*DesertWatch Extension*

# Assessment and monitoring of land condition in Portugal, 2000-2010

Maria E. Sanjuan[1], Gabriel del Barrio[2]*, Alberto Ruiz[3]& Juan Puigdefabregas[4]
EEZA (CSIC), Almeria

[1] marieta@eeza.csic.es
[2] gabriel@eeza.csic.es (*Corresponding author)
[3] alberto@eeza.csic.es
[4] puigdefa@eeza.csic.es

*Dissemination level of this document:*
***Confidential**, only for members of DWE, including ESA services*

March 2011

**Contents**



## 1. Scope

This document reports on the application of the *LDI-2dRUE* methodology as a contribution to desertification surveillance in Portugal. The *2dRUE* is an upgraded method for the assessment and monitoring of land condition, and it forms the current implementation of the Land Degradation Index (LDI) of the DesertWatch system.

The current delivery conveys the following UNCCD Impact Indicators[1] for Portugal in the analysis period: Aridity Index, Level of Land Degradation and Land Cover Status.

[1] L. Berry, E. Abraham & W. Essahli (2009). *UNCCD Recommended Minimum set of Impact Indicators*. Consultancy report.

*2dRUE* is applied in two stages. The first one is called Version 0 and corresponds to the results of the numerical application using default settings. Such results consist of a map set with associated databases that are already in the format of the final product. Its purpose is to start an interactive process of interpretation and validation involving the concerned users. That process is the second stage and involves several things: known facts from the real world are interpreted in light of the model results, map legends may need to be tuned accordingly, model thresholds and settings may require revision to generate a new model run, independent data are selected to test the model, etc. All those tasks mean a permanent feedback with Version 0, which will be then upgraded to a proper technical product. This is called Version 1 and corresponds to the delivered application.

This report concerns to the Version 0 of the 2dRUE-Portugal application. Its objective is to provide the Portuguese users with a formal basis to start the interactive process described above. This is therefore a working document, which justifies setting its dissemination level to confidential. In addition to that, this report has yet to be enhanced with further analyses, especially concerning the application results.

## 2. Objective

This application aims at developing a diagnostic of land condition in Portugal during the period 2000-2010. Land condition is considered to convey human and climatic effects on the landscape. The diagnostic of land condition reported here is based both on state of land and on its trends during the period.

## 3. Methods

### *3.1. Background on 2dRUE*

*2dRUE* is a methodology for the assessment and monitoring of land condition. It was developed in the frame of the EC DeSurvey Integrated Project (www.desurvey.net). The method is based on the application of statistical techniques to archived time-series of a remotely sensed vegetation density index, and corresponding climate fields. See del Barrio et al. (2010)[2] for a full description and for the application to the Iberian Peninsule during the preceding period 1989-2000. Nevertheless, it is important to stress that the methodology has been upgraded since that pioneering study, especially concerning how the assessment legend is derived. For that reason, the results of these applications to the same area in two successive periods cannot be directly compared without harmonizing their respective legends. This issue will be addressed in a later enhancement of this report of Version 0.

This document is oriented to users and reports only specific aspects of the Portugal application. The generic implementation of the *LDI-2dRUE* methodology is described in existing DWE documents (Table 1).

[2] del Barrio, G., Puigdefabregas, J., Sanjuan, M.E., Stellmes, M., & Ruiz, A. (2010). Assessment and monitoring of land condition in the Iberian Peninsula, 1989-2000. *Remote Sensing of Environment, 114*, 1817-1832

Table 1. Source documents in DWE for the LDI-2dRUE methodology.

| Id | Title | Delivery event | Description |
|---|---|---|---|
| TS V2 | Technical Specification V2 | CDR | Description of the LDI component approach (mathematical formulation) |
| ./SDD V2 | System Design Document V2 | QAR | System design for the LDI (SW description) - final |
| ./SUM EN | Software User Manual English | CDR | Contribution to the Software User Manual for the part of EEZA |
| SW-1 V1 | SW mock-up | CDR | Mock-up of the LDI SW |
| ./ | System Trade-off analysis V3 | QAR | Trade off on design solutions for the LDI component |
| PVP V3 | Product Validation Plan V3 | QAR | Validation plan for the LDI component |

All the computations were done using the *r2dRue* software library, which can be downloaded from http://cran.r-project.org/web/packages/r2dRue/index.html. This package runs as stand alone in the frame of R, and will also be integrated into the DesertWatch software system.

### *3.2. Output description*

This section aims at providing with an elementary key to understand the nature of the output results and their legend captions.

Assessment and monitoring are performed separately in 2dRUE, each procedure yielding its own maps. Such maps are then merged to the final land condition map. The legend system of it is hierarchical: legend captions correspond to assessment results and reflect land states, and sub-legend captions correspond to monitoring results and reflect land trends.

Assessment

Assessment addresses land states under the paradigm that natural vegetation maximizes Aboveground Net Primary Production (ANPP) per unit rainfall. It is evaluated using Rain Use Efficiency (RUE), which is implemented on two temporal scales to detect long and short term vegetation responses, and corrected for aridity across the whole study area to enable direct comparisons between locations. States are graded accordingly in the corresponding map legend (Table 2).

Table 2. Assessment classes conveying land states used in the land condition map.

| Abbreviation | Legend caption | Interpretation |
|---|---|---|
| OA | *Overperforming anomaly* | Vegetation well above the maximum RUE found in rainfed conditions. Typically, irrigated crops. |
| RP | *Reference performance* | Vegetation within the confidence interval of maximum RUE. Typically, undisturbed natural vegetation. |
| M | *Range performance: mature* | Vegetation with a relatively high biomass but a relatively low productivity. For example, areas under low intensity grazing. |
| P | *Range performance: productive* | Vegetation with both relatively high biomass and productivity. This refers typically to initial phases of overgrazing or incipient degradation. |
| D | *Range performance: degraded* | Vegetation with a relatively low biomass but a relatively high productivity. For example, well established degradation associated with overgrazing or decaying rainfed crops. |
| VD | *Range performance: very degraded* | Vegetation with both relatively low biomass and productivity. For example, advanced degradation due to overgrazing in the recent past or soil exhaustion after intensive crop management. |
| BP | *Baseline performance* | Vegetation within the confidence interval of minimum RUE. For example, vegetation limited by other factors than rain, such as saline areas. |
| UA | *Underperforming anomaly* | Vegetation well below the minimum RUE. For example, heavily disturbed areas. |
| NA | *Non assigned* | Vegetation excluded from the assessment for methodological reasons. Typically, a small set of locations in the wet extreme of the aridity gradient. Also includes masked territory (snow, etc.) |

This system essentially means a two-step discrimination. First, locations are objectively classified according to their observed long term vegetation performance using statistically significant thresholds. In that classification, marginal classes (*Reference performance* and *Baseline performance* respectively) are rather small and need no further discussion. However, the central class (*Range performance*) contains the majority of locations because of the built-in use of boundary functions. Then, the second step is performed on this class.

The central class is likely to target to locations under active land use (because they show neither very good nor very bad performance), where different responses can be expected from the vegetation cover. For that reason, a one-dimensional gradient might not be very clarifying to assess the 'range' class. Instead, we have adapted the original hypothesis of Pickup et al. (1994)[3], by which annual average biomass and NPP may be expected to decrease as land degradation proceeds, whilst peak NPP would be maximum at intermediate degradation states. The two implementations of RUE used in*2dRUE* target respectively to such functions, but their observed values cannot be used

[3] Pickup, G., Bastin, G.N., & Chewings, V.H. (1994). Remote-sensing-based condition assessment for nonequilibrium rangelands under large-scale commercial grazing. *Ecological Applications, 4*, 497-517

in comparisons across the study area because of the influence of climate. Therefore, their relative transformations are used for this purpose.

Monitoring

Monitoring addresses land trends (irrespectively of states) observed along the study period. The effects of inter-annual variations of aridity and those of time are explicitly separated. The former explain resilience to changing rainfall, for example, the wetter the year, the greener the vegetation. Once such effects are removed, the accumulation of depletion of biomass over time is interpreted in terms of ecological self-organisation or ongoing degradation. Three maps make the primary result of monitoring:

- Effect of interannual variations of aridity on vegetation. This map reflects sensitivity to yearly oscillations of aridity (defined as PET/P). Negative values mean that vegetation is less green in dry years. No trend is assessed on the long term.
- Effect of time on vegetation. This map conveys the long term vegetation trends after the interannual climate oscillations have been removed. Positive values mean a linear biomass accumulation over time (e.g. a secondary ecological succession after abandonment), whilst negative values mean some ongoing degradation process.
- Detailed monitoring map. This map is simply a combination of positive, negative and non effects from the two previous maps.

Those results must be distinguished respectively from good conditions or degraded states, which is a subject for the assessment map. Whilst such maps are useful for detailed studies, their respective legends are too complex for showing in the final land condition map. Therefore a simplification is made to provide the trends sub-legend in the final map of land condition (Table 3).

Table 3. Monitoring sub-classes conveying land trends used in the land condition map.

| **Abbreviation** | **Sub-legend caption** | **Interpretation** |
|---|---|---|
| I | *Improving* | Biomass accumulation over time, whatever the response to interannual variations of aridity. Typically, ongoing ecological succession after a disturbance or land abandonment. |
| F | *Fluctuating* | Biomass fluctuates according to the year rainfall, but with no significant variation on the long term. For example, rainfed crops or grasslands dominated by annual plants. |
| S | *Static* | No response detected over time neither to changing rainfall within the study period. |
| D | *Degrading* | Biomass depletion over time, whatever the response to interannual variations of aridity. Typically, ongoing degradation processes. Recently burnt areas may also be included. |

## 4. Data

### *4.1. Study area*

The study area is mainland Portugal.

### *4.2. Input data sets*

*2dRUE* requires the following input data over a time period approximately spanning 10 years:

- Archived time-series at a monthly temporal resolution:
  - NDVI or other RS-derived vegetation density index
  - Corresponding climate fields (mean maximum, mean and mean minimum temperature, and precipitation)
- Land use or land cover map, to mask irrigated areas, wetlands and other non rainfed surfaces during the climate detrending routine.
- Natural reserves and other pristine natural vegetation areas for validating the maximum potential vegetation performance.
- Also convenient, but not strictly required, are layers of administrative divisions, natural vegetation zones, and other complementary data sets that can be used for the interpretation of the results

The data sets used for Version 0 of the 2dRUE-Portugal application are shown in Table 4.

Table 4. Input data sets for Version 0 of 2dRUE-Portugal.

| **Variable** | ***Product* and source** | **URL** |
|---|---|---|
| Vegetation density archive | *SPOT VEGETATION NDVI*. Available from 1998 onwards. Coordinated by VITO. Worldwide data are recorded every ten days (dekade) at a spatial resolution of 0.00892857º (approximately 1 km). A quality channel is available to mask clouds and snow. Monthly data were assembled by selecting the maximum value in the three concerned sequential dekades. | http://free.vgt.vito.be/ |
| Temperature and Precipitation archives | *Ad hoc* interpolations following the scheme described in the preceding application. 10 years were added to the existing archive at the same spatial and temporal resolutions of 1 km and 1 month respectively. Georeferenced monthly summaries were downloaded from the Portuguese Sistema Nacional de Informaçao de Recursos Hídricos (SNIRH) and from the Global Summary of the Day (GSOD) database maintained by the US NOAA-NCDC. | http://snirh.pt/<br>http://lwf.ncdc.noaa.gov/cgi-bin/res40.pl?page=gsod.html |
| Land use / land cover | *Corine Land Cover 2006 raster data version 13*, and *Corine Land Cover 2000-2006 changes version 13*. Managed by the European Environment Agency. Both datasets in raster format at 100 m resolution in ETRS-LAEA system. | http://www.eea.europa.eu/data-and-maps/data#c5=all&c11=&c17=&c0=5&b_start=0 |

### *4.3. Study period and resolutions*

The study period was 2000-2010. Hydrological years (from 1 September to 31 August) were used, hence the period is made of ten years starting in 2000/2001. This is a continuation of the previous application that extended from 1989/1990 to 1999/2000. The temporal resolution over that period was of 1 month.

The map sets have been managed using the same Coordinate Reference System (CRS) and grid specification of the *SPOT VEGETATION NDVI* product, to keep the integrity of vegetation values. That CRS consists of unprojected geodetic coordinates in the WGS84 datum. The resolution is of 0.00892857 degrees, which approximately equals to 1 km on a maximum circle. One advantage of this procedure is that relevant maps or window regions can be projected to the CRS of a target user agency with minimum distortion or loss of information.

## 5. Results and discussion

*To be developed in the forthcoming weeks*

## 6. Preliminary conclusions

*To be developed in the forthcoming weeks*

## 7. Output dataset description

The layers in the table below are delivered along with this document to make Version 0 of the Portugal_2dRUE application. They represent the end products, and as such are closer to a layman, interpreted approach to land condition in the area. All the layers are raster with the following specifications:

```
data type   : byte
file type   : binary
columns     : 400
rows        : 667
ref. system : latlong (WGS84)
ref. units  : deg
unit dist.  : 1.0000000
min. X      : -9.6010000
max. X      : -6.0010002
min. Y      : 36.4990002
max. Y      : 42.5019997
resolution  : 0.0089999995
```

The files are delivered in ERDAS Imagine format because it preserves the associated color palette, and can be easily imported into other software packages as required.

| **Layer name** | **Description** |
|---|---|
| v-fao aridity index.img | FAO-UNEP Aridity Index (ERDAS Imagine format) |
| v-portugal land condition.img | Land condition map (ERDAS Imagine format) |
| v-portugal-assess.img | Assessment map (ERDAS Imagine format) |
| v-portugal-mon.img | Monitoring map (detailed) (ERDAS Imagine format) |
| portugal-assessment 0010.kmz | Assessment map (to be overlaid using Google Earth) |
| portugal-land condition 0010.kmz | Land condition map (to be overlaid using Google Earth) |

See map legend codes in the next page.

Legend codes of the land condition map:

```
code      1 : UNDERP A DEGRADING
code      2 : UNDERP A FLUCTUATING
code      3 : UNDERP A IMPROVING
code      4 : UNDERP A STATIC
code      5 : BASELINE P DEGRADING
code      6 : BASELINE P FLUCTUATING
code      7 : BASELINE P IMPROVING
code      8 : BASELINE P STATIC
code      9 : VERY DEG DEGRADING
code     10 : VERY DEG FLUCTUATING
code     11 : VERY DEG IMPROVING
code     12 : VERY DEG STATIC
code     13 : DEG DEGRADING
code     14 : DEG FLUCTUATING
code     15 : DEG IMPROVING
code     16 : DEG STATIC
code     17 : PRODUCTIVE DEGRADING
code     18 : PRODUCTIVE FLUCTUATING
code     19 : PRODUCTIVE IMPROVING
code     20 : PRODUCTIVE STATIC
code     21 : MATURE DEGRADING
code     22 : MATURE FLUCTUATING
code     23 : MATURE IMPROVING
code     24 : MATURE STATIC
code     25 : REFERENCE P DEGRADING
code     26 : REFERENCE P FLUCTUATING
code     27 : REFERENCE P IMPROVING
code     28 : REFERENCE P STATIC
code     29 : OVERP A DEGRADING
code     30 : OVERP A FLUCTUATING
code     31 : OVERP A IMPROVING
code     32 : OVERP A STATIC
code     33 : NON ASSIGNED
```

Legend codes of the assessment map:

```
code      1 : underperforming ANOMALY
code      2 : baseline performance
code      3 : very degraded
code      4 : degraded
code      5 : productive
code      6 : mature
code      7 : reference performance
code      8 : overperforming ANOMALY
code      9 : non assigned
```

Legend codes of the monitoring map:

```
code      1 : Decrease in Time and with Aridity
code      2 : Decrease with Aridity
code      3 : Increase in Time and decrease with Aridity
code      4 : Decrease in Time
code      5 : Non significant response to Time or Aridity
code      6 : Increase in Time
code      7 : Decrease in Time and increase with Aridity
code      8 : Increase with Aridity
code      9 : Increase in Time and with Aridity
code     10 : Masked areas
```