Workshop on Land Productivity Indicators for Drylands

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Presentation Overview

1. Dryland testsites
2. Technical production environment at Brockmann Consult and GeoVille
3. Earth Observation data used
4. Applied methods
5. EO time series data issues
6. First order products
7. Preliminary booklets, downloads
Distribution of the 23 testsites

CGIAR CSI Global Aridity Index
## Properties of the five validation sites

<table>
<thead>
<tr>
<th>Nr</th>
<th>Dryland geographical area (WWF ecoregion no.)</th>
<th>Size</th>
<th>Aridity Index WWF Info</th>
<th>Diversity Hotspot (Global 2000)</th>
<th>Other criteria</th>
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<tbody>
<tr>
<td>10</td>
<td>S-Europe: Iberian conifer forests, Northeastern Spain and Southern France Mediterranean forests (PA1208), Iberian sclerophyllous and semi-deciduous forests (PA1209), Southwest Iberian Mediterranean sclerophyllous and mixed forests (PA1221), Northwest Iberian montane forests (PA1216), Tyrrenian-Adriatic Sclerophyllous and mixed forests (PA1222), South Appenine mixed montane forests (PA1218), Southeastern Iberian shrubs and woodlands (PA1219)</td>
<td>524.698 km²</td>
<td>AI 0.21 – 1.78 Mediterranean forests, woodlands, and shrub</td>
<td>Part of Mediterranean Forests, Woodlands and Scrub (G200_NUM 123)</td>
<td>Area contains two Centres of Plant Diversity and Transboundary Protected Areas WRI Major Watersheds: Parts of Rhone, Garonne, Ebro, Douro-Duero, Tagus, Guadiana and Guadalquivir</td>
</tr>
</tbody>
</table>

![Cabo de Gata Natural Park, Andalusia, Spain. © C.Michael Hogan](http://www.eoearth.org/view/article/156156/)

![Southeastern Spain. Source: Pedro Regato / WWF MedPO](http://en.wikipedia.org/wiki/Portugal)

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**Coto Dorana National Park, Spain. (Photograph by WWF-Canon / Michel Gunther)**
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<td>12</td>
<td>S-Africa: Namibian savanna woodlands (AT1316), Nama Karoo (AT1314)</td>
<td>576.085 km² Angola, Namibia, South Africa</td>
<td>AI 0,02 – 0,58 Deserts and xeric shrublands</td>
<td>Biodiversity Hotspot (The Succulent Karoo, one of only two hotspots that are entirely arid (the other being the newly recognized Horn of Africa))</td>
<td>Part of Namib-Karoo-Kaokoveld Deserts and Shrublands (G200_NUM 124)</td>
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Bush encroachment in Namibia
Weaver birds in Namibia
Weaver bird nest holes in Namibia
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<td>13</td>
<td>West Sudanian savannah (AT0722)</td>
<td>1.641.911 km²</td>
<td>AI 0,17 – 1,08</td>
<td>No hotspot, but the entire Sudanian area has e.g. more than 1000 endemic plants. The total area of protected lands is over 90,000 km² (6.7 %)</td>
<td>Part of the Sudanian regional center of endemism</td>
</tr>
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http://www.connect4climate.org/blog/terrafrica-as-part-of-the-solutions

http://www.fredhoogervorst.com/photo/02436/

http://savannaenvironment.files.wordpress.com/2008/04/acacia.jpg

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<td>15</td>
<td>Caatinga (NT1304)</td>
<td>718.135 km²</td>
<td>AI 0,2 – 1,03 Deserts and xeric shrublands</td>
<td>No hotspot, but: Caatinga is unique to Brazil yet only 1% of its habitats are protected; Several ongoing protection activities</td>
<td>Most populated semi-arid region in the world</td>
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[http://www.nature.org/ourinitiatives/regions/southamerica/brazil/placesweprotect/caatinga.xml](http://www.nature.org/ourinitiatives/regions/southamerica/brazil/placesweprotect/caatinga.xml)

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<td>20</td>
<td>Australien: Tirari-Sturt stony desert (AA1309), Central Ranges xeric scrub (AA1302)</td>
<td>660.019 km² Australia</td>
<td>AI 0,06 – 0,24 Deserts and xeric shrublands</td>
<td>Part of Great Sandy-Tanami-Central Ranges Desert (G200_NUM 129)</td>
<td>Area contains a Centre of Plant Diversity and Protected Areas WRI Major Watersheds: Part of Murray-Darling</td>
</tr>
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http://www.eoearth.org/view/article/177278/
Dryland Processing Components:
Hardware and Processing Infrastructure

GeoVille infrastructure for Dryland Processing:

- Storage capacity of data servers currently ca. 45 TB
- Ca. 20 workstations (with 4 + 1 ERDAS licenses) equipped with
  - Xeon processors (quad-core)
  - Up to 16 GB RAM
  - Up to 3 TB local storage (including some SSD)
  - nVidia graphics cards
- Network with 1 GBit/sec for fast internal data exchange
- Fiber optic Internet with 30 GBit/sec for rapid external data exchange
Dryland Processing Components:

Software Systems

Software Systems for Dryland Processing:

- ERDAS 2011/2013/2014
- ArcGIS 9.3/10.2
- Timesat 3.2
- QGIS 2.2
- R environment v. 3.0.2
Overall Diversity II production scheme
One of the developed ERDAS models, in this case for the *derivation of phenological and productivity parameters*,

Currently being translated into the newer ERDAS Spatial Modeler and from there to Python.
Input and Test Data

1. MERIS FR, RR fAPAR and NDVI (2002 – 2012)
2. GIMMS NDVI (1982 – 2011)
3. Rainfall data: GPCP (from 1979), TRMM (from 1997), CMORPH (from 2002)
4. Soil Moisture data: CCI Soil Moisture (from 1979)
5. NCEP temperature – not yet used
6. (MODIS Evapotranspiration)
7. CGIAR CSI Aridity Index map
NPP Proxies - fAPAR

• fAPAR directly expresses a canopy’s energy absorption capacity

• fAPAR is the index *most directly related to loss of plant productive capacity* and it is the core variable used in models of primary production in terrestrial ecosystems (GEO BON, 2011)

• The fAPAR has been recognized as one of the fundamental Essential Climate Variable (ECV) by Global Terrestrial Observing System (GTOS) and Global Climate Observing System (GCOS 2003)

• The systematic observation of fAPAR is suitable to reliably monitor the seasonal cycle and inter-annual variability of vegetation photosynthetic activity over terrestrial surfaces (GTOS 2009)
MERIS fAPAR

• fAPAR assessments from space remote sensing platforms are retrieved by numerically inverting physically-based models.

• The design of the fAPAR algorithm (MGVI – MERIS Global Vegetation Index) is based on the following procedure (Gobron et al. 2006):

1. Input data are MERIS Level 1 data, i.e. Top Of Atmosphere (TOA) Bidirectional Reflectance Factors (BRFs)

2. First the spectral reflectances measured in the red and near-infrared bands are rectified in order to ensure their ‘decontamination’ from atmospheric and angular effects and,

3. second combined together in a mathematical formula to generate the fAPAR value.
NDVI from MERIS (will be used for comparison to fAPAR)

- Prince et al. (2009) like many other authors take the NDVI as a surrogate for NPP and state that *there is a near-linear relationship between NPP and ΣNDVI in tropical grassland, cropland and sparse woodland* and light use efficiency has been shown not to improve accuracy (Fensholt et al., 2006).”

- As the MERIS NDVI will be computed to compare it with the longer time series of the AVHRR GIMMS NDVI, a thorough band selection of the MERIS bands has to be performed for NDVI calculation.

\[ \rho_1 = \alpha (\rho_6 + \rho_7) \]

\[ \rho_2 = \beta (\rho_{10} + \rho_{12} + \rho_{13} + \rho_{14} + \rho_{15}) \]

- The MERIS NDVI will be modeled by deriving weighted sums of the MERIS bands that correspond to the red and NIR bands of the AVHRR (Günther and Maier 1999, AVHRR Compatible NDVI).
Overall dryland processing chain

1. Intake of MERIS Data
2. Intake of Auxiliary Data
3. Global Project Input Database
   - MERIS Indices Veg, years/Seasons
   - Detailed Phenological Parameterisation
   - Water Indices Veg, years/Seasons
4. Project Output Database by Region
   - NPP Average Epochs
   - NPP Status Veg, year/Seasons
   - NPP Changes
   - NPP Trends
   - RUE Status Veg, year/Seasons
   - RUE Trends
   - RUE Average Epochs
   - RUE Changes
   - Water Status Veg, year/Seasons
   - Water Trends
   - Water Average Epochs
   - Water Changes
5. Generation of Second Level Indicators
   - Combined classified NPP Status/Change/Trend Information
   - Combined classified RUE Status/Change/Trend Information
6. Spatial Aggregation
Why detailed phenological and productivity parameters of drylands?

• As phenology varies between years, it must be taken into account when making year to year comparisons of VI data and analyses involving yearly trends.

• Only when considering the growing season fraction of vegetation development can we derive the direct response of vegetation to rainfall.

• A lack of direct response of the vegetation to rainfall is our „classical“ measure for potentially degraded land in this context (RUE).

• They can provide indirect information to broad categories of land cover when we put the vegetation greenness of the different seasons in relation to each other.

• Shifts and changes of pheno-production parameters can thus give clues about land cover changes, and to trends of the functional vegetation composition.
## Testsite Southern Africa East

<table>
<thead>
<tr>
<th>Description</th>
<th>Area</th>
<th>Features</th>
<th>Additional Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zimbabwe: Zambezian and Mopane woodlands (AT0725), Southern Miombo woodlands (AT0719), Zambezian Balkiaea woodlands (AT0726), Southern Africa bushveld (AT0717)</td>
<td>870.742 km²</td>
<td>Zimbabwe, Zambia, Mozambique, Botswana, South Africa, Malawi</td>
<td>Tropical and subtropical grasslands, savannas, and shrublands</td>
</tr>
<tr>
<td>AI 0.19 – 1.81</td>
<td>Part of Central and Eastern Miombo Woodlands (G200_NUM 88)</td>
<td></td>
<td>Area contains Protected Areas and Transboundary Protected Areas</td>
</tr>
<tr>
<td></td>
<td>WRI Major Watersheds: Parts of Zambezi, Okavango, Limpopo and Save</td>
<td></td>
<td></td>
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### Location of derived time series diagram

![Map of Southern Africa showing the Testsite Southern Africa East area](image)
Phenological and Productivity Parameters

Growing season length

- Cyclic fraction
- Vegetation year

MERIS fAPAR x 1000

Dry season values

Base value

Season amplitude

TRMM rainfall

Rainfall veg. year start

CCI SoilMoisture

Rainfall [mm]:
- 01.07.07: 30 mm
- 01.11.07: 40 mm
- 01.03.08: 50 mm
- 01.07.08: 60 mm
- 01.11.08: 70 mm
- 01.03.09: 80 mm
- 01.07.09: 90 mm
- 01.11.09: 100 mm
- 01.03.10: 110 mm
- 01.07.10: 120 mm

Soil moisture [m^3/m^3]:
- 01.07.07: 0.1
- 01.11.07: 0.2
- 01.03.08: 0.3
- 01.07.08: 0.4
- 01.11.08: 0.5
- 01.03.09: 0.6
- 01.07.09: 0.7
- 01.11.09: 0.8
- 01.03.10: 0.9
- 01.07.10: 1.0

Values:
- 15.03.2008: 350
- 01.04.2010: 400
- 01.03.2009: 250
Phenological and Productivity Parameters

Based on Vegetation Year time series

**Phenological Parameters**

1. Dominant start time of vegetation year
2. Start time of growing season
3. End time of growing season
4. Length of growing season including all peaks
5. Length of growing season excluding small/short peaks (2 variants)
6. Time of maximum
7. Number of peaks within growing season separated by values below base value
8. Overall number of peaks in vegetation year

**Productivity Parameters**

1. Base values (separate growing season from dry season)
2. Maximum
3. Amplitude
4. Cyclic fraction (all)
5. Cyclic fraction (excluding short/small peaks)
6. Dry season average
7. Dry season average (including short/small peaks)
8. Peak values
Start of Vegetation Year (Median 2003 – 2010)
NOAA GIMMS median of dominant start of vegetation year 1982 - 2011
NOAA GIMMS median of dominant start of vegetation year 1982 - 1991
NOAA GIMMS median of dominant start of vegetation year 2002 - 2011
Length of growing season 2007 vs. 2008 (right)
Length of growing season 2007 vs. 2008 (ye)

X 25.1263889, Y -29.0652778
EO time series data issues

- NOAA GIMMS
- Rainfall data (GPCP, TRMM, CMORH)
- Soil moisture data (surface soil moisture TU Vienna)
Shift in AVHRR-sensor configuration

Fensholt et al., 2009

Horion et al., in press
Possible effects of AVHRR sensor degradation
Passive/Active Sensors of the CCI Soil Moisture product
CCI Soil Moisture Time Series 1978 – 2013

Caatinga

Number of missing data:
- 65
- 77
- 47

Soil moisture [m³·m⁻²]
CCI Soil Moisture Time Series 1978 – 2013
Southern Spain
Preliminary Conclusions regarding the Soil Moisture Data

• Long term time series may be affected by sensor related shifts and derived trends may therefore not be valid

• The MERIS period seems to be less or not affected by those shifts

• First visual inspections of the raster images show that the data availability becomes better towards more recent times

• This also positively effects the usage of the SM data for MERIS based efficiency indices
TRMM rainfall trends 2003 – 2010
p: 0.05
CMORPH rainfall trends 2003 – 2010
p: 0.05
Surface soil moisture trends 2003 – 2010
p: 0.05
GIMMS NDVI Vegetation Year Trends
1982 - 2010

Threshold for significant pearson r: 0.367 ( p: 0.05)
GIMMS NDVI Vegetation Year Trends
1982 - 2002

Threshold for significant pearson r: 0.433 (p: 0.05)
Threshold for significant pearson r: 0.707 (p: 0.05)
MERIS fAPAR trends versus GIMMS trends

MERIS fAPAR 2003 – 2010

GIMMS NDVI 2003 – 2010

GIMMS NDVI 1982 - 2010
MERIS fAPAR trends versus GIMMS trends

MERIS fAPAR 2003 – 2010

GIMMS NDVI 2003 – 2010

GIMMS NDVI 1982 - 2010
MERIS fAPAR trends versus GIMMS trends

MERIS fAPAR 2003 – 2010

GIMMS NDVI 2003 – 2010

GIMMS NDVI 1982 - 2010
First order product examples: Southern Africa West

**Average Vegetation Year Greenness**

Description:
Status of ENVISAT MERIS NDVI average vegetation year greenness, calculated as mean value for the period 2003-2011 in the Western Africa. The NDVI is derived from the reflectance of red and near-infrared vegetation bands in the visible spectrum. The vegetation greenness index is an indicator of the overall health of the vegetation.

Legend:
- Healthy vegetation (green)
- Stressed vegetation (yellow)
- Dead vegetation (brown)

**Vegetation Year Variability**

Description:
Variability of ENVISAT MERIS NDVI average vegetation year greenness expressed by the coefficient of variation for the period 2003-2011 in the Western Africa. The coefficient of variation is a measure of the dispersion of the data around the mean.

Legend:
- Low variability (blue)
- High variability (red)

**Vegetation Year Greenness Trend (abs.)**

Description:
Trends of absolute changes of ENVISAT MERIS NDVI average vegetation year greenness for the period 2003-2011 in the Western Africa. The absolute changes are expressed as percentage changes per year. The trend is calculated using the Mann-Kendall test for significance.

Legend:
- Trend increase (+)
- Trend decrease (-)

**Dry Season Greenness Trend (abs.)**

Description:
Trends of absolute changes of ENVISAT MERIS NDVI dry season greenness for the period 2003-2011 in the Western Africa. The dry season is defined as the period from the end of the wet season to the beginning of the next wet season.

Legend:
- Trend increase (+)
- Trend decrease (-)
First order product examples: Caatinga, Brazil
First order product examples: Southern Europe
First order product examples: Southern Australia
Direct NPP Proxy – rainfall relation