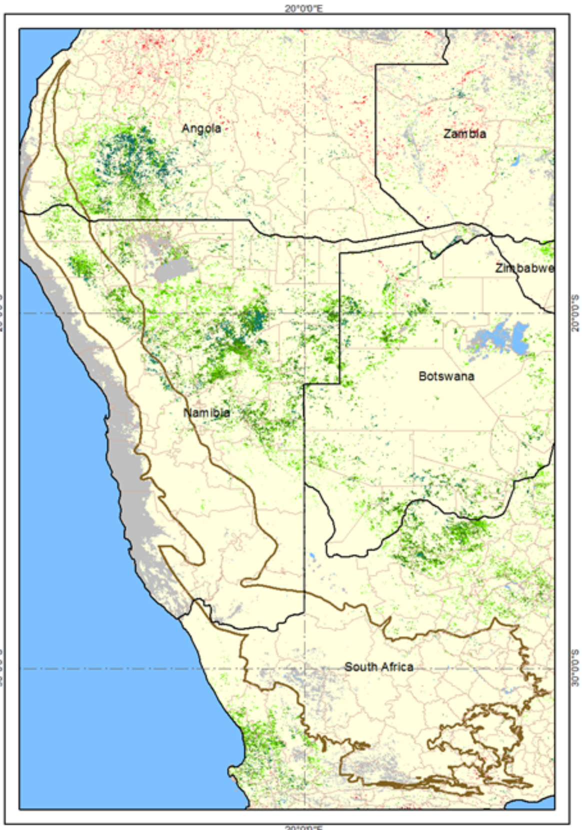
Variability of ENVISAT MERIS fAPAR dry season greenness expressed by the coefficient of variation for the period 2002-2011 in test site southern Afrika. The dry season greenness values reflect the portion of plants that remain green after senescence of the annual vegetation or grow new green leaves during the dry period.





## Dry Season Greenness Trend (abs.)




**Description:**

Slopes of absolute trends of ENVISAT MERIS fAPAR dry season averages in test site southern Africa throughout the period 2002-2011. For the dry season the low fAPAR values after the green peak are taken, defined by a 10% amplitude threshold. The dry season greenness values reflect the portion of plants that remain green after senescence of the annual vegetation or grow new green leaves during the dry period.

Trends are calculated using the median trend estimator after Theil (1950) and Sen (1968). Only significant trends (p 0.05) are depicted based on the trend test on significance according to Mann (1945) and Kendall (1975).

Trend values indicate average change per year. Original fAPAR values reach from 0 to 1 and have been stretched from 0 to 1000.

Data gaps in the time series resulting from cloud cover, a too pronounced aridity or water bodies have been masked out from the analysis.

**Legend**

- National borders
- District borders
- Test Site AOI

**Absolute trend slopes of dry season greenness 2002 – 2011**

- yearly decrease > 10
- yearly decrease 8 - 10
- yearly decrease 6 - 8
- yearly decrease 4 - 6
- yearly decrease 2 - 4
- yearly decrease 1 - 2
- yearly increase 1- 2
- yearly increase 2 - 4
- yearly increase 4 - 6
- yearly increase 6 - 8
- yearly increase 8 - 10
- yearly increase > 10
- Insignificant or trend < 1
- Data gaps (clouds, water, aridity)
- Water (Globcover 2009)

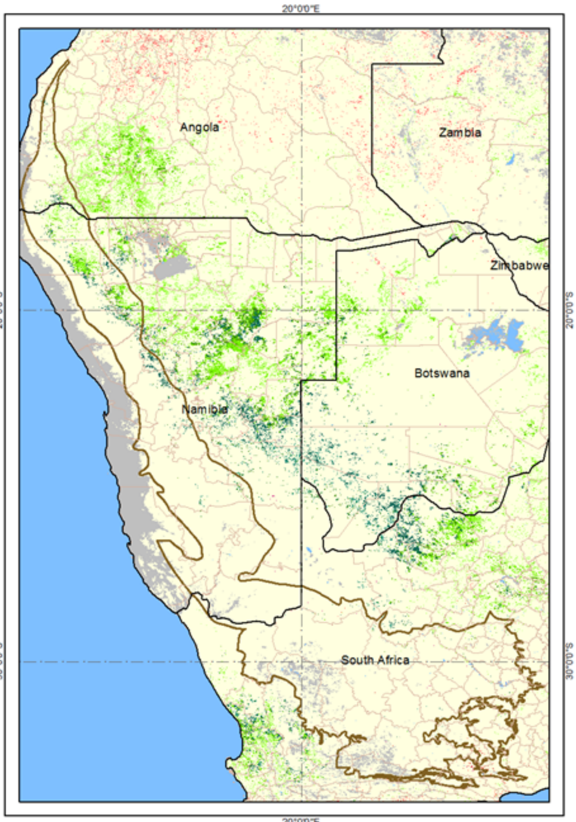
0 350 700 1.400 Kilometers

N

**Cartographic Reference:**

**Projection: GCS_WGS_1984**
**Datum: WGS 1984**

## Dry Season Greenness Trend (rel.)




**Description:**

Relative yearly changes of ENVISAT MERIS fAPAR dry season averages in test site southern Africa throughout the period 2002-2011. For the dry season the low fAPAR values after the green peak are taken, defined by a 10% amplitude threshold. The dry season greenness values reflect the portion of plants that remain green after senescence of the annual vegetation or grow new green leaves during the dry period.

Trends are calculated using the median trend estimator after Theil (1950) and Sen (1968). Only significant trends (p 0.05) are depicted based on the trend test on significance according to Mann (1945) and Kendall (1975).

Data gaps in the time series resulting from cloud cover, a too pronounced aridity or water bodies have been masked out from the analysis.

**Legend**

- National borders
- District borders
- Test Site AOI

**Relative trend of dry season greenness 2002 – 2011**

- yearly decrease > 15%
- yearly decrease 10 - 15 %
- yearly decrease 5 - 10 %
- yearly decrease < 5 %
- yearly increase < 10 %
- yearly increase 10 - 20 %
- yearly increase 20 - 30 %
- yearly increase 30 - 40 %
- yearly increase 40 - 50 %
- yearly increase 50 - 60 %
- yearly increase 60 - 80 %
- yearly increase > 80 %
- Insignificant or abs. trend < 0.5
- Data gaps (clouds, water, aridity)
- Water (Globcover 2009)

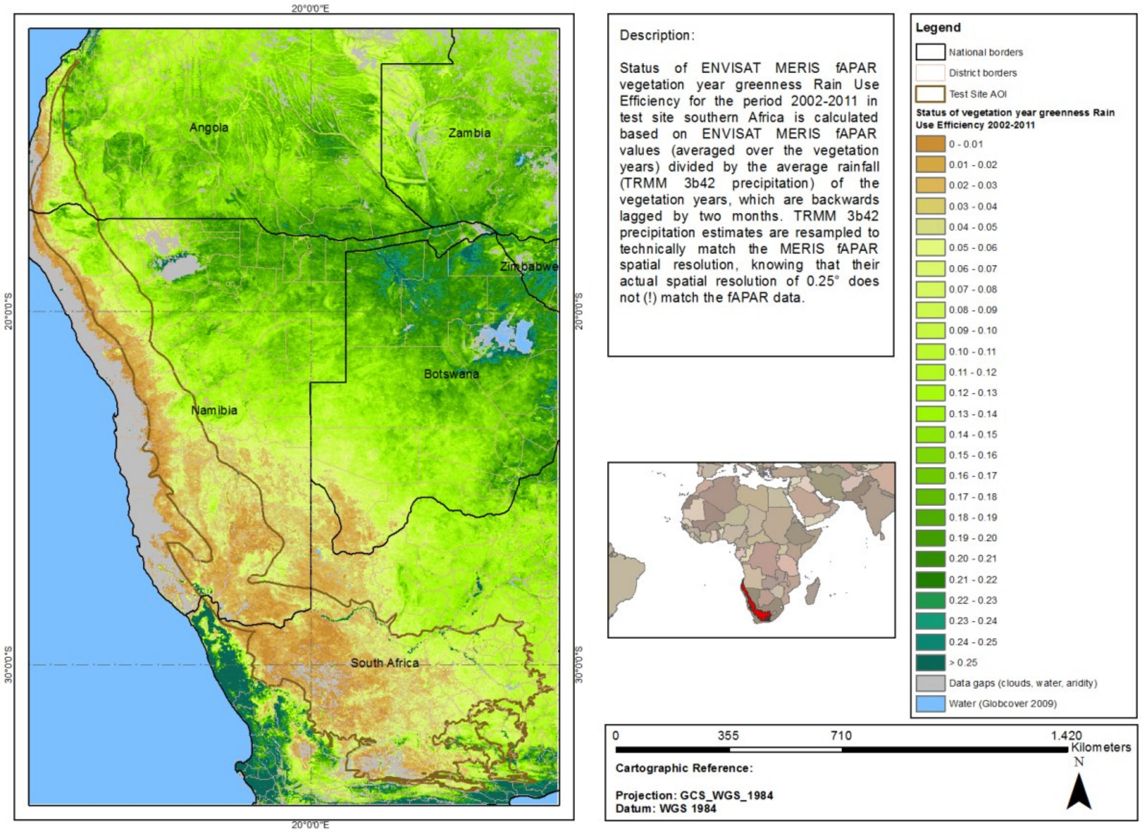
0 370 740 1.480 Kilometers

N

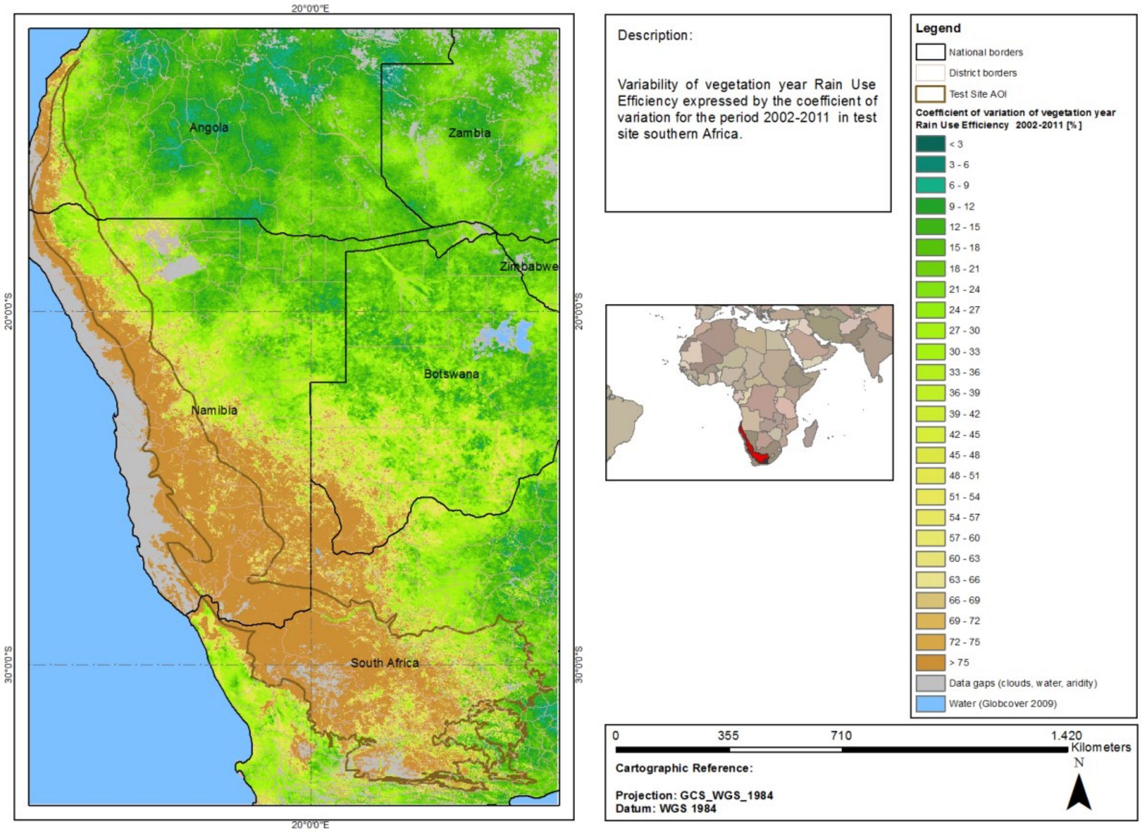
**Cartographic Reference:**

**Projection: GCS_WGS_1984**
**Datum: WGS 1984**

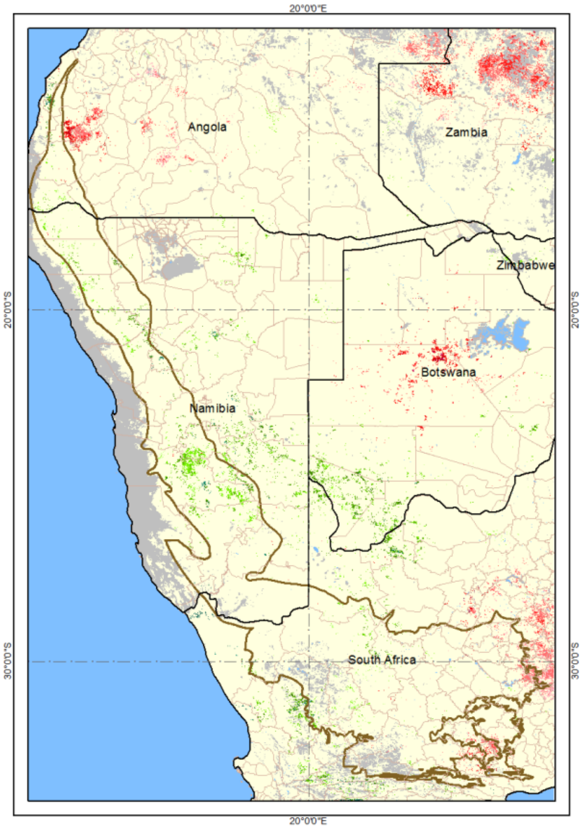
## Average Vegetation Year Rain Use Efficiency Status




## Vegetation Year Rain Use Efficiency Variability



## Vegetation Year Rain Use Efficiency Trend (abs.)




Description:

Slopes of absolute trends of vegetation year average greenness Rain Use Efficiency (RUE) in test site southern Africa throughout the period 2002-2011. Vegetation year average greenness RUE calculation is based on ENVISAT MERIS fAPAR values (averaged over one vegetation year) divided by rainfall data (TRMM 3b42 precipitation). TRMM 3b42 precipitation estimates are bilinearly resampled to technically match the MERIS fAPAR spatial resolution, knowing that their actual spatial resolution of 0.25° does not (!) match the fAPAR data.

Trends are calculated using the median trend estimator after Theil (1950) and Sen (1968). Only significant trends (p 0.05) are depicted based on the trend test on significance according to Mann (1945) and Kendall (1975).

Trend values indicate average change per year. Original fAPAR values reach from 0 to 1 and have been stretched from 0 to 1000. Data gaps in the time series resulting from cloud cover, a too pronounced aridity or water bodies have been masked out from the analysis.

**Legend**

- National borders
- District borders
- Test Site AOI

**Absolute trend slopes of vegetation year average greenness Rain Use Efficiency 2002 –2011**

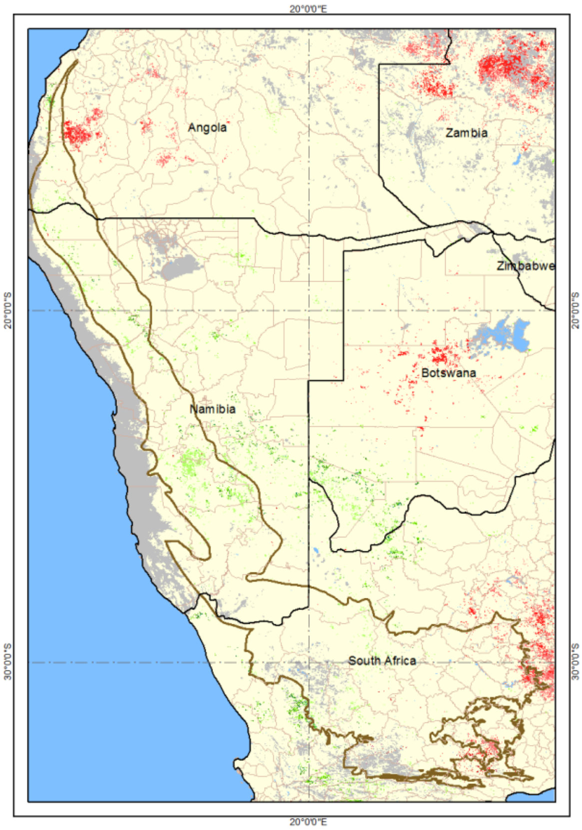
- yearly decrease > 0.05
- yearly decrease 0.04 - 0.05
- yearly decrease 0.03 - 0.04
- yearly decrease 0.02 - 0.03
- yearly decrease 0.01 - 0.02
- yearly decrease 0.001 - 0.01
- yearly increase 0.001 - 0.01
- yearly increase 0.01 - 0.02
- yearly increase 0.02 - 0.03
- yearly increase 0.03 - 0.04
- yearly increase 0.04 - 0.05
- yearly increase > 0.05
- Insignificant or trend < 0.001
- Data gaps (clouds, water, aridity)
- Water (Globcover 2009)

0 370 740 1.480 Kilometers

**Cartographic Reference:**

**Projection: GCS_WGS_1984**
**Datum: WGS 1984**

## Vegetation Year Rain Use Efficiency Trend (rel.)




Description:

Relative yearly changes of vegetation year average greenness Rain Use Efficiency (RUE) in test site southern Africa throughout the period 2002-2011. Vegetation year average greenness RUE calculation is based on ENVISAT MERIS fAPAR values (averaged over one vegetation year) divided by rainfall data (TRMM 3b42 precipitation). TRMM 3b42 precipitation estimates are bilinearly resampled to technically match the MERIS fAPAR spatial resolution, knowing that their actual spatial resolution of 0.25° does not (!) match the fAPAR data.

Trends are calculated using the median trend estimator after Theil (1950) and Sen (1968). Only significant trends (p 0.05) are depicted based on the trend test on significance according to Mann (1945) and Kendall (1975).

Trend values indicate average change per year. Original fAPAR values reach from 0 to 1 and have been stretched from 0 to 1000.Data gaps in the time series resulting from cloud cover, a too pronounced aridity or water bodies have been masked out from the analysis.

**Legend**

- National borders
- District borders
- Test Site AOI

**Relative trend of vegetation year average greenness Rain Use Efficiency 2002 –2011**

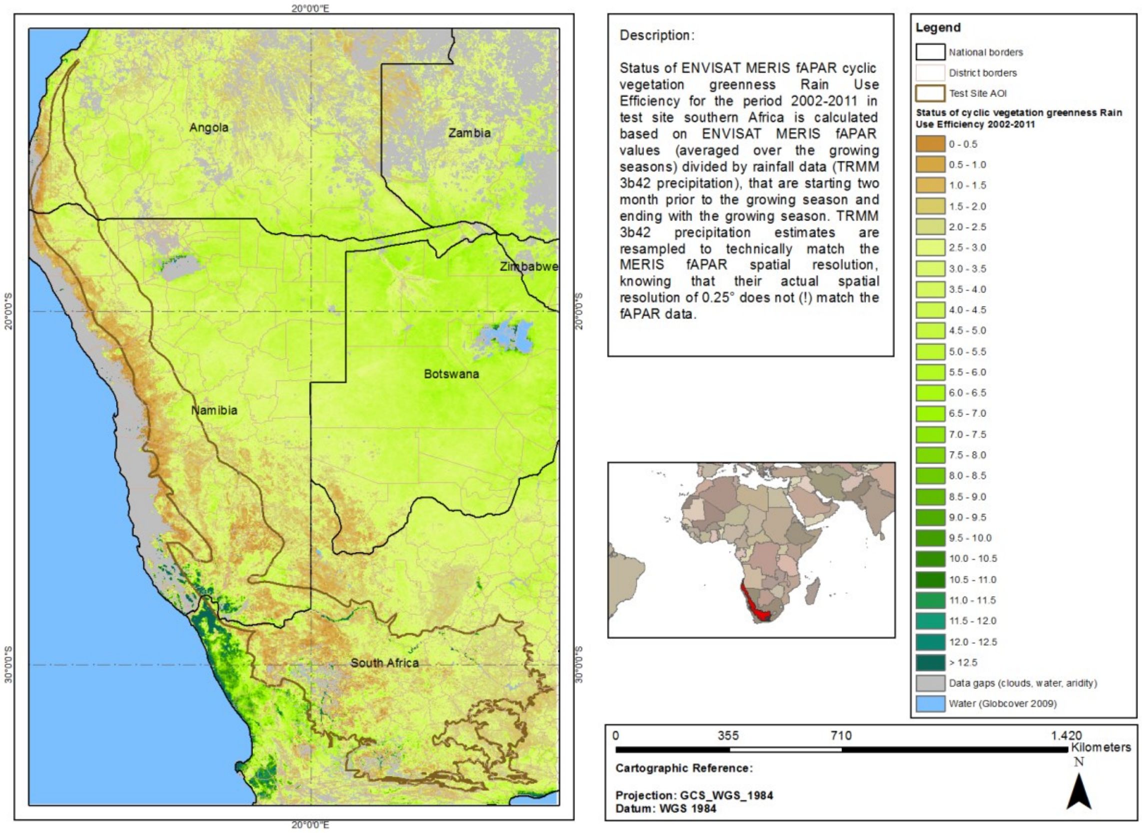
- yearly deacrease > 15%
- yearly deacrease 10 - 15%
- yearly deacrease 5 - 10%
- yearly increase < 5%
- yearly increase < 10 %
- yearly increase 10 - 20%
- yearly increase 20 - 30%
- yearly increase 30 - 40%
- yearly increase 40 - 50%
- yearly increase 50 - 60 %
- yearly increase 60 - 80%
- yearly increase > 80 %
- Insignificant or abs. trend < 0.05
- Data gaps (clouds, water, aridity)
- Water (Globcover 2009)

0 365 730 1.460 Kilometers

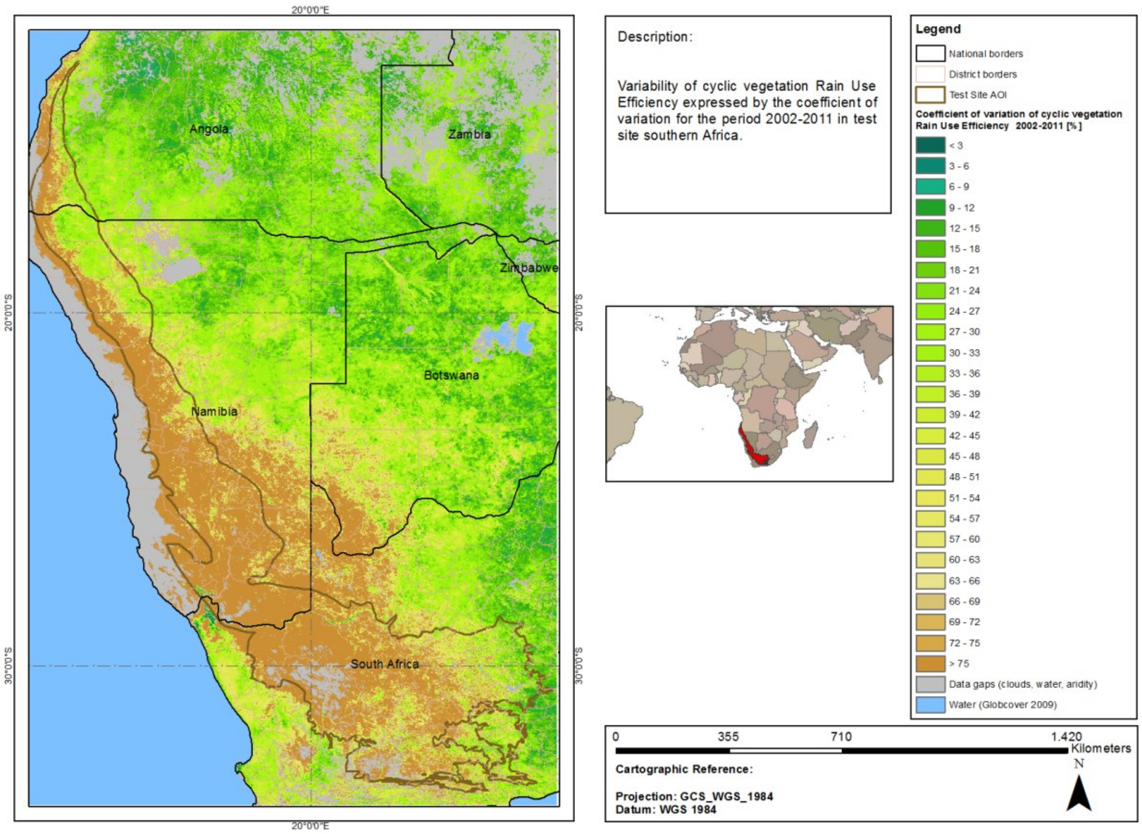
**Cartographic Reference:**

**Projection: GCS_WGS_1984**
**Datum: WGS 1984**

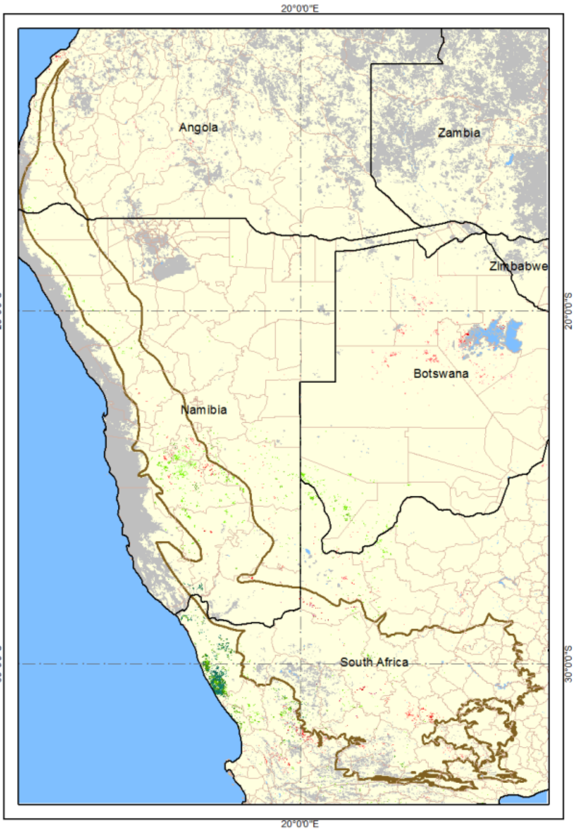
## Cyclic Vegetation Rain Use Efficiency Status




## Cyclic Vegetation Variability Rain Use Efficiency Variability



## Cyclic Vegetation Rain Use Efficiency Trend (abs.)




Description:

Slopes of absolute trends of cyclic vegetation greenness Rain Use Efficiency (RUE) in test site southern Africa throughout the period 2002-2011. Cyclic vegetation greenness RUE calculation is based on ENVISAT MERIS fAPAR values (of the green peak – "cyclic fraction") divided by rainfall data (TRMM 3b42 precipitation). TRMM 3b42 precipitation estimates are bilinearly resampled to technically match the MERIS fAPAR spatial resolution, knowing that their actual spatial resolution of 0.25° does not (!) match the fAPAR data.

Trends are calculated using the median trend estimator after Theil (1950) and Sen (1968). Only significant trends (p 0.05) are depicted based on the trend test on significance according to Mann (1945) and Kendall (1975).

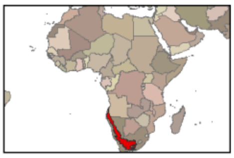
Trend values indicate average change per year. Original fAPAR values reach from 0 to 1 and have been stretched from 0 to 1000.
Data gaps in the time series resulting from cloud cover, a too pronounced aridity or water bodies have been masked out from the analysis.

**Legend**

- National borders
- District borders
- Test Site AOI

**Absolute trend slopes of cyclic vegetation greenness Rain Use Efficiency 2002 –2011**

- yearly decrease > 1.5
- yearly decrease 1.2 - 1.5
- yearly decrease 0.9 - 1.2
- yearly decrease 0.6 - 0.9
- yearly decrease 0.3 - 0.6
- yearly decrease 0.05 - 0.3
- yearly increase 0.05 - 0.3
- yearly increase 0.3 - 0.6
- yearly increase 0.6 - 0.9
- yearly increase 0.9 - 1.2
- yearly increase 1.2 - 1.5
- yearly increase > 1.5
- Insignificant or trend < 0.05
- Data gaps (clouds, water, aridity)
- Water (Globcover 2009)



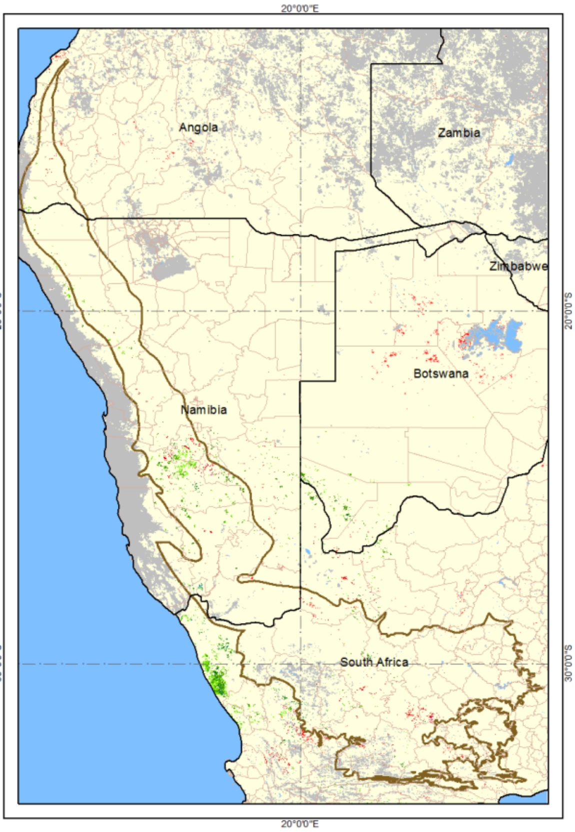
0 370 740 1.480 Kilometers

N

**Cartographic Reference:**

**Projection: GCS_WGS_1984**
**Datum: WGS 1984**

## Cyclic Vegetation Rain Use Efficiency Trend (rel.)




Description:

Relative yearly changes of cyclic vegetation greenness Rain Use Efficiency (RUE) in test site southern Africa throughout the period 2002-2011. Cyclic vegetation greenness RUE calculation is based on ENVISAT MERIS fAPAR values (of the green peak – "cyclic fraction") divided by rainfall data (TRMM 3b42 precipitation). TRMM 3b42 precipitation estimates are bilinearly resampled to technically match the MERIS fAPAR spatial resolution, knowing that their actual spatial resolution of 0.25° does not (!) match the fAPAR data.

Trends are calculated using the median trend estimator after Theil (1950) and Sen (1968). Only significant trends (p 0.05) are depicted based on the trend test on significance according to Mann (1945) and Kendall (1975).

Trend values indicate average change per year. Original fAPAR values reach from 0 to 1 and have been stretched from 0 to 1000.Data gaps in the time series resulting from cloud cover, a too pronounced aridity or water bodies have been masked out from the analysis.

**Legend**

- National borders
- District borders
- Test Site AOI

**Relative trend of cyclic vegetation greenness Rain Use Efficiency 2002 –2011**

- yearly deacrease > 15%
- yearly deacrease 10 - 15%
- yearly deacrease 5 - 10%
- yearly increase < 5%
- yearly increase < 10 %
- yearly increase 10 - 20%
- yearly increase 20 - 30%
- yearly increase 30 - 40%
- yearly increase 40 - 50%
- yearly increase 50 - 60 %
- yearly increase 60 - 80%
- yearly increase > 80 %
- Insignificant or abs. trend < 0.05
- Data gaps (clouds, water, aridity)
- Water (Globcover 2009)

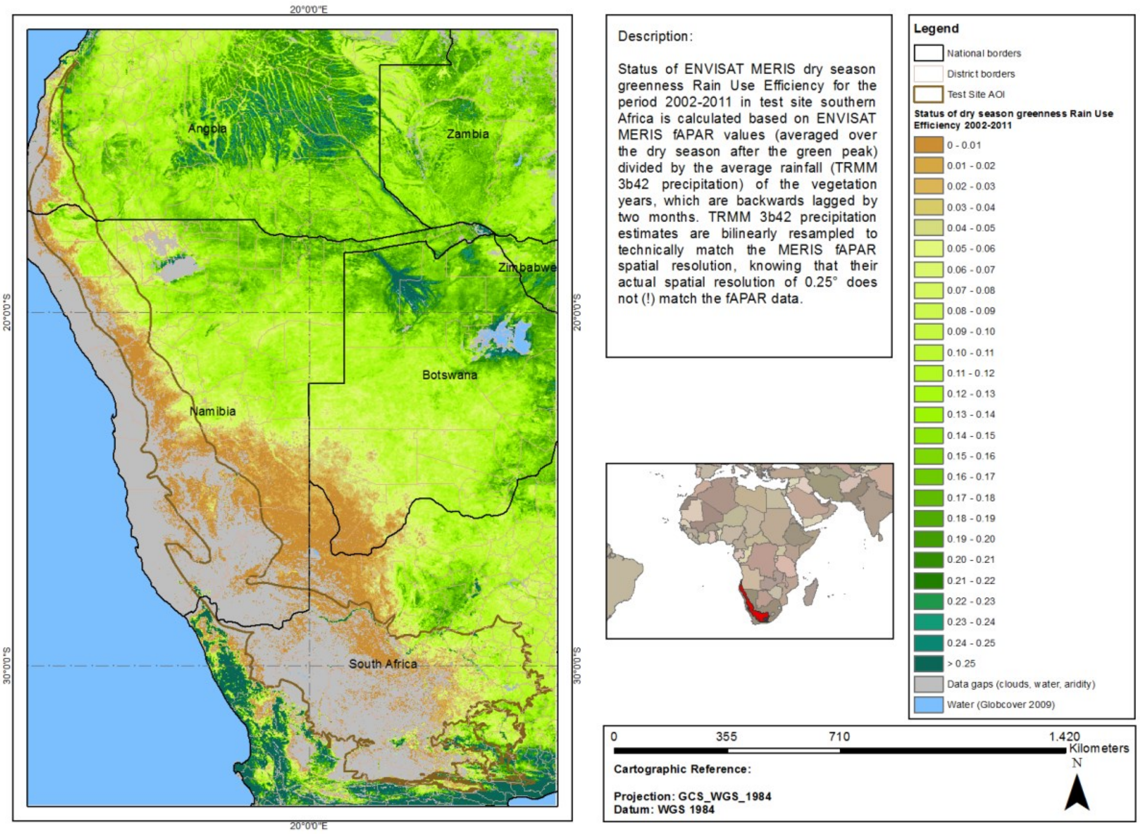
0 365 730 1.460 Kilometers

N

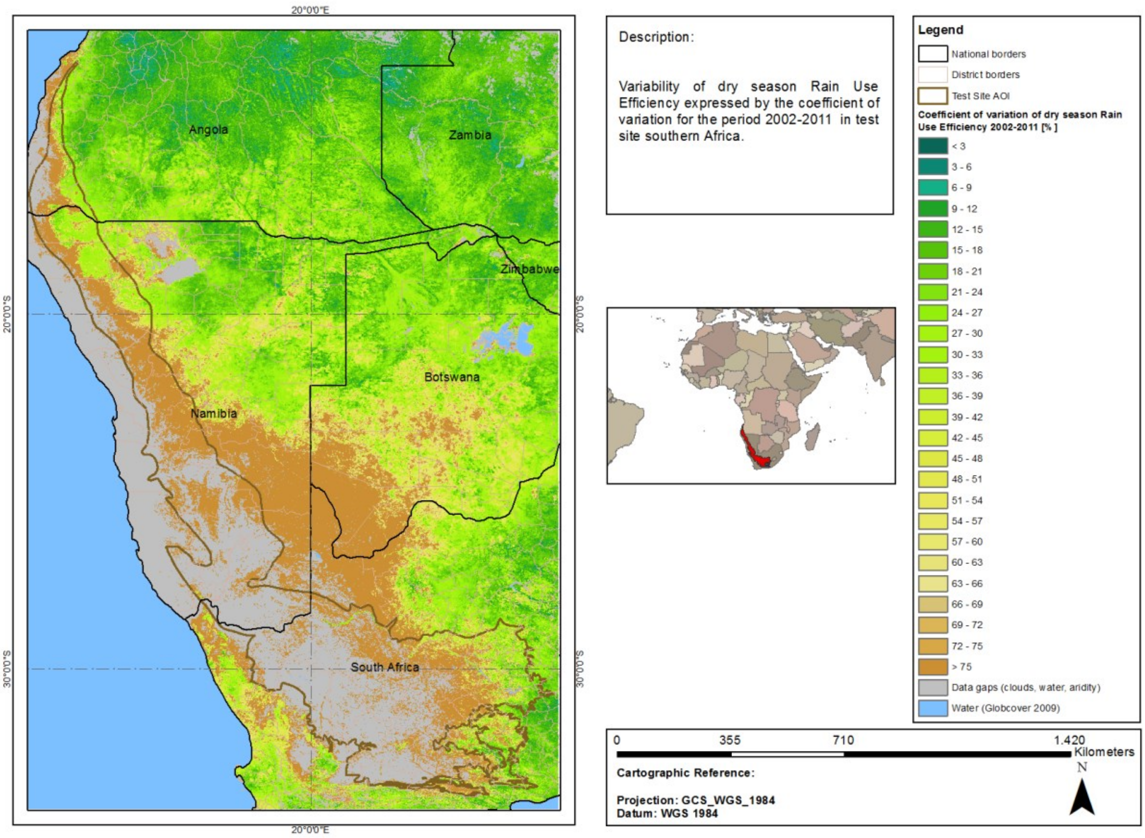
**Cartographic Reference:**

**Projection: GCS_WGS_1984**
**Datum: WGS 1984**

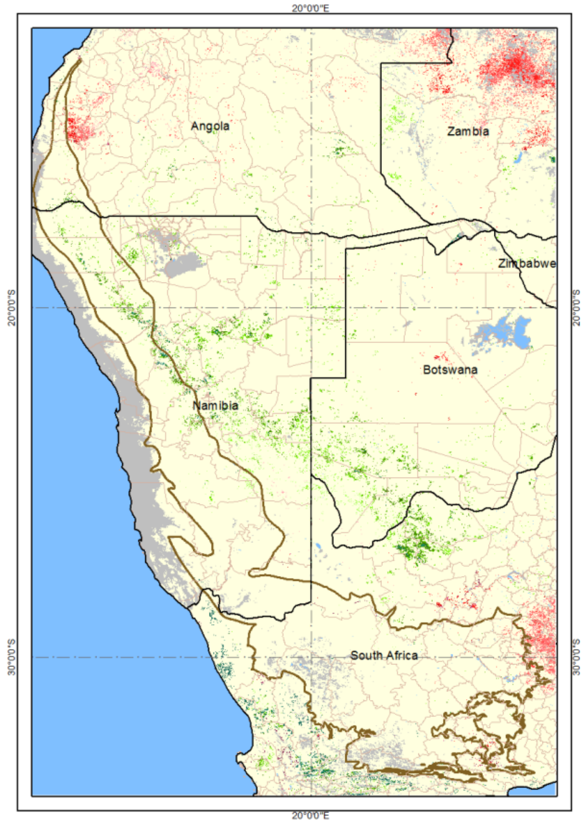
## Dry Season Rain Use Efficiency Status




## Dry Season Rain Use Efficiency Variability



## Dry Season Rain Use Efficiency Trend (abs.)




Description:

Slopes of absolute trends of dry season greenness Rain Use Efficiency (RUE) in test site southern Africa throughout the period 2002-2011. Dry season greenness RUE calculation is based on ENVISAT MERIS fAPAR values (averaged over the dry season after the green peak) divided by rainfall data (TRMM 3b42 precipitation). TRMM 3b42 precipitation estimates are bilinearly resampled to technically match the MERIS fAPAR spatial resolution, knowing that their actual spatial resolution of 0.25° does not (!) match the fAPAR data.

Trends are calculated using the median trend estimator after Theil (1950) and Sen (1968). Only significant trends (p 0.05) are depicted based on the trend test on significance according to Mann (1945) and Kendall (1975).

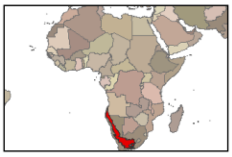
Trend values indicate average change per year. Original fAPAR values reach from 0 to 1 and have been stretched from 0 to 1000.Data gaps in the time series resulting from cloud cover, a too pronounced aridity or water bodies have been masked out from the analysis.

**Legend**

- National borders
- District borders
- Test Site AOI

**Absolute trend slopes of dry season greenness Rain Use Efficiency 2002 –2011**

- yearly decrease > 0.025
- yearly decrease 0.02 - 0.025
- yearly decrease 0.015 - 0.02
- yearly decrease 0.01 - 0.015
- yearly decrease 0.005 - 0.01
- yearly decrease 0.001 - 0.005
- yearly increase 0.001 - 0.005
- yearly increase 0.005 - 0.01
- yearly increase 0.01 - 0.015
- yearly increase 0.015 - 0.02
- yearly increase 0.02 - 0.025
- yearly increase > 0.025
- Insignificant or trend < 0.001
- Data gaps (clouds, water, aridity)
- Water (Globcover 2009)



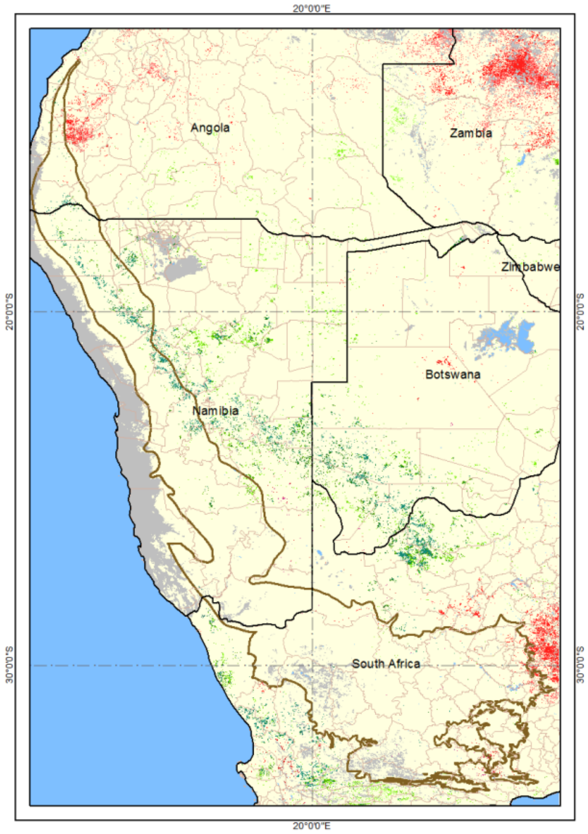
0 370 740 1.480 Kilometers

N

**Cartographic Reference:**

**Projection: GCS_WGS_1984**
**Datum: WGS 1984**

## Dry Season Rain Use Efficiency Trend (rel.)




Description:

Relative yearly dry season vegetation greenness Rain Use Efficiency (RUE) in test site southern Africa throughout the period 2002-2011. Dry season vegetation greenness RUE calculation is based on ENVISAT MERIS fAPAR values (averaged over the dry season after the green peak) divided by rainfall data (TRMM 3b42 precipitation). TRMM 3b42 precipitation estimates are bilinearly resampled to technically match the MERIS fAPAR spatial resolution, knowing that their actual spatial resolution of 0.25° does not (!) match the fAPAR data.

Trends are calculated using the median trend estimator after Theil (1950) and Sen (1968). Only significant trends (p 0.05) are depicted based on the trend test on significance according to Mann (1945) and Kendall (1975).

Trend values indicate average change per year. Original fAPAR values reach from 0 to 1 and have been stretched from 0 to 1000. Data gaps in the time series resulting from cloud cover, a too pronounced aridity or water bodies have been masked out from the analysis.

**Legend**

- National borders
- District borders
- Test Site AOI

**Relative trend of dry season greenness Rain Use Efficiency 2002 –2011**

- yearly deacrease > 15%
- yearly deacrease 10 - 15%
- yearly deacrease 5 - 10%
- yearly increase < 5%
- yearly increase < 10 %
- yearly increase 10 - 20%
- yearly increase 20 - 30%
- yearly increase 30 - 40%
- yearly increase 40 - 50%
- yearly increase 50 - 60 %
- yearly increase 60 - 80%
- yearly increase > 80 %
- Insignificant or abs. trend < 0.05
- Data gaps (clouds, water, aridity)
- Water (Globcover 2009)

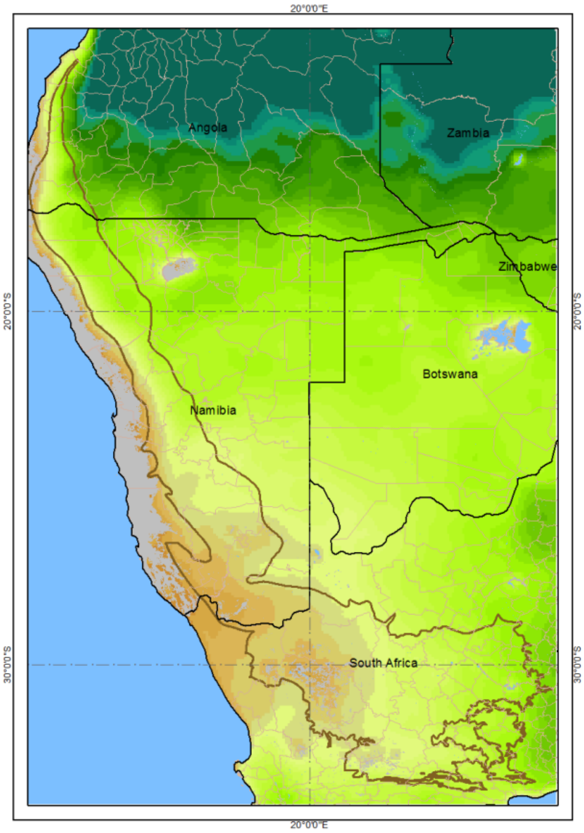
0 365 730 1.460 Kilometers

N

**Cartographic Reference:**

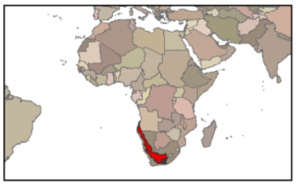
**Projection: GCS_WGS_1984**
**Datum: WGS 1984**

# Vegetation Year Precipitation Status




Description:

Status of TRMM 3b42 precipitation estimates summed over vegetation years calculated as mean value for the period 2002-2011 in test site southern Africa. Yearly aggregation periods are derived from the corresponding vegetation year with a temporal backward shift of two months. Thus, each precipitation vegetation year starts and ends two months earlier than the corresponding vegetation year.



**Legend**

- National borders
- District borders
- Test Site AOI

**Status of vegetation year precipitation 2002-2011**

- < 40
- 40 - 80
- 80 - 120
- 120 - 160
- 160 - 200
- 200 - 240
- 240 - 280
- 280 - 320
- 320 - 260
- 360 - 400
- 400 - 440
- 440 - 480
- 480 - 520
- 520 - 560
- 560 - 600
- 600 - 640
- 640 - 680
- 680 - 720
- 720 - 760
- 760 - 800
- 800 - 840
- 840 - 880
- 880 - 920
- 920 - 960
- 960 - 1000
- > 1000
- Data gaps/no rainfall
- Water (Globcover 2009)

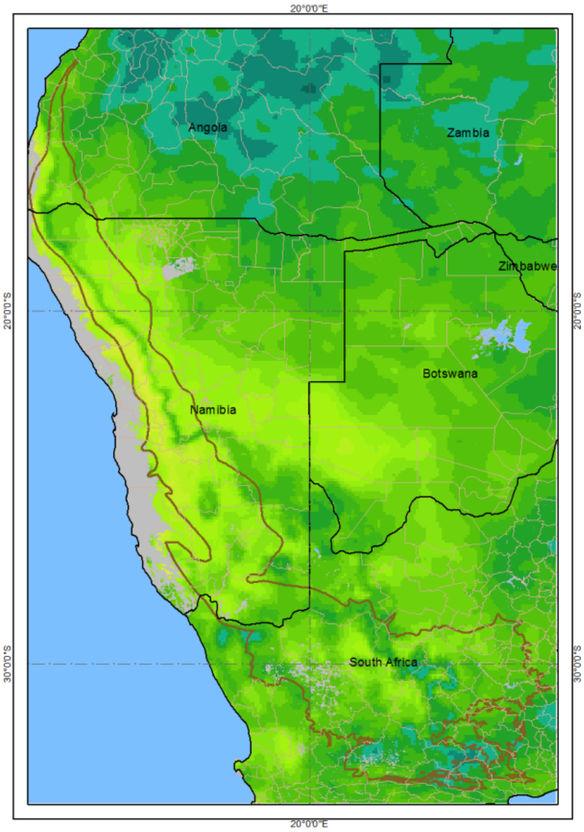
0 355 710 1.420 Kilometers

N

**Cartographic Reference:**

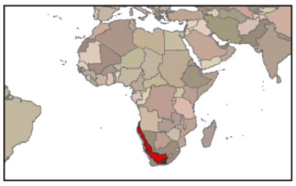
**Projection: GCS_WGS_1984**
**Datum: WGS 1984**

# Vegetation Year Precipitation Variability




Description:

Variability of TRMM 3b42 precipitation estimates summed over vegetation years expressed by the coefficient of variation for the period 2002-2011 in test site southern Africa. Yearly aggregation periods are derived from the corresponding vegetation year with a temporal backward shift of two months. Thus, each precipitation vegetation year starts and ends two months earlier than the corresponding vegetation year.



**Legend**

- National borders
- District borders
- Test Site AOI

**Coefficient of variation of vegetation year precipitation 2002-2011 [%]**

- > 5
- 5 - 10
- 10 - 15
- 15 - 20
- 20 - 25
- 25 - 30
- 30 - 35
- 35 - 40
- 40 - 45
- 45 - 50
- 50 - 55
- 55 - 60
- 60 - 65
- 65 - 70
- 70 - 75
- 75 - 80
- 80 - 85
- 85 - 90
- 90 - 95
- 95 - 100
- 100 - 105
- 105 - 110
- 110 - 115
- 115 - 120
- 120 - 125
- > 125
- Data gaps/no rainfall
- Water (Globcover 2009)

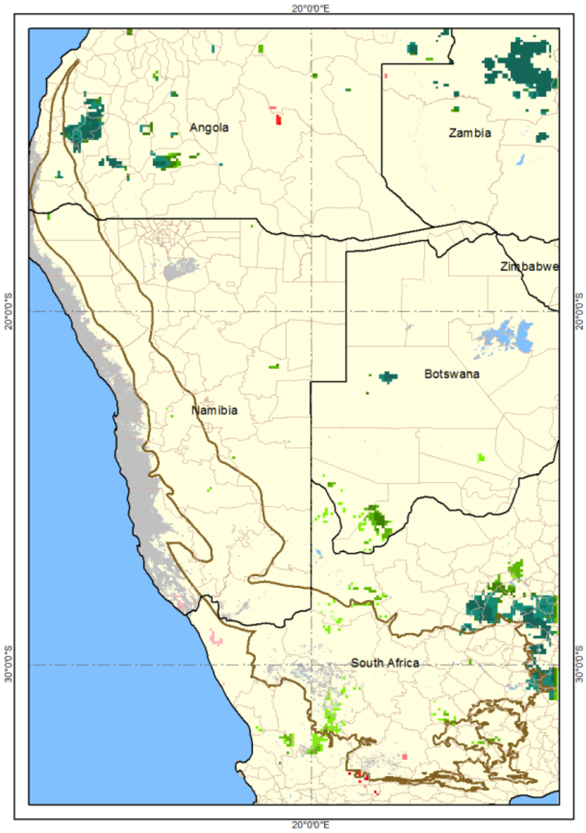
0 355 710 1.420 Kilometers

N

**Cartographic Reference:**

**Projection: GCS_WGS_1984**
**Datum: WGS 1984**

## Vegetation Year Precipitation Trend (abs.)




Description:

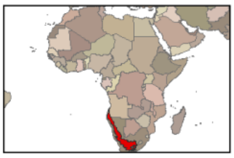
Slopes of absolute trends of TRMM 3b42 precipitation estimates summed over vegetation years in test site southern Africa throughout the period 2002-2011. Yearly aggregation periods are derived from the corresponding vegetation year with a subsequent temporal backward shift of two months. Thus, each precipitation vegetation year starts and ends two months earlier than the corresponding vegetation year.

**Legend**

- National borders
- District borders
- Test Site AOI

**Absolute trend slopes of vegetation year precipitation 2002-2011**

- yearly decrease > 15
- yearly decrease 12 - 15
- yearly decrease 9 - 12
- yearly decrease 6 - 9
- yearly decrease 3 - 6
- yearly decrease 0.5 - 3
- yearly increase 0.5 - 3
- yearly increase 3 - 6
- yearly increase 6 - 9
- yearly increase 9 - 12
- yearly increase 12 - 15
- yearly increase > 15
- Insignificant or no trend
- Data gaps (clouds, water, aridity)
- Water (Globcover 2009)



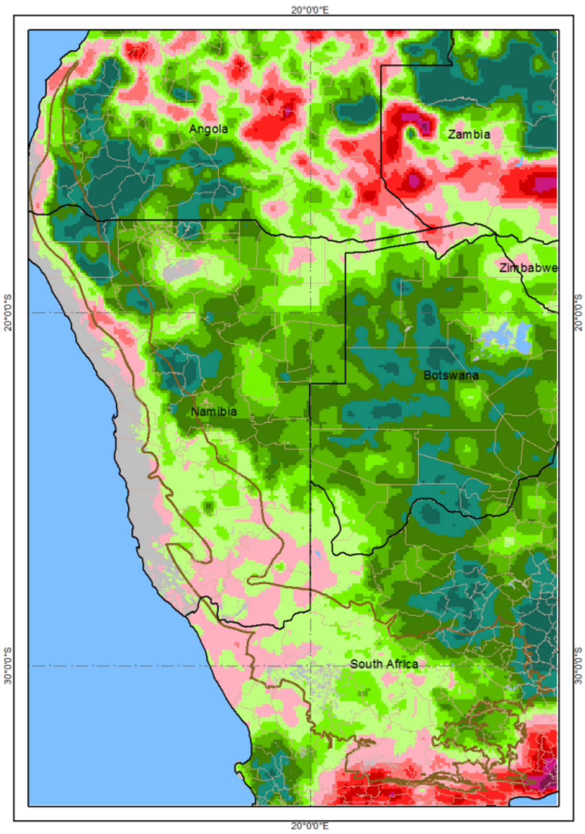
0 370 740 1.480 Kilometers

**Cartographic Reference:**

**Projection: GCS_WGS_1984**
**Datum: WGS 1984**

N

## Vegetation Year Precipitation Change




Description:

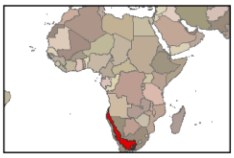
Change in TRMM 3b42 precipitation estimates summed over vegetation years between the two epochs 2002-2006 and 2007-2011 in test site souther Africa. The calculation of per-epoch precipitation is based on epoch median values. Yearly aggregation periods are derived from the corresponding vegetation year with a temporal backward shift of two months. Thus, each precipitation year starts and ends two months earlier than the corresponding vegetation year.

**Legend**

- National borders
- District borders
- Test Site AOI

**Change in vegetation year precipitation between the epochs 2002-2006 and 2007-2011**

- decrease > 200
- decrease 160 - 200
- decrease 120 - 160
- decease 80 - 120
- decrease 40 - 80
- decrease 0 - 40
- increase 0 - 40
- increase 40 - 80
- increase 80 - 120
- increase 120 - 160
- increase 160 - 200
- increase > 200
- Data gaps/no rainfall
- Water (Globcover 2009)



0 370 740 1.480 Kilometers

**Cartographic Reference:**

**Projection: GCS_WGS_1984**
**Datum: WGS 1984**

N

## Generic Interpretation of the Maps with regard to Degradation and Potential Loss of Biodiversity

The maps that are so far shown in the booklet include phenologically differentiated NPP proxy (Net Primary Production) and RUE (Rain Use Efficiency) status and trend maps, as well as rainfall status, trend – and change maps.

Overall the status maps describe the amount and variability (coefficient of variation) of greenness (NPP proxy) in the differentiated phenological seasons, as well greenness in relation to the amount of rainfall (RUE).

While vegetation productivity obvious follows the rainfall gradients at the large scale (not considering temperature and radiation differences), the smaller scale differentiations exhibit the presence of further influences on vegetation growth at more local scales. These local and regional factors are especially land use, soil properties and topography and include also the protection status of areas. For instance many linear features with (mostly) higher NPP proxy and RUE values than their surroundings can be related to river valleys (often with only seasonal or ephemeral surface water).

Consequently, the spatial distribution of RUE varies not only with rainfall, but depends on the constellation of all these factors at various scales. Hence RUE status (average condition) values, even if stratified according to aridity, cannot directly be interpreted in terms of existing soil degradation or exposure to degradation or richness/poverty of biodiversity without knowledge about growth factors other than rainfall, and about bio-geographical properties.

Biomes with rich floristic biodiversity can be expected to exhibit higher NPP response to rainfall throughout the year as diverse plant communities may be characterised by a high phenological variability with optimised water exploitation. However, it is not known whether, where and to which degree this theory translates into measurable spatial differences of RUE. Here an assessment of the results by local experts and the usage of reference maps and information will help interpret the results. An example with an extended area of extraordinary high average RUE conditions is the Succulent Karoo biome in South Africa (“*The Succulent Karoo is notable for the world's richest flora of succulent plants, and harbours about one-third of the world’s approximately 10,000 succulent species*” http://en.wikipedia.org/wiki/Succulent_Karoo ).

The differentiation of the NPP and RUE indicators into phenological periods helps diagnose the seasonal behaviour of the vegetation and thus provides clues about the presence and dominance of evergreen perennial vegetation versus annual vegetation (e.g. annual grasses, crops). Accordingly, changes and trends of the phenological vegetation behaviour can be used as indicators for developments such as land use change and land cover change. For instance the worldwide observed phenomenon of bush encroachment (woody encroachment, woody thickening) in drylands (Ratajczak et al. 2011) will lead to a shift of vegetation phenology, where especially an increase of dry season greenness, possibly, but not necessarily combined with a decrease of the cyclic greenness can be expected.

Bush encroachment in drylands is often perceived as negative development, where the bushes lead to range land degradation by reducing grass cover and impeding the access of cattle to the remaining grass. Also impoverishment of biodiversity was frequently found as an effect of bush encroachment (Ratajczak et al. 2011). The greening trends especially in the dry season are indeed a widespread phenomenon in the derived NPP proxy maps (p.16), possibly pointing to continued bush encroachment or enhanced growth and greening of existing bushes, partly related to rainfall increases. Dry season greening may also be caused by the plantation of (especially evergreen) woody plants and forests. In case of greening trends related to commercial forest plantations, the trends can also be interpreted as a biodiversity loss.

The “classical” degradation measure is exhibited by decreasing RUE trends, i.e. the decrease of NPP proxies in relation to rainfall, theoretically indicating the decreasing ability of the vegetation to exploit available water. In the test sites so far studied, RUE decreases are rarely observed for the cyclic vegetation of the growing season (p. 20). This means, the cyclic vegetation response to rainfall is not widespread diminished and degradation of soils leading to reduced usability of rainfall for vegetation growth seems to be hardly found in the test sites so far. Where it is found it seems to co-occur with regional rainfall increases, and may be interpreted as lacking ability of the vegetation to respond to apparently improved hydrologic growing conditions. Extended areas in South and East Portugal are an example for wide spread RUE decreases of the cyclic vegetation related to rainfall increase (p. 24) without cyclic vegetation decrease (p. 14). However, increased rainfall quantities may also come with higher rainfall intensities and may have also negative effects (increased runoff, more erosive power), and can be assumed to be not generally positively correlated with vegetation productivity.

RUE decreases are more frequently found when looking at the vegetation of the entire vegetation year (p. 18), and are also often related to rainfall increases, and not to greenness decreases. RUE decreases are not only indicating potential degradation developments (progressing degradation triggered e.g. by land over-utilisation), but may be as well related to land cover/use changes, such as the conversion of rangeland into cropland, deforestation (less important in dry lands), etc. Especially processes such as urbanisation or mining will lead to extreme NPP proxy and RUE decreases. Decreases of only the dry season RUE (p. 22) may in particular be related to conversion of rangeland into rainfed cropland, assuming a lower primary productivity of the cropland during the dry season. Also the clearing of shrubs, bushland and savannah vegetation may lead especially to dry season RUE decreases.

To summarize the observable NPP proxy and RUE trends cannot be directly interpreted as degradation or biomass losses, or, in case of positive trends, as land improvements. There are always multiple possible underlying causes and developments, hence in situ knowledge and information is indispensable for the interpretation of these developments, as well as for the average conditions expressed in the status maps. Especially the frequently found greening trends in the dry season, at first glance positive trends, may even be primarily related to adverse processes such as bush encroachment. However, caution is also necessary in this respect, as likewise range land improvement and tree planting activities may lead to diverse positive trends.

Finally it must me stated that the observation period is rather short, with several consequences for this study. The variability of rainfalls and subsequently vegetation greenness from year to year is so significant in drylands that it certainly hides trends, which in such a short period may be rare and not very pronounced. Trends must pass a high statistical significance threshold to be recognised as significant trends. There may be more relevant changes going on than the trend maps with only the highly significant trends can show, especially as many change events cannot be expected to exhibit gradual indicator developments. Also the rainfall trend maps (p. 24) show hardly any significant trends, while the rainfall change map between the two epochs shows large positive and negative change regions with partly big epochal rainfall differences.

On the other hand, the epochal change maps (differences between the means or median values of epochs, part of the overall products) are strongly influenced by variability and do certainly not only reflect “true” changes in the sense of concrete changes (e.g. land use change) or persisting developments (trends). Therefore these maps (that - except for rainfall - are not shown in the booklet) must be used with care.

# Outlook

The phenologically differentiated analysis of NPP proxies and RUE so far performed will allow for a combination of the single results into integrated second order products. Their intention is to provide more evaluative assessments of the possible recent developments than the individual indicators. For instance, the occurrence of dry season greening in the absence of positive cyclic vegetation trends or in combination with negative cyclic vegetation trends may be derived as a an indicator for bush encroachment, either in the past and/or ongoing, where theoretically also the trend of the ratio of dry season to vegetation year greenness may support the diagnosis of increases of woody vegetation at the expense of grasses. The generation and/or interpretation of second order products may also be supported by means of land cover data.

Further on, CCI soil moisture (http://www.esa-soilmoisture-cci.org/) data, where available without greater data gaps, will be used as an additional and alternative measure for available water, and “Soil Moisture Use Efficiency” (SMUE) products analogue to RUE products will be derived thereof. Theoretically, soil moisture is the better suited water parameter for this purpose, as it almost directly constitutes the available water for plants, whereas rainfall only partly penetrates into the soil. The comparison of the SMUE with the RUE products will be of high interest.

Selected second order indicators will be added to these booklets, while the first order indicator maps may be reduced to keep the booklets focused on the most significant results. The results will be interpreted in terms of so-called “Biodiversity Stories”, which will verbally highlight the most prominent and significant developments found in the data.

# Description of Biodiversity of Test Site 12 Southern Africa

The study area is comprised of two ecoregions: the Nama Karoo Biome consists of a vast and open arid region, characterized by dwarf shrubland vegetation, the majority of which is located on the central plateau of the Cape Province in South Africa, but also extends further northwest into Namibia (Palmer & Hoffman 1997; WWF 2013h); and the Namibian savannah woodland that stretches from western Angola down into Namibia, ending just north of the Groot Karas Berg plateau, forming a narrow belt that covers the Great Escarpment and delimiting the Namib desert in the west (WWF 2013i).

The topography of the region is very diverse, encompassing many plateaus and mountains, including the highest peak in Namibia, the Brandberg (2038 m) (WWF 2013i). Typical landscape features are the mesas (flat-topped isolated mountains) that act as inselbergs, providing more suitable climatic and ecological conditions for more water dependent species, in comparison with the arid settings of the surrounding areas (Burke 2003). These mesas are normally formed of dolerite that is more resistant to erosion than the predominant limestone, sandstone and shale (WWF 2013hi).

The region is subjected to a harsh and seasonal climate, with low unpredictable rainfalls concentrated mostly during the summer (up to 70% during January-March), and high daily fluctuations of temperature (Chase et al. 2010; WWF 2013hi). The precipitation displays an increasing gradient from west to east and from north to south. In the woodland savannah, mean annual rainfall ranges between 50 in 200 mm from west to east, while in the Nama Karoo region mean annual rainfall is generally higher in the northern part (500 mm) and decreases to the south (around 100 mm) (Palmer & Hoffmann 1997; WWF 2013hi). However, as mentioned before, high elevation landscapes features like plateaus, mesas and mountains can hold more humid conditions despite the more dry surroundings (Burke et al. 2003). In the more northern regions, the Benguela Current (Atlantic Ocean) brings a fresh sea breeze, so temperatures are more moderate during the summer and in winter frost rarely occurs. In more southern and continental areas that do not receive the cooling effect of the current, temperature variations becomes more extreme and frost is common, with mean monthly temperatures going above zero during winter, and the mean maximum monthly temperature surpassing 40°C in the summer (Burke et al. 2003; WWF 2013hi).

The diversity of vegetation in the study area reflects the two biomes, the variety of landscape features and associated soils and microclimates. In the north, the savannah is dominated by the mopane (*Colophospermum mopane*) that can occur as a tree and form dense woodlands, or as short-stemmed shrub amongst other trees like *Balanites welitschii* and of the genus *Sesamothamnus* (Mags et al. 1998; WWF 2013i). As we go southwards and reach the Brandberg Mountain, the vegetation reaches a transition zone between savannah and semi-desert, demonstrating great diversity and endemicity. Typical species of this zone include *Euphorbia guerichiana*, *Cyphostemma* spp., the quiver tree (*Aloe dichotoma*), *Comiphora* spp., and two endemic species of *Acacia*, *A. montisustii* and *A. robynsiana* (Mags et al. 1998; WWF 2013i). To the south begins the Nama-Karoo biome and its representative dwarf shrubs and grasses. These include shrub species of the genus *Drosanthemum*, *Eriocephalus*, *Galenia*, *Rhigozum* and *Ruschia*, while for grasses we have the cases of *Aristida*, *Digitaria*, *Enneapogon* and *Stipagrostis*. Trees like *Acacia karoo*, *Dyospyros lycioides* and *Tamarix usneoides* are more restricted to watercourses (Palmer & Hoffman 1997; WWF 2013h).

In terms of fauna, the Namibian woodland savannah presents a higher species richness and endemism than the poorer Nama-Karoo, especially in the mountainous region of Brandberg (Simmons et al. 1998; Proches & Cowling 2006). The first biome holds two endemic amphibians, the Okahandja toad (*Bufo hoeschi*) and the Mossamedes toad (*B. grandisonae*), while for reptiles we have endemic or near-endemic species like the Albert's burrowing skink (*Sepsina alberti*), the Nama padloper tortoise (*Homopus solus*), two lizards of the genus *Corydilus* (*C. namaquensis* and *C. pustulatus*) and the Brandberg thick-toed gecko (*Pachydactylus gaiasensis*) (Simmons et al. 1998; WWF 2013i). For the mammalian fauna, the woodland savannah harbours important populations of elephant (*Loxodonta africana*), black rhinoceros (*Diceros bicornis*), lion (*Panthera leo*) and cheetah (*Acinonyx jubatus*), among other large mammals. Endemic species are mostly smaller species like the Angola wing-gland bat (*Myotis seabrai*), slender mongoose (*Galerella swalius*) and rock mouse (*Petromyscus shortridgei*). The Kaoko Escarpment has the highest bird diversity, hosting up to 297 species like the greybacked cisticola (*Cisticola subruficapillus*), the Cinderella waxbill (*Estrilda thomensis*) and the Herero chat (*Namibornis herero*) (Simmons et al. 1998; WWF 2013i).

Relatively to the Karoo, endemicity is lower since most species come from adjacent regions. Examples of herpetofauna include the olive toad (*Bufo garmani*), Karoo dwarf chameleon (*Bradypodion karrooicum*) and Boulenger's padloper tortoise (*Homopus boulengeri*). Amongst mammals, one of the rarest and most endangered species in the world occurs in the region, the riverine rabbit (*Bunolagus monticularis*), as well as the Grant's rock mouse (*Aethomys granti*), bushy-tailed hairy-footed gerbil (*Gerbillurus vallinus*), bat-eared fox (*Otocyon megalotis*) and Cape fox (*Vulpes chama*). Finally for the case of avian fauna, relevant examples comprise of the Karoo (*Cercomela sclegelii*) and tractrac chats (*C. tractrac*), tawny (*Aquila rapaz*) and martial eagles (*Polemaetus bellicosus*), red lark (*Certhilauda burra*) and Karoo scrub robin (*Cercotrichas coryphaeus*) (Vernon 1999; WWF 2013h).

## References


Burke, A. (2003), The role of Namibian inselbergs in contributing to local and regional plant species richness. *Biodiversity and Conservation*, 12: 469-486.

Burke, A., Esler, K.J., Pienaar E. and Barnard, P. (2003), Species richness and floristic relationships between mesas and their surroundings in southern African Nama Karoo. *Diversity and Distributions*, 9: 43-53.

Chase, B.M., Meadows, M.E., Carr, A.S. and Reimer, P.J. (2010), Evidence for progressive Holocene aridification in southern Africa recorded in Namibian hyrax middens: Implications for African Monsoon dynamics and the ''African Humid Period''. *Quaternary Research*, 74: 36-45.

Gobron N., Pinty, B, Verstaete, M. and Govaerts, Y. (1999), The MERIS Global Vegetation Index (MGVI): description and preliminary application. *International Journal of Remote Sensing*, 9: 1917-1927.

Kendall, M.G. (1962), Rank Correlation Methods, Charles Griffin and Company: London.

Mags, G.l., Craven, P. and Kolberg, H.H. (1998), Plant species richness, endemism and genetic resources in Namibia. *Biodiversity and Conservation*, 7: 513-530.

Palmer, A.R. and Hoffman, M.T. (1997), Nama Karoo. In Cowling RM, Richardson DM and Pierce SM (Eds.), *Vegetation of Southern Africa*. Cambridge University Press, Cambridge.

Proches, S. and Cowling, R.M. (2006), Insect diversity in Cape fynbos and neighbouring South African vegetation. *Global Ecology and Biogeography*, 15: 445-451.

Ratajczak, Z., Nippert, J.B. and Scott, L. (2011), The effects of woody encroachment on plant diversity in global grasslands and savannas: a meta-analysis. http://media.wix.com/ugd/d270f9_013ee3e8ed68377da3047468fb523488.pdf

Sen, P. K. (1968), Estimates of regression coefficients based on Kendall's tau. *J. Amer. Statist. Assoc.* 63: 1379–1389.

Simmons, R.E., Griffin, M., Griffin, R.E., Marais, E. and Kolberg, H. (1998), Endemism in Namibia: patterns, processes and predictions. *Biodiversity and Conservation*, 7: 513-530.

Theil, H. (1950), A rank-invariant method of linear and polynomial regression analysis" I, II and III, Nederl. Akad. Wetensch. Proc., 53.

WWF (h) (World Wildlife Fund) *Ecoregions – Nama Karoo*. Retrieved from http://worldwildlife.org/ecoregions/at1314 (March 2013).

WWF (i) (World Wildlife Fund) *Ecoregions – Africa: Namibia*. Retrieved from http://worldwildlife.org/ecoregions/at1315 (March 2013).

Zomer, R.J., Bossio, D.A., Trabucco, A., Yuanjie, L., Gupta, D.C. & Singh, V.P., 2007, Trees and Water: Smallholder Agroforestry on Irrigated Lands in Northern India. Colombo, Sri Lanka. *International Water Management Institute. pp 45. (IWMI Research Report 122).*

Zomer, R.J., Trabucco, A., Bossio, D.A., van Straaten, O., Verchot, L.V., 2008, Climate Change Mitigation: A Spatial Analysis of Global Land Suitability for Clean Development Mechanism Afforestation and Reforestation*. Agric. Ecosystems and Envir.* 126: 67-80.

## User Questionnaire

You can find an on-line version of this questionnaire here:

http://www.diversity2.info/testsites/ppd/uq/

1. How do you judge the overall relevance and quality of the presented products?

2. Please comment shortly on the presentation of the methods and results

3. What further products (level one) would be interesting to you to have?

4. Do you have any suggestions concerning possible "second level" products, which are supposed to show the results in a more abstract and/or synthesised way?