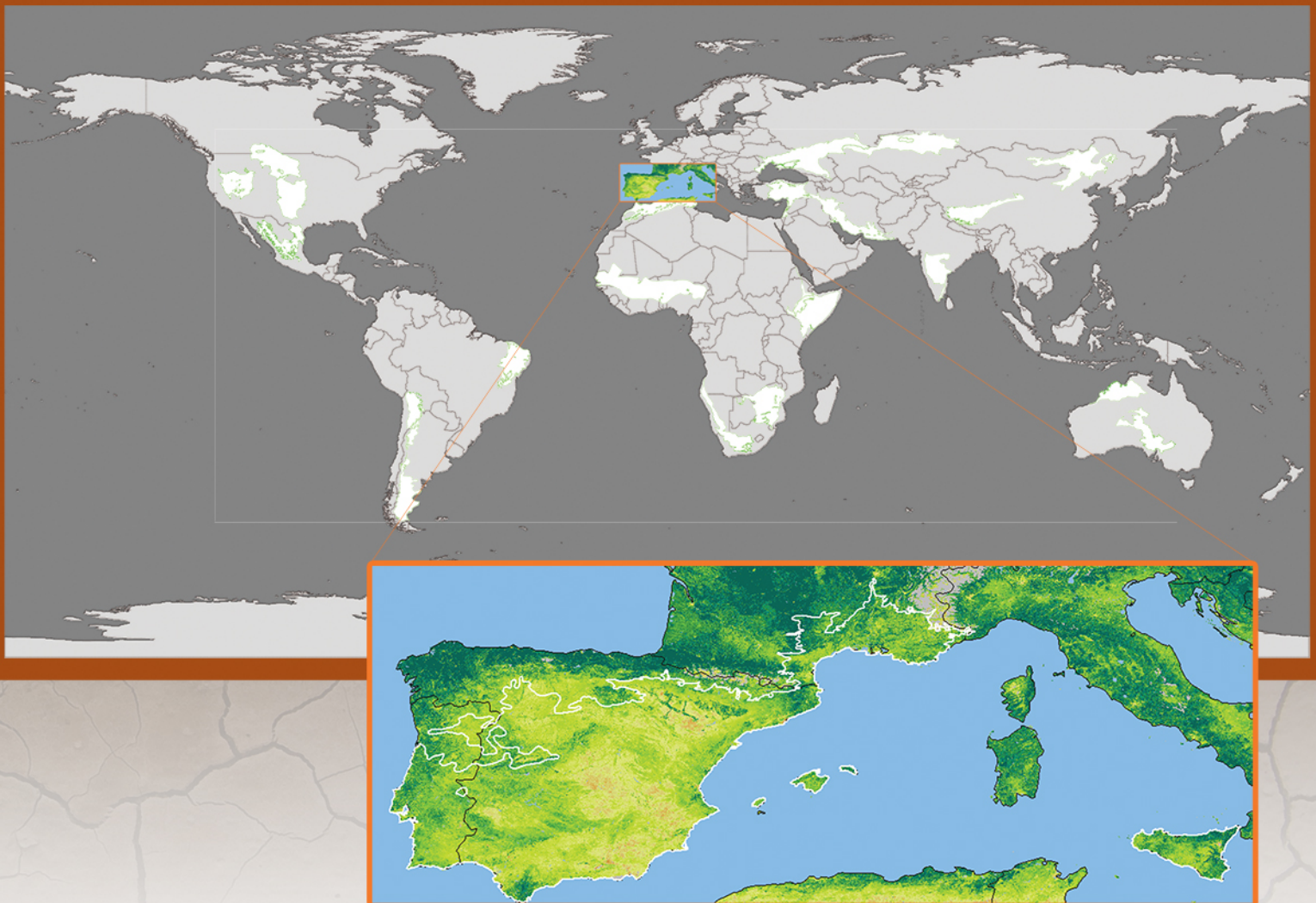


## → ESA DIVERSITY II - DRYLAND PRODUCTS

Booklet for Test Site 10 | Southern Europe



All Drylands Booklets are available on **[www.diversity2.info](http://www.diversity2.info)**

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## **Acknowledgement**

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## **About the Booklet**

The booklets provide information about the vegetation condition of major dry regions of the world and how it developed during the first decade of this century as seen by ENVISAT MERIS. Focus is on vegetation productivity combined with detailed phenological analyses. The booklets present part of the developed indicators, which comprise status and trend/change information.

Chapter 1 gives a short introduction to the Diversity II project and the scope of the booklet.

Chapter 2 introduces the test site with a condensed biodiversity summary, and a regional “dryland” story, which users might relate to some of the map products provided. Further overview information is given such as LCC Land Cover and aridity maps, as well as climate diagrams.

Chapter 3 is a short overview of the data and methods applied.

Chapter 4 describes the developed indicators and presents selected indicator maps.

Chapter 5 discusses the indicators and their information content.

Chapter 6 contains a short outlook.

Annex 1 contains more detailed biodiversity descriptions for five dryland test sites: site 10 Southern Europe, site 12 Southern Africa West, Site 13 Western Sahel, site 15 Caatinga, Brazil, and site 20 Southern Australia.





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# 1 Introduction to Diversity II

With the Diversity II project 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. **The specific aim of this project is to set up an EO-based monitoring scheme for the 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 primarily based on ENVISAT MERIS data, which have been recorded from June 2002 to April 2012. Figure 1 gives an overview of the selected dryland sites, which constitute WWF (World Wildlife Fund) ecoregions.



**Figure 1: Distribution of global Diversity II dryland sites with internal numbering**

## 1.1 Scope of the Booklet

The booklet compiles and summarizes important outcomes per test site, and thus constitutes a regional complement to the project reports and the product user handbook (PUH). The PUH provides in depth and complete project documentation, though without highlighting every test site.

Interested users, for instance those who will not look at the map files themselves, will find some major results presented in the booklet, as well as a short description of the methodology and of the individual products shown.

The booklets and the PUH can be downloaded at <http://www.diversity2.info/products/>.

## 2 The Test Site Southern Europe

### **Dryland Story of Southern Europe**

When including the Middle East and North Africa, drylands “cover 33.8% of the Mediterranean and poor soil management, overgrazing, deforestation and wild fires are turning large sections of these areas into deserts. Some studies have estimated that 30% of semi-arid Mediterranean drylands are now affected by desertification, which is also a security issue as it has the potential to speed up migration from the Middle East and North Africa into Europe, studies suggest” ([http://ec.europa.eu/environment/integration/research/newsalert/pdf/mediterranean\\_land\\_degradation\\_threatens\\_food\\_security\\_391na6\\_en.pdf](http://ec.europa.eu/environment/integration/research/newsalert/pdf/mediterranean_land_degradation_threatens_food_security_391na6_en.pdf)).

The scope of this statement goes beyond the geographic extent of the southern Europe test site, but relates well to the area covered by Diversity II as a whole. Concentrating on the European countries and regions covered by the test site, i.e. southern France, Sicily, Portugal, and southern Spain, the **WWF ecoregion descriptions point to a large bundle of degradation factors and processes** going on:

<http://www.worldwildlife.org/ecoregions/pa1208> (several mountain ranges of Spain): “Mountain tourism, ski facilities, and road construction are strongly degrading large mountain forest ecosystems. Due to the soil instability of the steep mountain slopes, road construction and clear-cutting operations have provoked serious landslides. Other primary threats include forest fires, overly intense and inadequately managed logging operations, and overgrazing and unsustainable plant-collecting”.

<http://www.worldwildlife.org/ecoregions/pa1209> (inner Spain), <http://www.worldwildlife.org/ecoregions/pa1221> (southeastern coast of Spain): “Degradation is mainly a result of agricultural intensification and large irrigation plans including extensive greenhouse crops on coastal land, inadequate forestry programs promoted by European Union subsidies, dam construction, road building, and inadequate and overly intense hunting practices”, as well as “climate change impact on overexploited sylvopastoral woodlands, coastal tourism and urbanization”.

<http://www.worldwildlife.org/ecoregions/pa1216> (Northwestern Spain and northeastern Portugal): “Due to the high density of flammable resinous pine species, these secondary forests are very vulnerable to forest fires, which are generally started by man. Very remote and wild areas are still to be found along the border of Spain and Portugal, due to the low human population that has historically characterized this area (i.e. the Arribes del Duero international river canyons). Nevertheless, overly intense and poorly regulated hunting is threatening many faunal species, especially in Portugal”.

<http://www.worldwildlife.org/ecoregions/pa1222> (Portions of the southern Italian mainland and parts of the islands of Corsica, Sardinia, and Sicily): “Major threats are related to a number of different human activities. These include coastal tourism development and urbanization; intensive agriculture through irrigation systems, conversion of natural to agricultural land, overuse and pollution of water bodies; forest fires, mainly due to human negligence and arson; unsustainable collection of rare, wild plant species; hunting; and the spread of invasive species, promoted by human induced changes to the coastal zone (i.e. exotic species introduced for gardening, such as *Carpobrotus edulis* and *Agave americana*)”.

<http://www.worldwildlife.org/ecoregions/pa1219> (southeastern coast of Spain): “Recent land use changes, such as intense greenhouse agriculture and coastal tourism development, have produced significant impact. These are difficult to challenge due to the high economic interests behind them. Greenhousing, house building, and golf courses are threatening important habitats and the fragile water balance of the ecoregion (water-bearing salinization).

Uncontrolled collection of aromatic and medicinal plants is a growing threat in the ecoregion, as referred to by TRAFFIC in the 1999 report on medicinal plants in Europe”.

Figure 2 shows that the hotspots of soil erosion in Europe are concentrated in the Mediterranean countries, where a high soil erodibility often combines with a high rainfall erosivity.

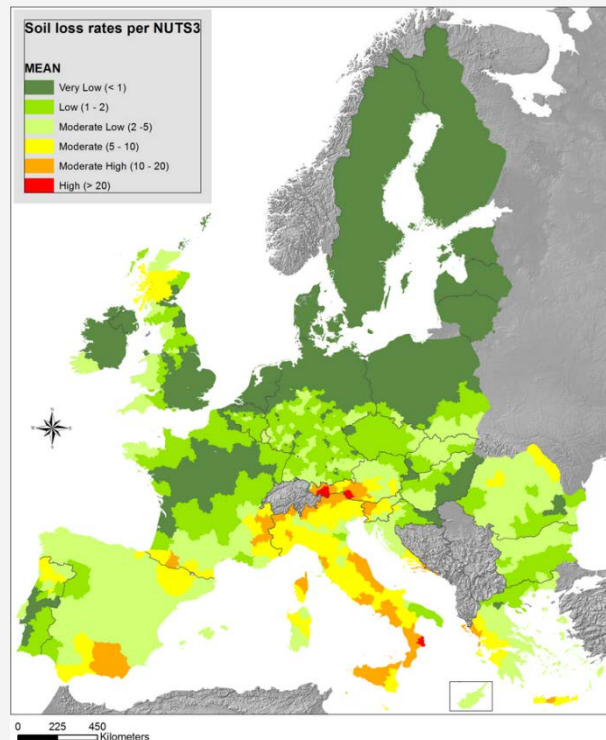


Figure 2: Soil erosion by water (tonnes per ha per year), 2010, EU-28, NUTS 3. Source: [http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental\\_indicator\\_-\\_soil\\_erosion](http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_soil_erosion)



Figure 3: Severe gully erosion, Baranco de Belarda, Darro (S.E. Spain). Source: <http://ees.kuleuven.be/geography/projects/recondes/>

However, conservation and management measures (reduced tillage, management of plant residues and winter crops, contouring, stone walls, grass margins) had a significant impact on reducing soil loss, leading to a reduction of 9.5% on average in the EU during the last decade ([http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental\\_indicator\\_-\\_soil\\_erosion](http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_soil_erosion)).

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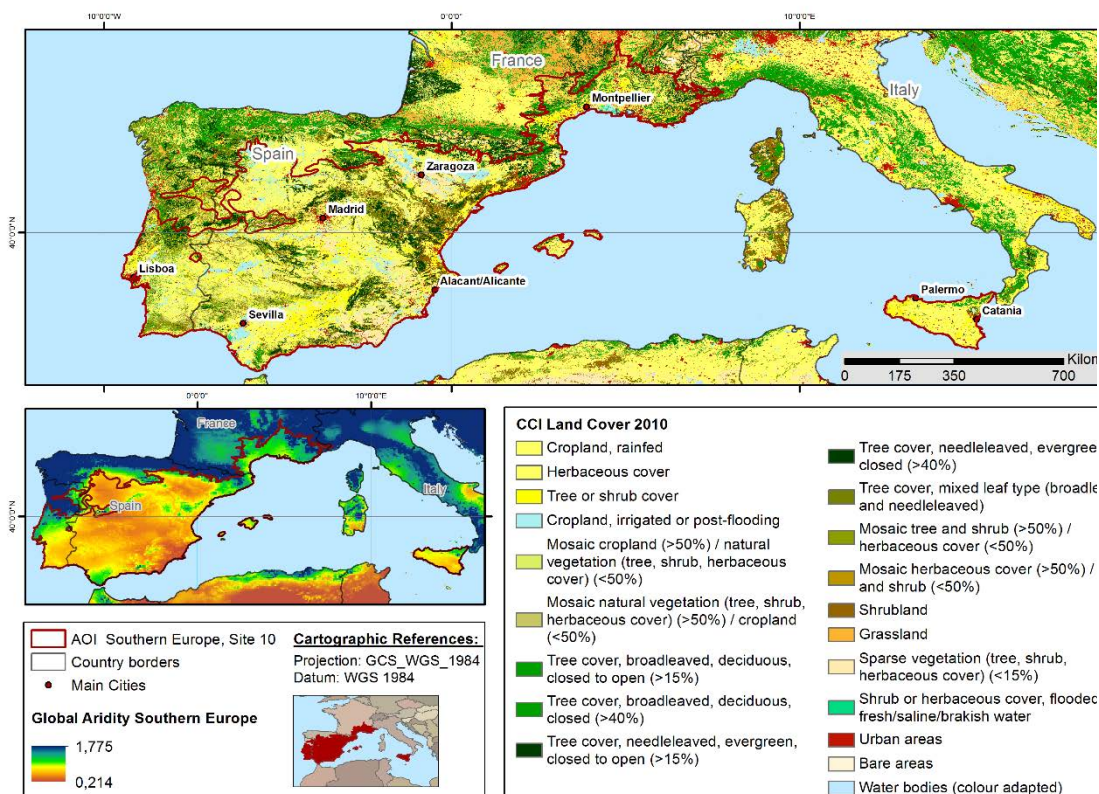


## 2.1 Overview of Land Cover and Climate of the Test Site

The study AOI is made up by the WWF ecoregions Mediterranean forests (PA1208, <http://www.worldwildlife.org/ecoregions/pa1208>), Iberian sclerophyllous and semi-deciduous forests (PA1209, <http://www.worldwildlife.org/ecoregions/pa1209>), Southwest Iberian Mediterranean sclerophyllous and mixed forests (PA1221, <http://www.worldwildlife.org/ecoregions/pa1221>), Northwest Iberian montane forests (PA1216, <http://www.worldwildlife.org/ecoregions/pa1216>), Tyrrhenian-Adriatic Sclerophyllous and mixed forests (PA1222, <http://www.worldwildlife.org/ecoregions/pa1222>), South Appenine mixed montane forests (PA1218), Southeastern Iberian shrubs and woodlands (PA1219, <http://www.worldwildlife.org/ecoregions/pa1219>).

For most of the ecoregions, information on geography, biodiversity, threats, etc. is found on <http://www.eoearth.org/view/article/51cbcd7a7896bb431f692731/?topic=51cbfc77f702fc2ba8129ab9>. Inserting the ID of the ecoregion (e.g., PA1208) or the name into the search window will lead to the respective ecoregion description site.

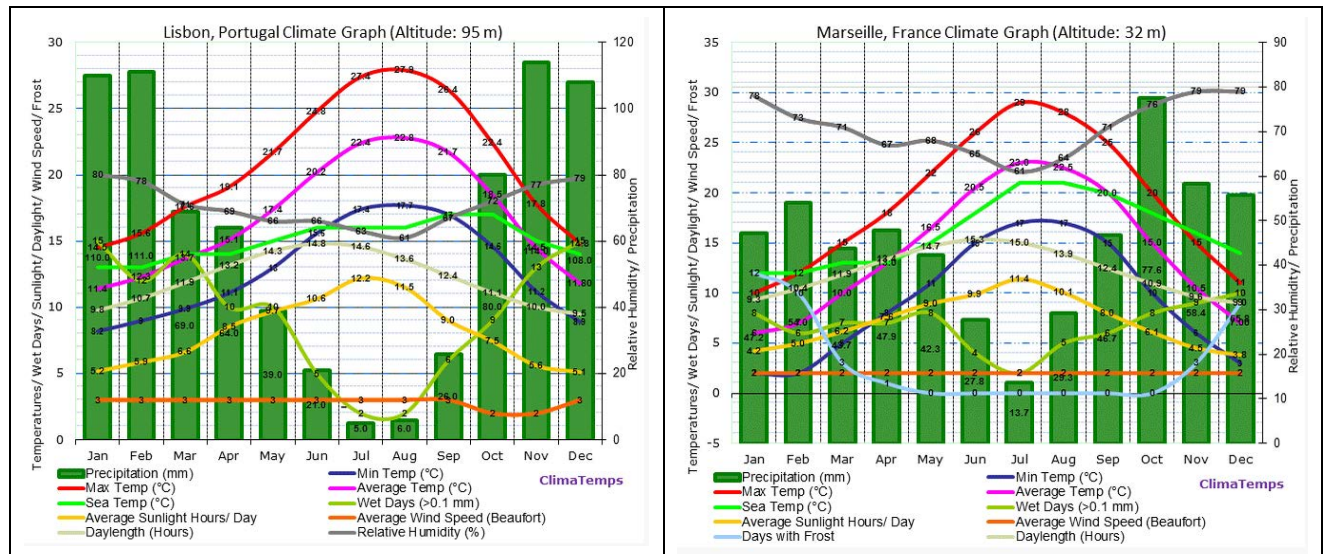
The maps in Figure 4 provide an overview of the study site. The upper map presents the CCI Land Cover v1.4 2010 data, which were derived (<http://www.esa-landcover-cci.org/>) based on ENVISAT MERIS (300m) data. Below, the CGIAR-CSI global aridity index map (Zomer et al. 2007, Zomer et al. 2008) is shown. 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.



**Figure 4: Overview of test site 10, Southern Europe, showing land cover from the CCI Land Cover 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.**

While the larger test site within the rectangle spans a broad spectrum of climatic conditions ranging from hyperarid to humid, the actual AOI contains mainly semi-arid land, but also dry sub-humid and humid areas. The overall land cover patterns reflect roughly the aridity gradients, and range from herbaceous cover to closed tree cover.

Figure 5 shows two climographs of Lisbon, Portugal and Marseille, France, respectively. Both climographs show basically a similar seasonal behavior, though the Lisbon example exhibits a stronger rainfall seasonality with a more pronounced winter rain peak.



**Figure 5: Climographs of Lisbon, Portugal and Marseille, France. Sources:**

<http://www.lisbon.climatemps.com/>, <http://www.marseille.climatemps.com/>

## 2.2 Biodiversity Highlights in the Study AOI

The Mediterranean basin was one of the first regions to be recognized as one of the 25 Global Biodiversity Hotspots. Despite the historically strong human presence and high degree of habitat degradation the region is still home for a wide variety of species, such as the endemic Mediterranean tree frog (*Hyla meridionalis*), endangered raptors like the black vulture (*Aegypius monachus*) and the emblematic Iberian lynx (*Lynx pardinus*).

## 3 Materials and Methods

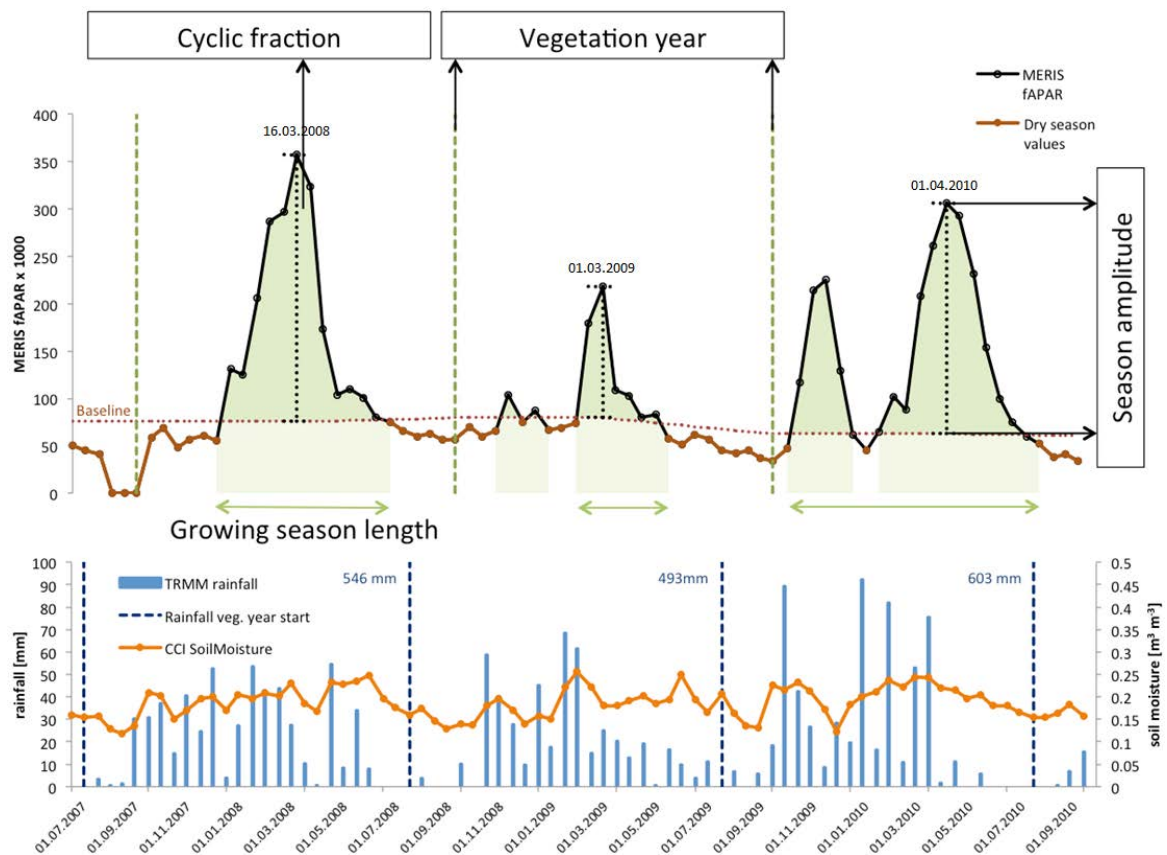
Based on ENVISAT MERIS FR and RR (Full and Reduced Resolution) data with a spatial resolution of 300m and respectively 1200m, all NPP proxies presented here and the indicators derived therefrom originate from the fraction of absorbed photosynthetically active radiation (fAPAR) computed according to Gobron et al. 2011. The fAPAR values are compiled on a bi-weekly basis, resulting in time series data with 24 halfmonthly values per calendar year. In addition, TRMM 3b42 rainfall data (<http://trmm.gsfc.nasa.gov/>) were used to relate the productivity data to precipitation, as well as CCI soil moisture data (<http://www.esa-soilmoisture-cci.org/>) as alternative data for water availability. Beyond 50° North and South, GPCP (<http://www.gewex.org/gpcpdata.htm>) rainfall data were taken, as TRMM data end at 50° N and S. For the period prior to the MERIS period, NOAA GIMMS NDVI data (<http://glcf.umd.edu/data/gimms/>) and GPCP rainfall data were confronted to show the “historical” development of vegetation and rainfall from 1982 to 2002 (map [P56](#)), i.e. prior to the MERIS period.

### 3.1 Generation of NPP-Proxies

In a first step, phenological parameters are derived individually for each year and pixel, shown in Figure 6. The diagram shows the temporal course of the MERIS fAPAR data during a 3-year period and the subdivision into different seasonal periods. The **vegetation year** includes the full yearly vegetation cycle starting at the turning of the preceding *dry or cold season* to the green season and

ending after the following **dry/cold season** – or in case of several green seasons during a year – at the begin of the (statistically) dominant green season. The **vegetation year length** varies with possible shifts of the green season start time, which results from the high rainfall variability typical for drylands. The average (median) start time of the vegetation years starting in 2003 to 2010 is presented in map [P57](#).

The **vegetation year** can be subdivided into different periods, limited by defined starting and ending points in time. The **growing season** includes the major peak(s), i.e. ascending and descending parts of the time series and starts once a selected greenness threshold is surpassed on the way from the SoS to the green peak. The starting time of the growing season is shown in map [P59](#). The **dry season** (brown parts of the curve) starts once a defined lower fAPAR threshold is passed. The thresholds depend on the seasonal amplitude and especially on the average level of the dry season values.



**Figure 6: Scheme of the extracted phenological parameters, and corresponding rainfall and soil moisture data. (Location: South Africa, X: 25.7373764, Y: -29.896337)**

The growing season length is shown in map [P58](#). For the above described phenological periods, the MERIS fAPAR values have been temporally integrated to either sum or average values. The results are called “**NPP proxies**”, and constitute yearly (one value per vegetation year) values. The developed indicator maps are primarily 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 (map [P01](#)) and/or standing green biomass.
- **Cyclic fraction fAPAR:** The cyclic fraction of the vegetation is comprised of 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 (map [P02](#)).



- **Average dry season fAPAR:** For the dry season the low fAPAR values after the green peak are averaged. 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 (map [P03](#)).
- **Percent cyclic vegetation of vegetation year greenness:** The share of the cyclic vegetation of the entire vegetation year NPP is expected to decline with the increasing presence of evergreen vegetation. Shrublands and forests (with fully or partly green leaves in the dry period) thus tend to have lower values for this indicator than crops and grassland (this indicator is contained in two second order indicators, see map [P50](#) and [P51](#)).

### **Rain Use Efficiency and Soil Moisture Use Efficiency**

In addition to the NPP proxies, Rain Use Efficiency (RUE) and Soil Moisture Use Efficiency (SMUE) indicators were derived, in order to relate vegetation productivity and its spatial patterns and temporal variability to rainfall. While RUE is based on a widely applied, tested, discussed, and partly modified approach of Le Houérou (1984), SMUE is an analogue concept based on soil moisture data instead of rainfall as water availability parameter. Le Houérou defined RUE as *quotient of annual primary production by annual rainfall*. RUE thus expresses the amount of biomass growing per unit rainfall water. Theoretically, soil moisture is more directly related to plant water availability than rainfall, so SMUE is offered as a potentially useful additional indicator. RUE (and assumedly also SMUE) depends heavily on climate, soil properties, and vegetation conditions. For instance, as Le Houérou states, it decreases with increasing aridity due to the decreasing rate of useful rainwater (increasing evaporation, heavy rains, soil crusting and consequently more runoff, etc.).

It further depends on the way it is derived, especially the input parameters/data sources used for vegetation and rainfall. Since RUE is known to not necessarily normalize vegetation productivity based on rainfall variability, as RUE can be found to be correlated with rainfall over the years at a given place, its actual usefulness as an indicator for vegetation degradation (where RUE is supposed to decrease) is therefore limited and widely disputed. Nevertheless, we have included RUE and SMUE status and trend products in our products and the users may decide about its usefulness. Respective RUE and SMUE trend products are shown in the maps [P37](#) and [P40](#).

The function of RUE (or SMUE) as status indicator of ecosystem productivity and its usefulness for the comparison of the productivity of different ecosystems as proposed by Le Houérou (1984) is obvious and demonstrated in the maps [P08](#), [P17](#).

## **4 Generated Indicators**

### **4.1 From NPP Proxies to First Order Indicators**

By analyzing the annual NPP proxies and RUE/SMUE indicators and rainfall and soil moisture through time, a set of indicators for vegetation/ecosystem condition and change was derived. These can be divided into status and trend type indicators. Given the MERIS data period from June 2002 to April 2012 and the globally varying vegetation cycles, NPP proxy and RUE/SMUE indicators for a total of eight vegetation years could be extracted, starting in 2003/(2002) and ending in 2011/(2012).

Hence, MERIS based status and trend indicators cover worldwide eight vegetation years. Status indicators for this period include 8-year averages (maps [P02](#), [P03](#)) and the coefficients of variation (maps [P04](#), [P26](#), [P30](#)). In addition, the 8-year period was subdivided into two epochs covering four vegetation years each. Epochal status maps and difference maps were generated for rainfall and soil moisture. The epochal difference map for rainfall is shown for rainfall in this booklet (map [P46](#)).

The trend slope maps were derived with the non parametric Theil Sen trend slope estimator (Theil 1950, Sen 1968) and constrained with the Mann Kendall significance test (Kendall 1962) to trends with a probability greater than 0.9 (maps P37 [P40](#) [P40](#) ).

All indicator maps have been classified into distinct ranges of the original continuous values, using the same class intervals and colour scheme worldwide. For this reason the maps are globally comparable, though in rare cases not locally optimized. However, users can apply their own colour schemes to their individual downloaded maps, and in addition to the classified maps, also **the underlying continuous data sets are provided for further analyses on request.**

## **4.2 From First Order to Second Order Indicators**

The first order status and trend indicators have been combined to derive more abstract and synoptic, second order indicators showing status, changes and trends of the most essential first order indicators in various relations to each other. Basically three types of such combinations were generated:

### ***1. Relation between NPP proxies (vegetation year average greenness) and the percent of cyclic vegetation of vegetation year greenness***

This indicator group highlights status, changes and trends of the relation between the two first order indicators. The status indicator (map [P50](#)) can be regarded as a functional classification of vegetation productivity and basic type: perennial versus annual/seasonal/ephemeral vegetation. The respective map is closely related to land use/cover patterns and also to soil type and terrain structures. The change indicator (map [P51](#)) displays epochal (2003-2006 versus 2007-2010) changes between the aggregated classes of the two underlying first order indicators.

### ***2. Trend relation between vegetation year greenness and seasonal greenness***

This indicator combines the vegetation year greenness trends with those of the cyclic vegetation and the dry season greenness. It has commonalities with [P51](#), but the trend patterns deviate partly from the change patterns. Essentially this indicator (map [P52](#)) shows the development of the perennial and seasonal green vegetation in relation to each other during the observation period. For example, a positive vegetation year or dry season trend without a positive cyclic vegetation trend may possibly exhibit the dominant growth of bushes/trees versus cyclic vegetation. Vice versa, a prevailing positive trend of the cyclic vegetation may potentially point to a dominant increase of crop areas or grasses.

### ***3. Direct relation between Rainfall and Vegetation Productivity***

As an alternative to RUE/SMUE trends contained in the first order products, as well as to the so called “RESTREND” approach (see for instance Wessels et al. 2012), which assume linearity or even proportionality (RUE) between rainfall and NPP, assumption-free relation indicators between rainfall and NPP trends were generated. Separate indicators were prepared for the relation between rainfall and vegetation year greenness, cyclic vegetation, and dry season greenness, respectively (see maps [P53](#), [P54](#), and [P55](#)). In addition, the same type of indicator was derived for a time span prior to the MERIS period (1981-2002), using GPCP rainfall data and NOAA GIMMS NDVI data (see map [P56](#)).

**Table 1: Overview of the Indicator Maps shown in the booklets**

Product number	Product name	Product description
1	Vegetation year average greenness 2003-2010	Vegetation year average greenness 2003-2010 26 greenness classes Mean of 8 vegetation years average values
2	Cyclic vegetation greenness 2003-2010	Cyclic vegetation greenness 2003-2010 26 greenness classes Mean of 8 cyclic fraction sum values
3	Dry season greenness 2003-2010	Dry season greenness 2003-2010 26 greenness classes Mean of 8 dry season average values
4	Variability of vegetation year greenness 2003-2010	Vegetation year greenness variability 2003-2010 26 greenness variability classes Variation coefficient of 8 vegetation year average values
8	Rain Use Efficiency of vegetation year average 2003-2010	Vegetation year RUE mean 2003-2010 26 RUE classes Mean of 8 vegetation year RUE values
17	Soil Moisture Use Efficiency of vegetation year average 2003-2010	Vegetation year SMUE 2003-2010 26 SMUE classes Mean of 8 vegetation year SMUE values
25	TRMM precipitation average of vegetation years 2003-2010	Vegetation year trmm rainfall mean 2003-2010 26 trmm rainfall classes Mean of 8 vegetation year rainfall sum values
26	TRMM precipitation variability of vegetation years 2003-2010	Vegetation year trmm rainfall variability 2003-2010 26 trmm rainfall variability classes Variation coefficient of 8 vegetation year rainfall sum values
29	Soil Moisture average of vegetation years 2003-2010	Vegetation year CCI Soil Moisture mean 2003-2010 26 SM classes Mean of 8 vegetation year SM average values
30	Soil Moisture variability of vegetation years 2003-2010	Vegetation year CCI Soil Moisture variability 2003-2010 26 SM variability classes Variation coefficient of 8 vegetation year SM average values
37	Rain Use Efficiency trend slopes of cyclic vegetation 2003-2010	Trendslope of cyclic fraction RUE 2003-2010 12 slope classes Theil-Sen median trend, masked at p 0.9
40	Soil Moisture Use Efficiency trend slopes of cyclic vegetation 2003-2010	Trendslope of cyclic fraction SMUE 2003-2010 12 slope classes Theil-Sen median trend, masked at p 0.9
46	Change in vegetation year precipitation between the epochs 2003-2006 and 2007-2010	Epochal difference of vegetation year TRMM rainfall 2003-2006 and 2007-2010 12 difference classes
50	Functional Classes	Relation between vegetation year greenness classes and the classified percentage of the cyclic vegetation of the yearly vegetation 2003-2010

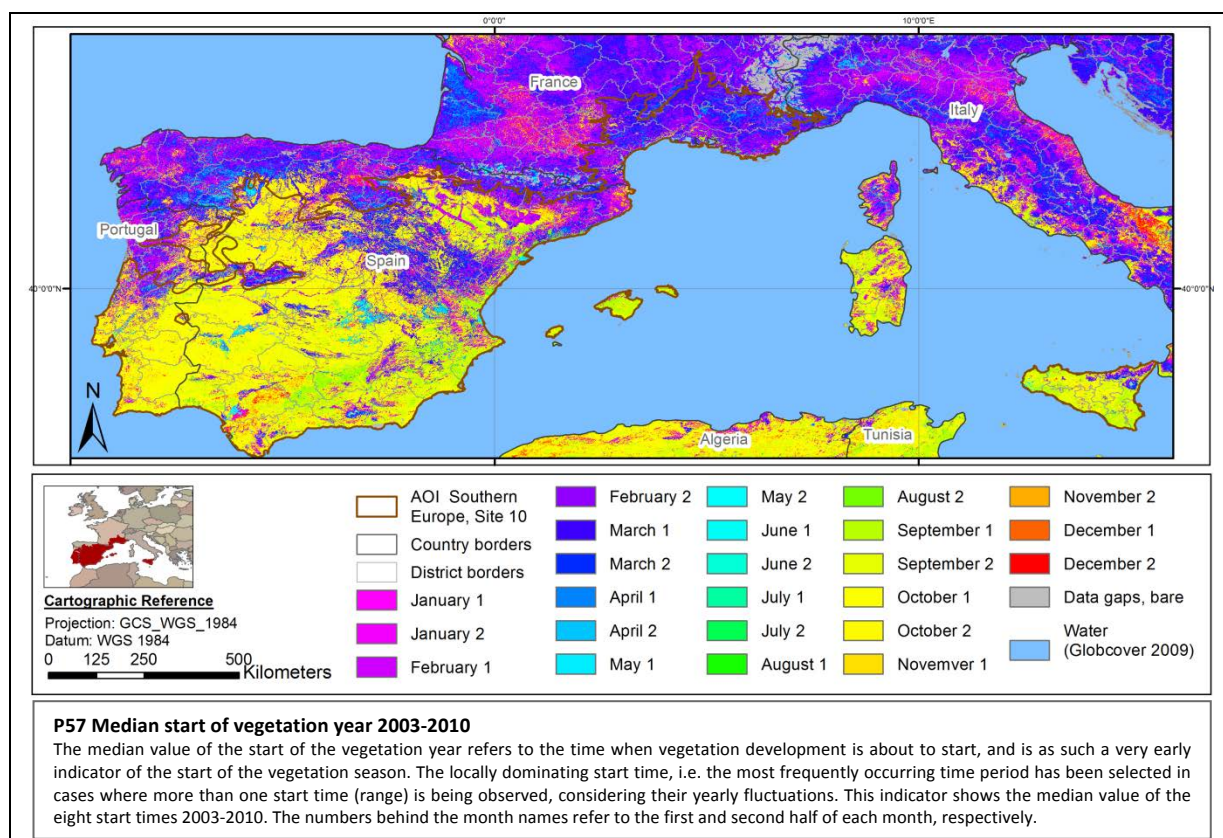
51	Functional Differences	Epochal (2003-2006/2007-2010) difference map of the relation between vegetation year greenness classes and the classified percentage of the cyclic vegetation of the yearly vegetation
52	Seasonal Trend Relations	Relation between vegetation year greenness trends and seasonal greenness trends 2003-2010
53	TRMM Rainfall versus MERIS fAPAR vegetation year greenness trend	Relation between vegetation year rainfall trends and vegetation year greenness trends 2003-2010
54	TRMM Rainfall versus MERIS fAPAR cyclic fraction greenness trend	Relation between cyclic fraction rainfall trends and cyclic fraction greenness trends 2003-2010
55	TRMM Rainfall versus MERIS fAPAR dry season greenness trend	Relation between vegetation year rainfall trends and dry season greenness trends 2003-2010
56	GPCP Rainfall versus GIMMS NDVI vegetation year greenness trend	Relation between vegetation year GPCP rainfall trends and vegetation year greenness (GIMMS NDVI) trends 1981-2002
57	Median start of vegetation year 2003-2010	Median of the start times (half month number in the calendar year) of the vegetation year 2003-2010
58	Mean length of vegetation season 2003-2010	Mean of the lengths of the vegetation seasons 2003-2010
59	Mean start time of vegetation season 2003-2010	Average start time (half month number in the calendar year) of the vegetation seasons 2003-2010

All map products shown in the booklet, and all other map products (which are of similar kind but with different seasonal and water parameter combinations) along with meta data, product lists and short descriptions can be downloaded <http://www.diversity2.info/products/> .

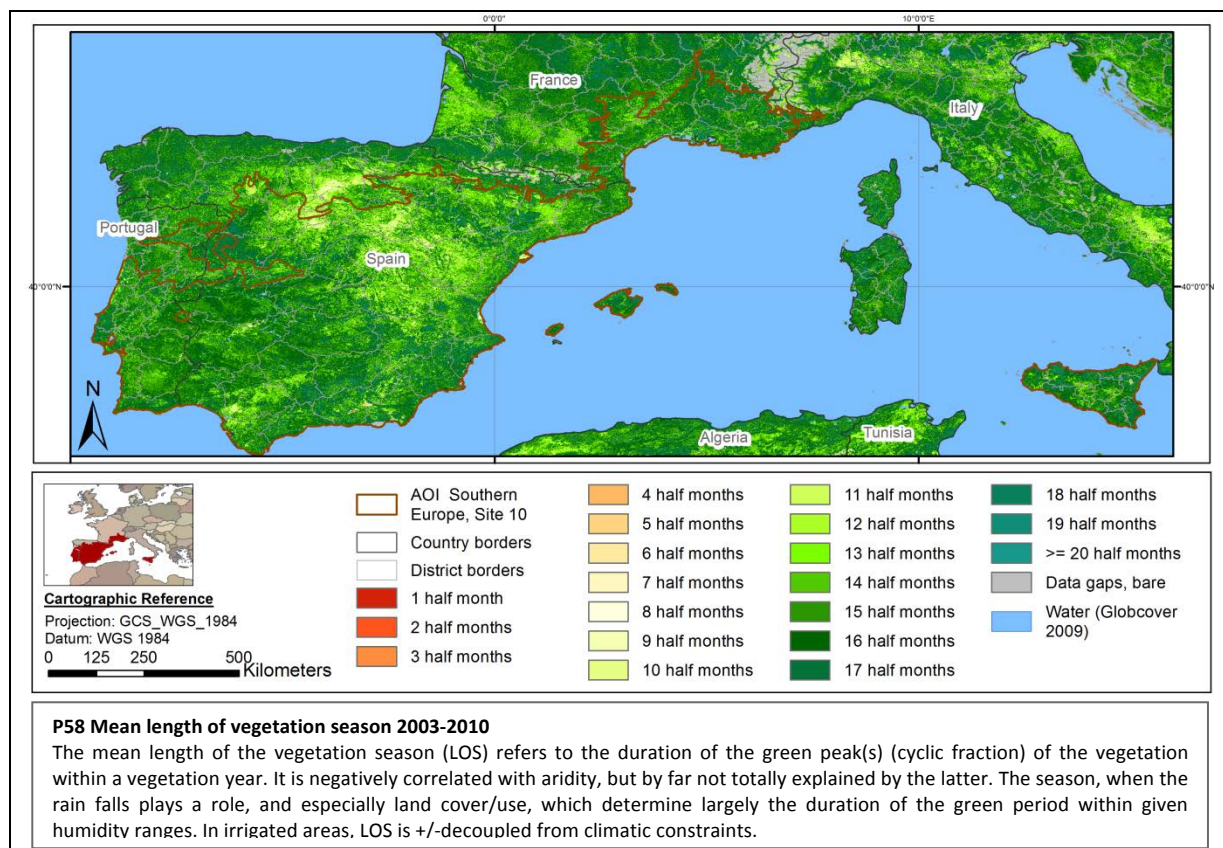
### 4.3 Selected Indicator Maps

In the next section, the listed indicator maps are shown with descriptions. First, the three phenological maps ([P57](#) – [P59](#)) are displayed, followed by the second order indicator maps ([P50](#) – [P56](#), with [P46](#) included). The last three pages contain representative first order indicator status and trend maps ([P1](#) – [P40](#)).

## P57 Median start of vegetation year 2003-2010

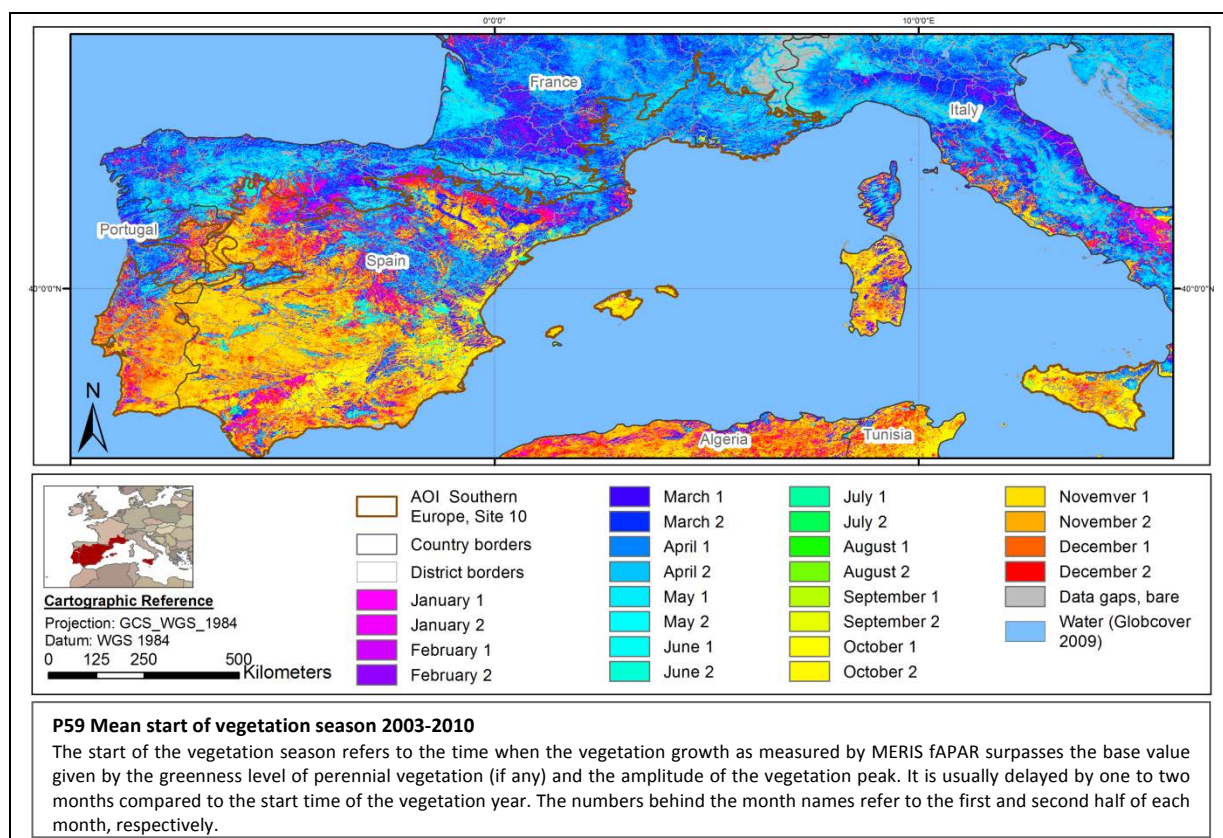


## P58 Mean length of vegetation season 2003-2010

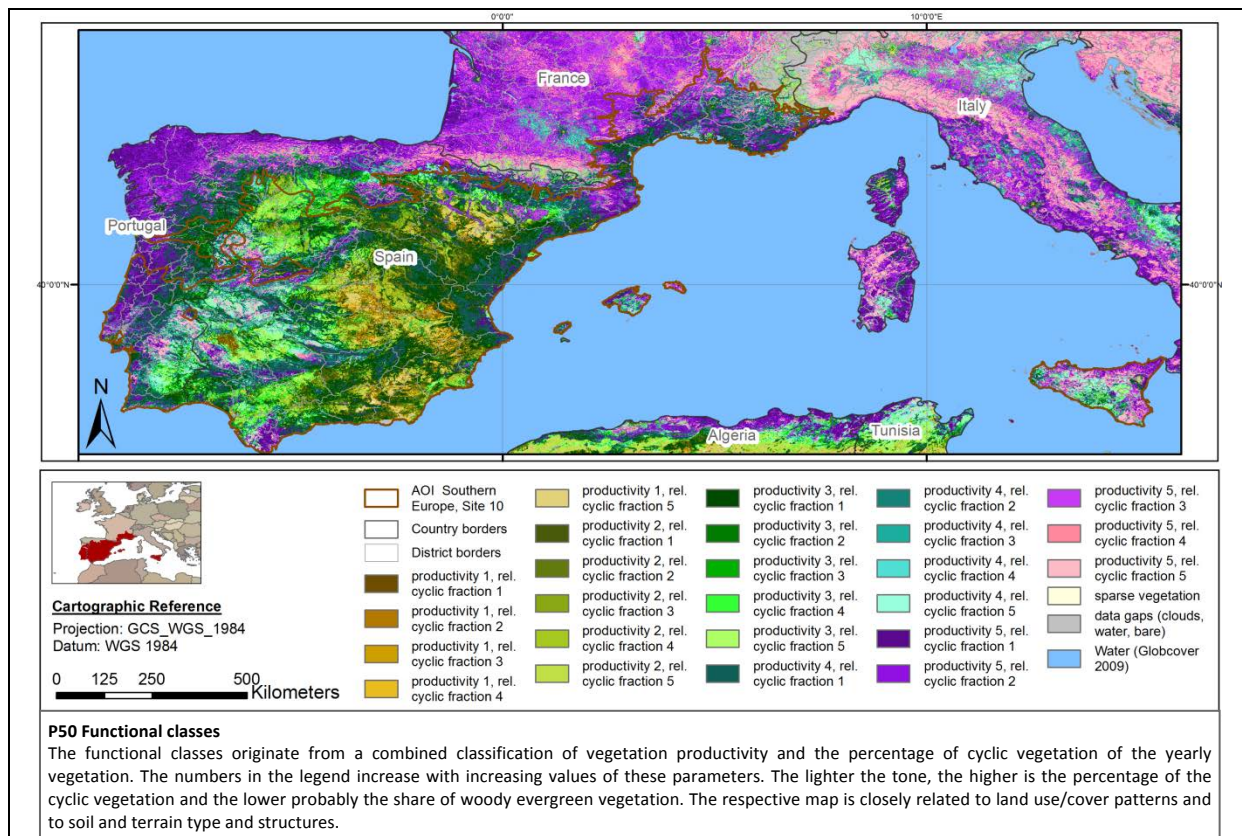




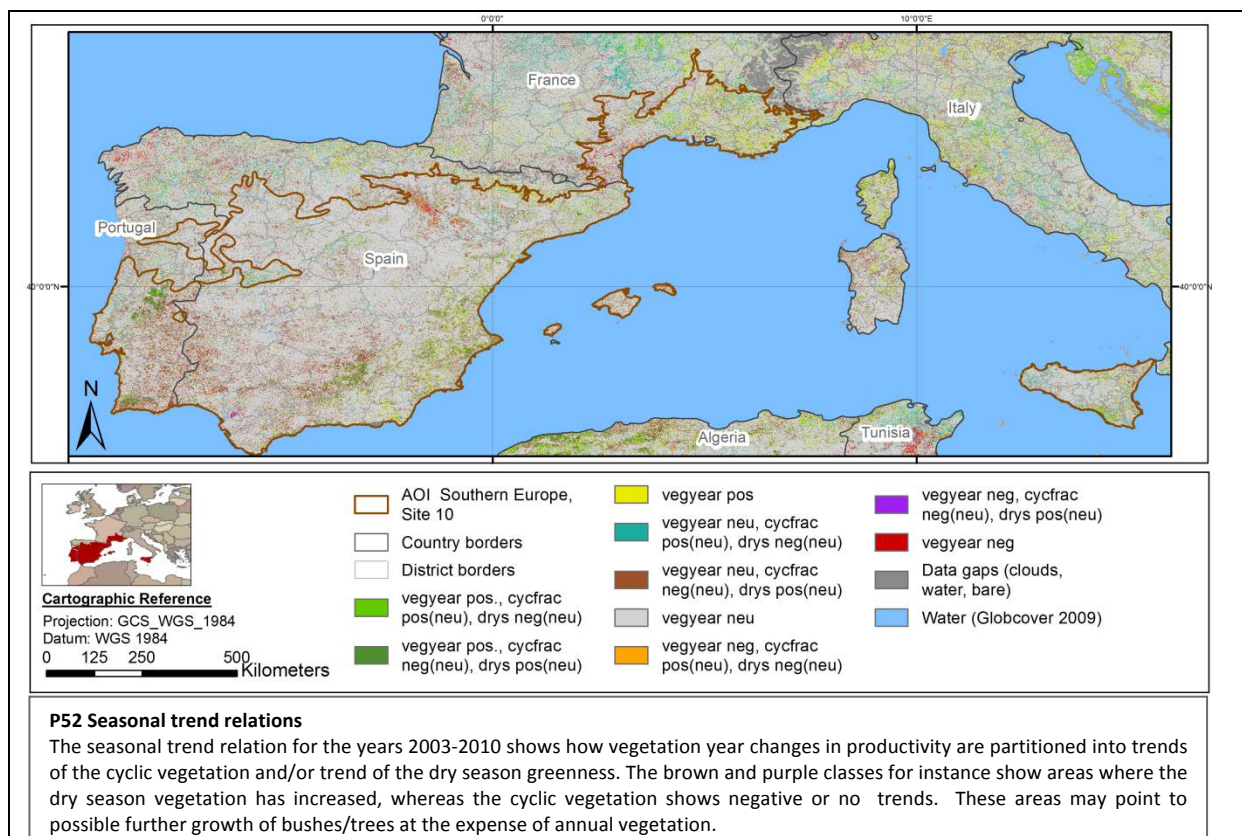
## P59 Mean start of vegetation season 2003-2010



## P50 Functional classes

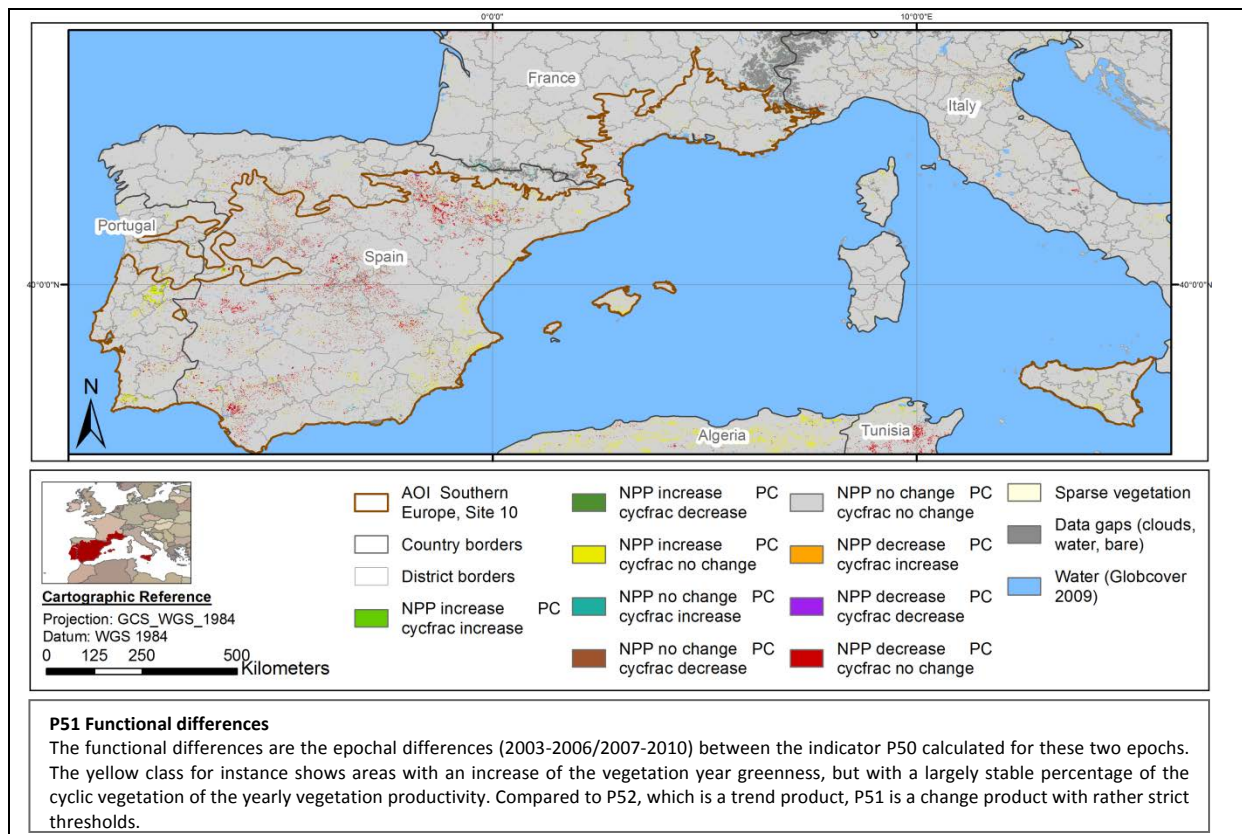


## P52 Seasonal trend relations

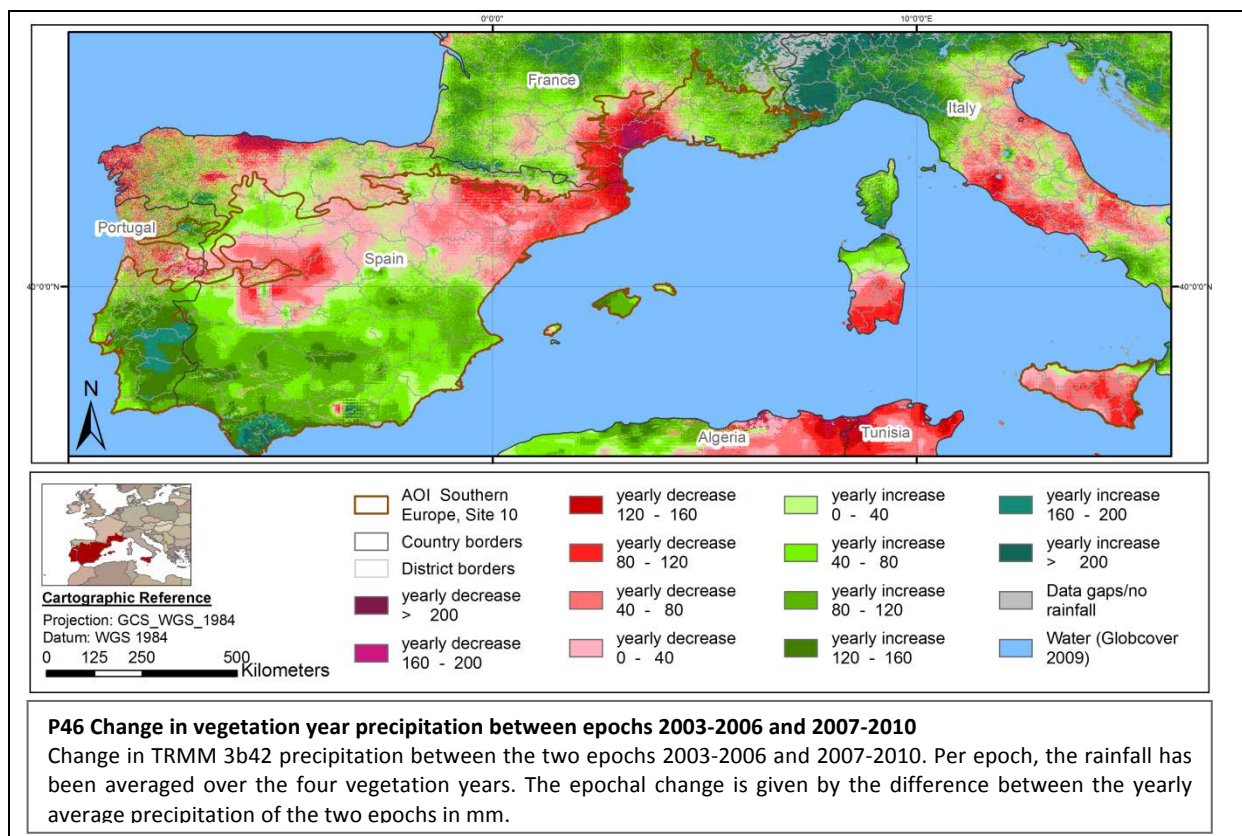




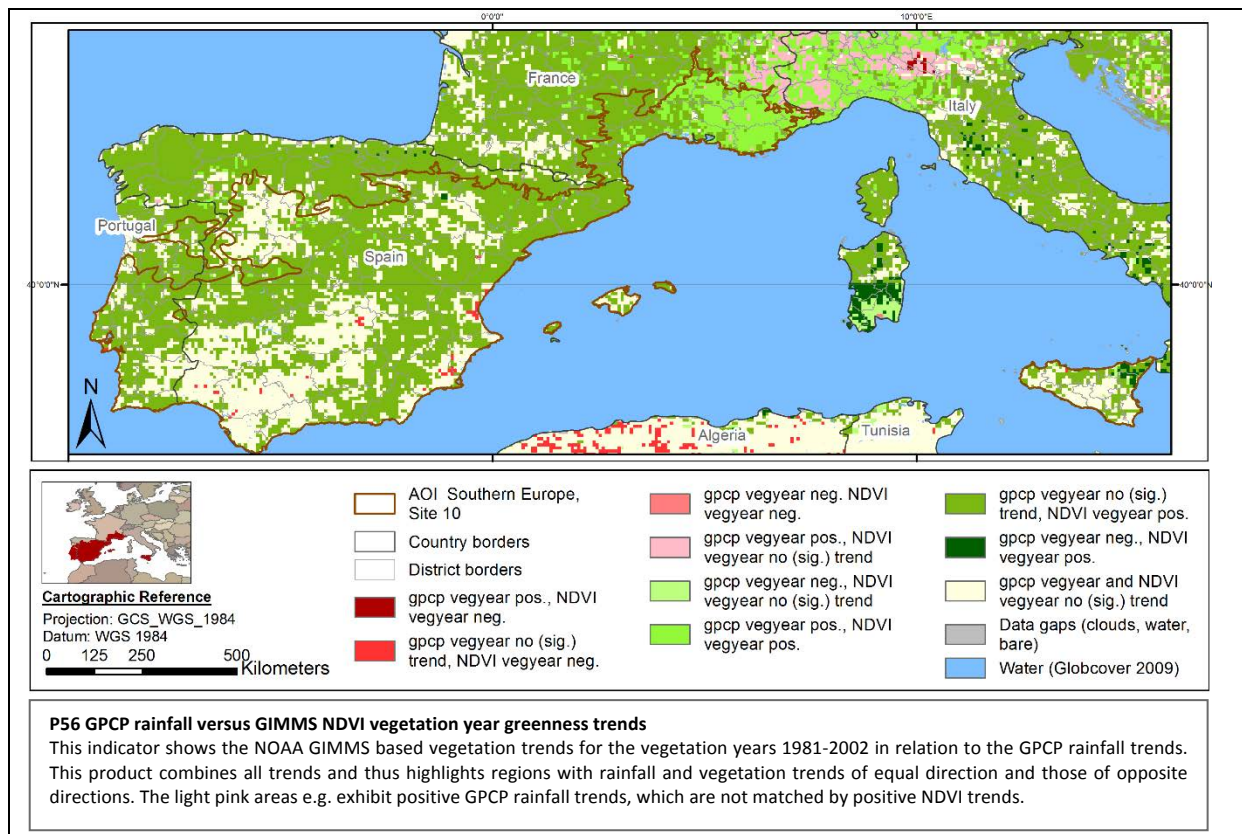
## P51 Functional differences



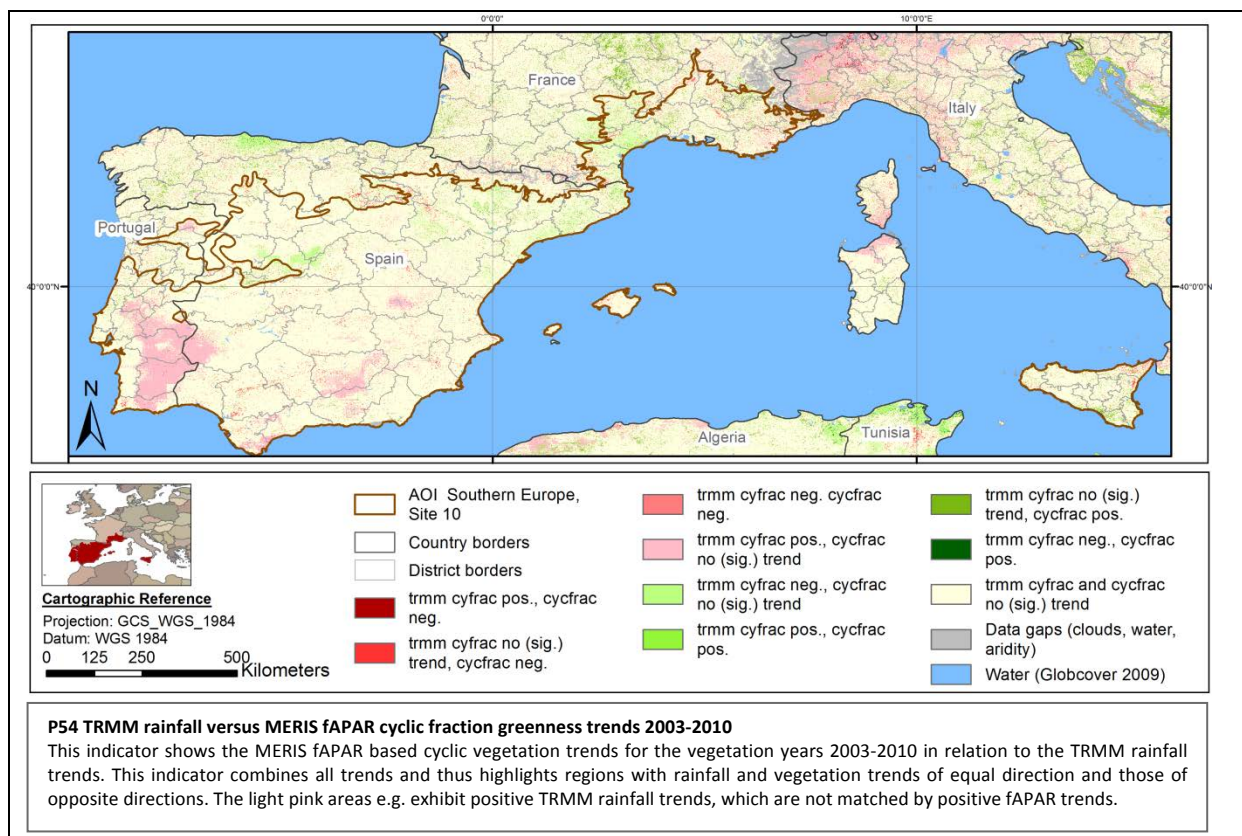
## P46 Change in vegetation year precipitation between epochs 2003-2006 and 2007-2010



## P56 GPCP rainfall versus GIMMS NDVI vegetation year greenness trends 1981-2002

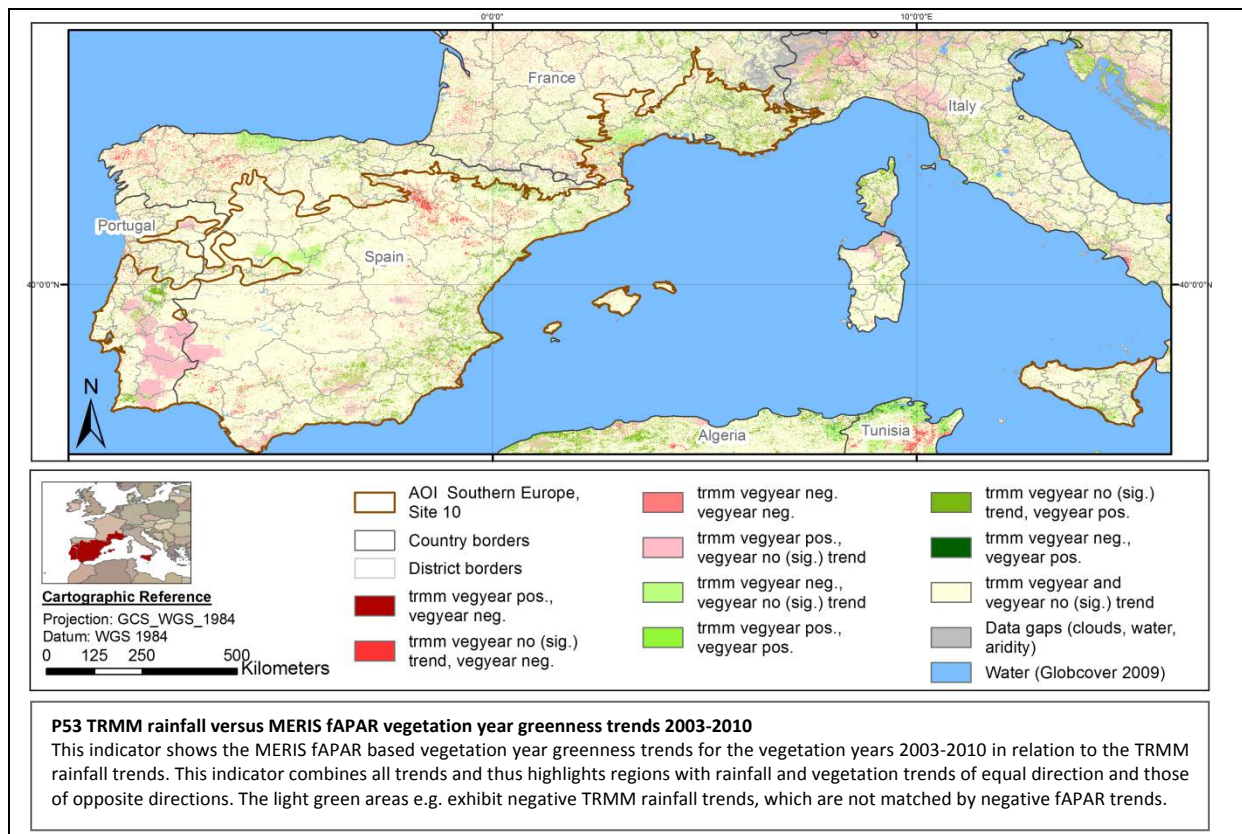


## P54 TRMM rainfall versus MERIS fAPAR cyclic fraction greenness trends 2003-2010

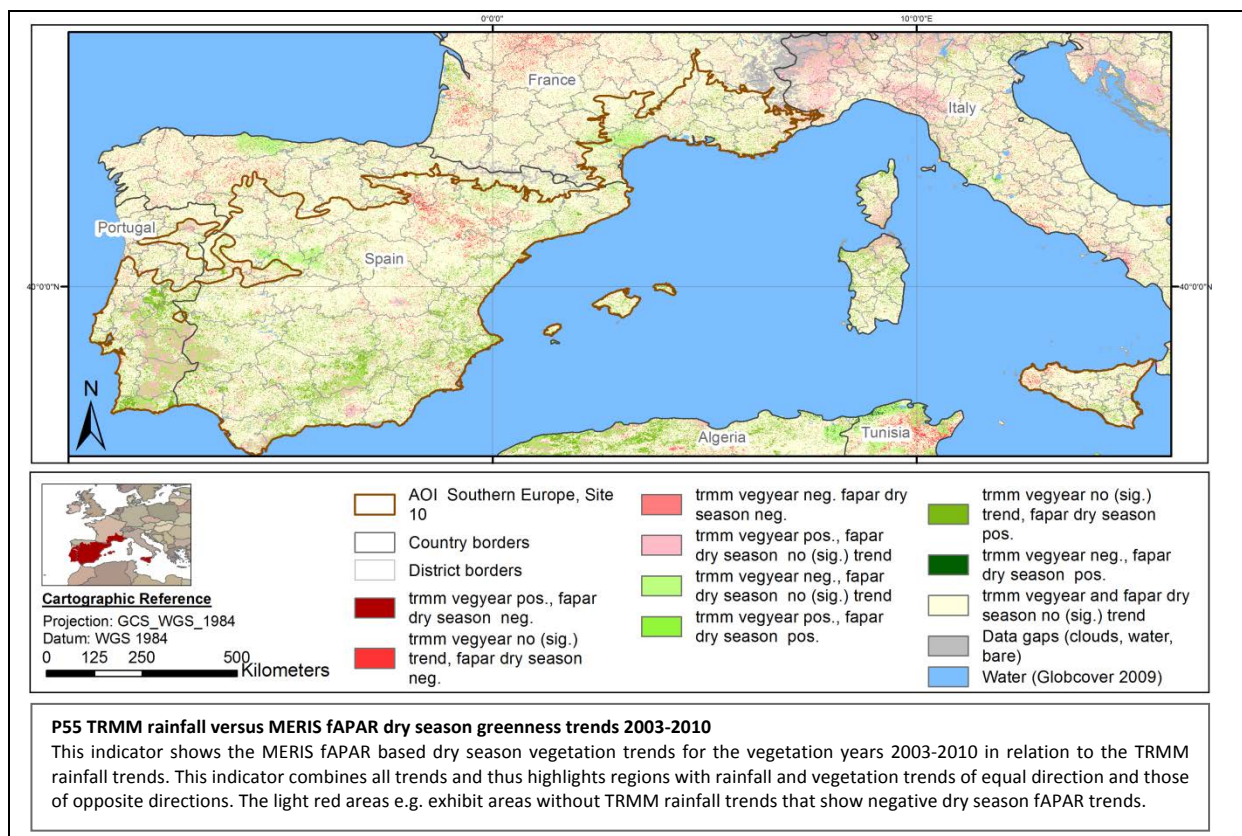




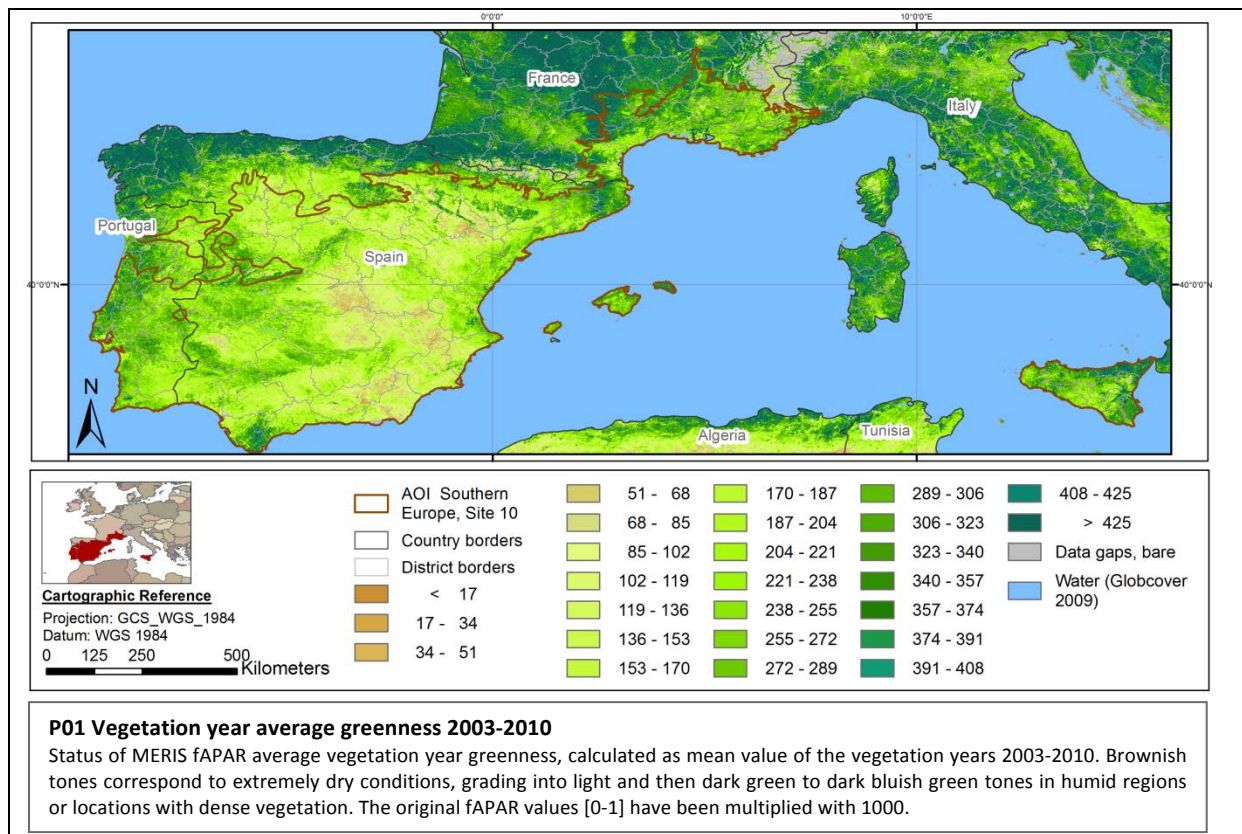
## P53 TRMM rainfall versus MERIS fAPAR vegetation year greenness trends 2003-2010



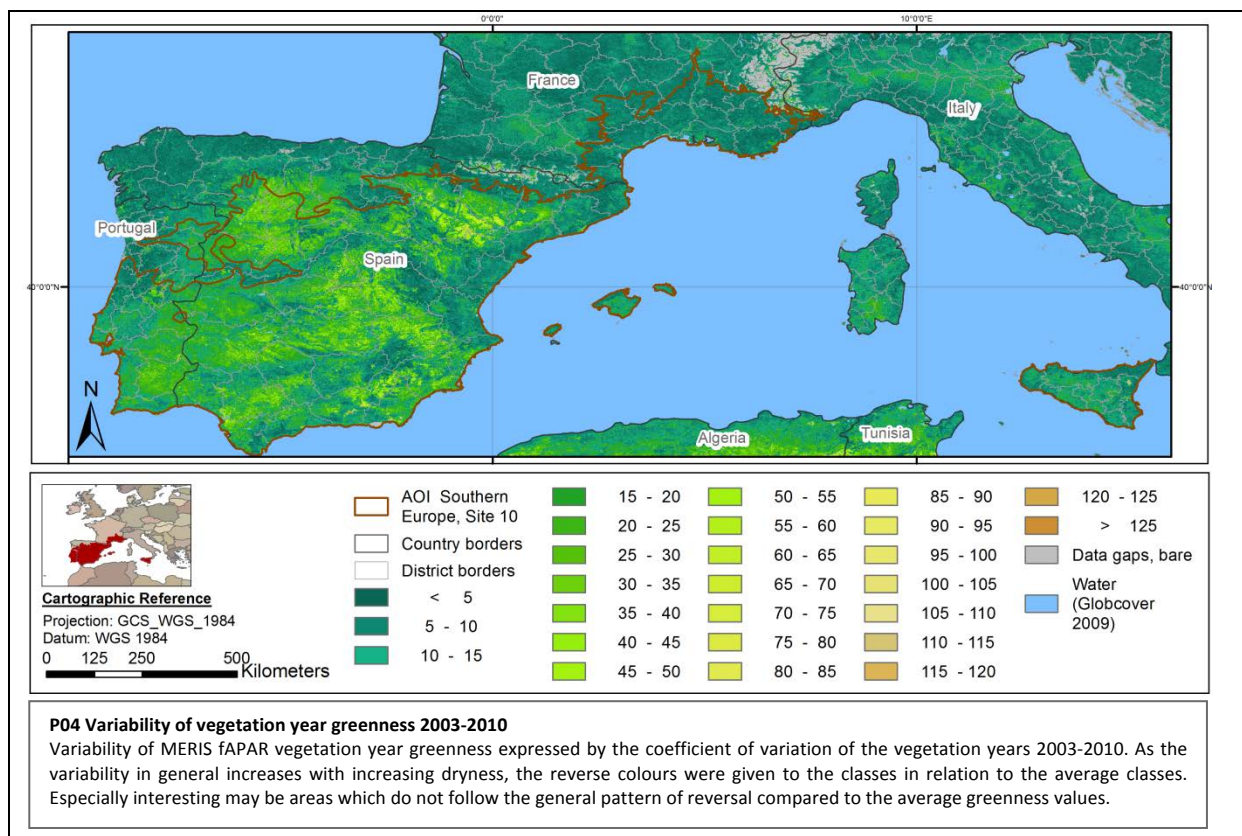
## P55 TRMM rainfall versus MERIS fAPAR dry season greenness trends 2003-2010



## P01 Vegetation year average greenness 2003-2010

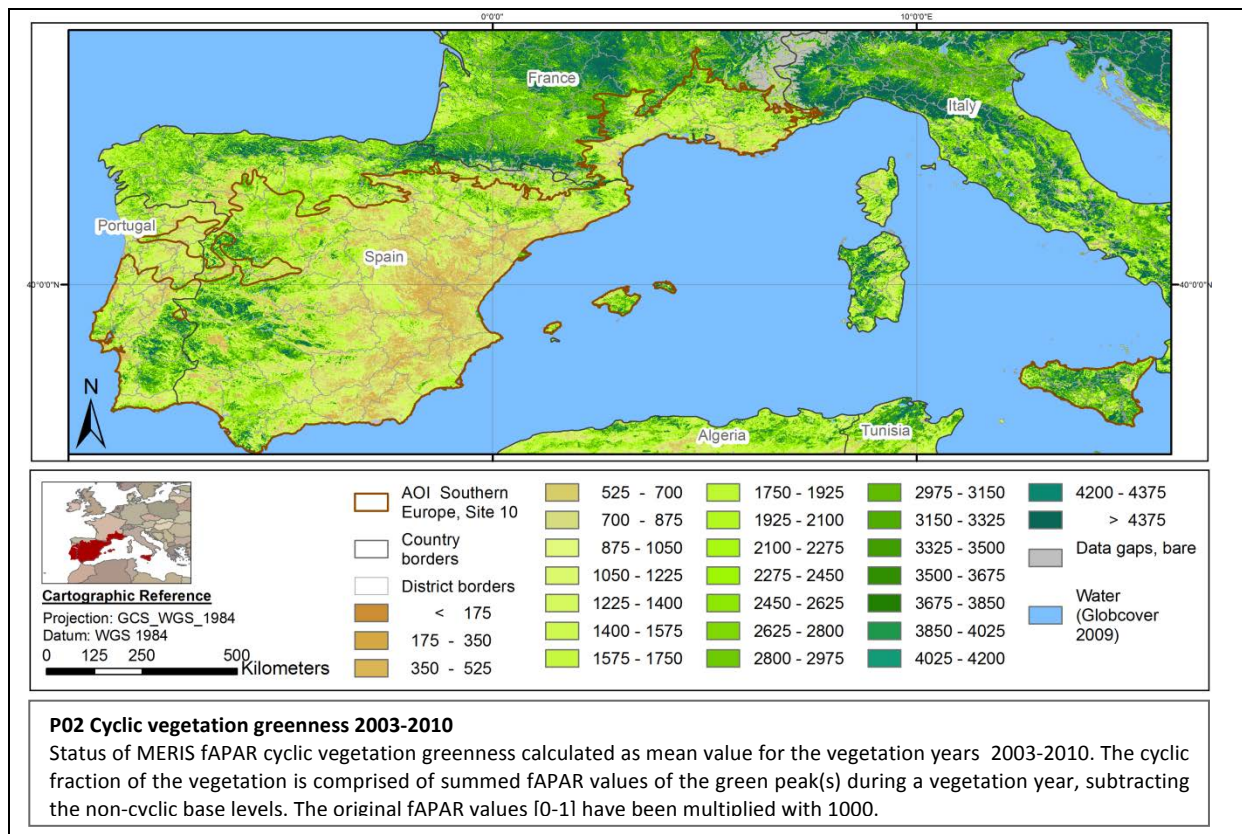


## P04 Variability of vegetation year greenness 2003-2010

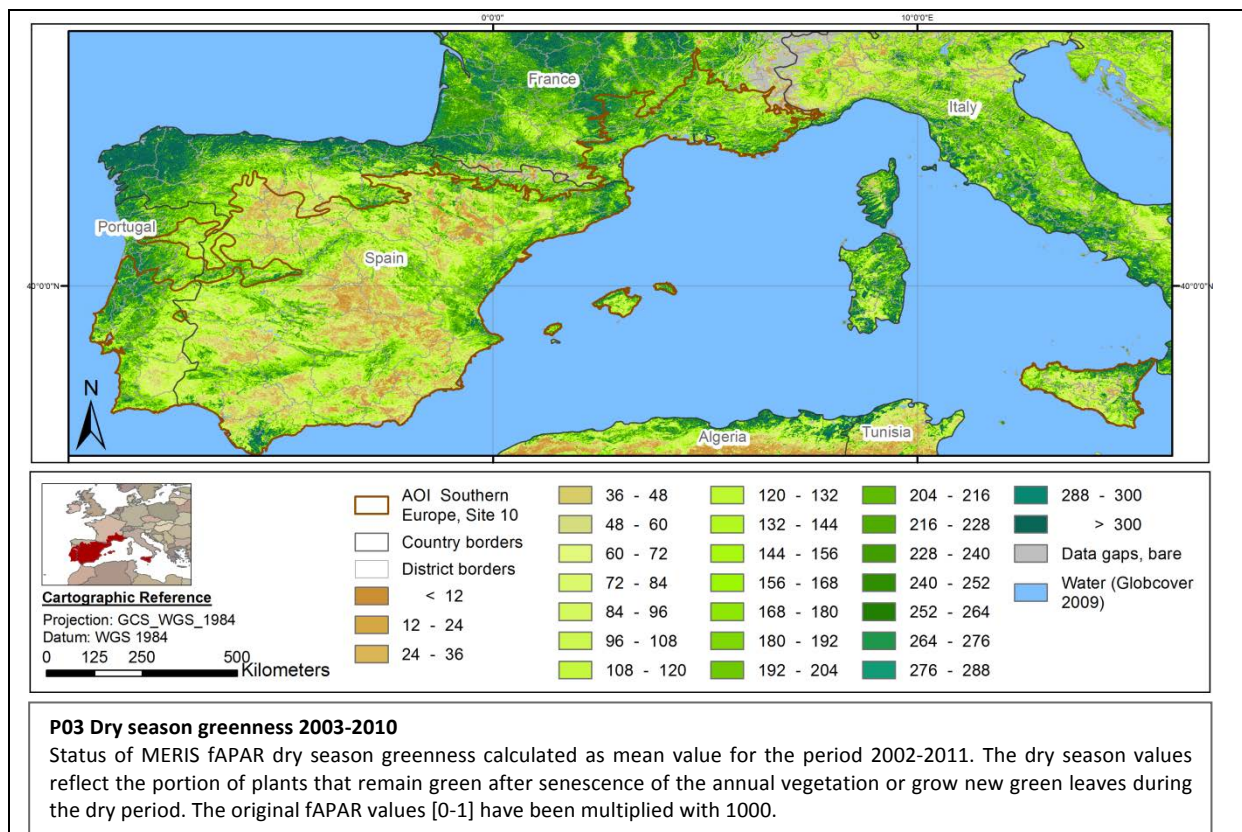




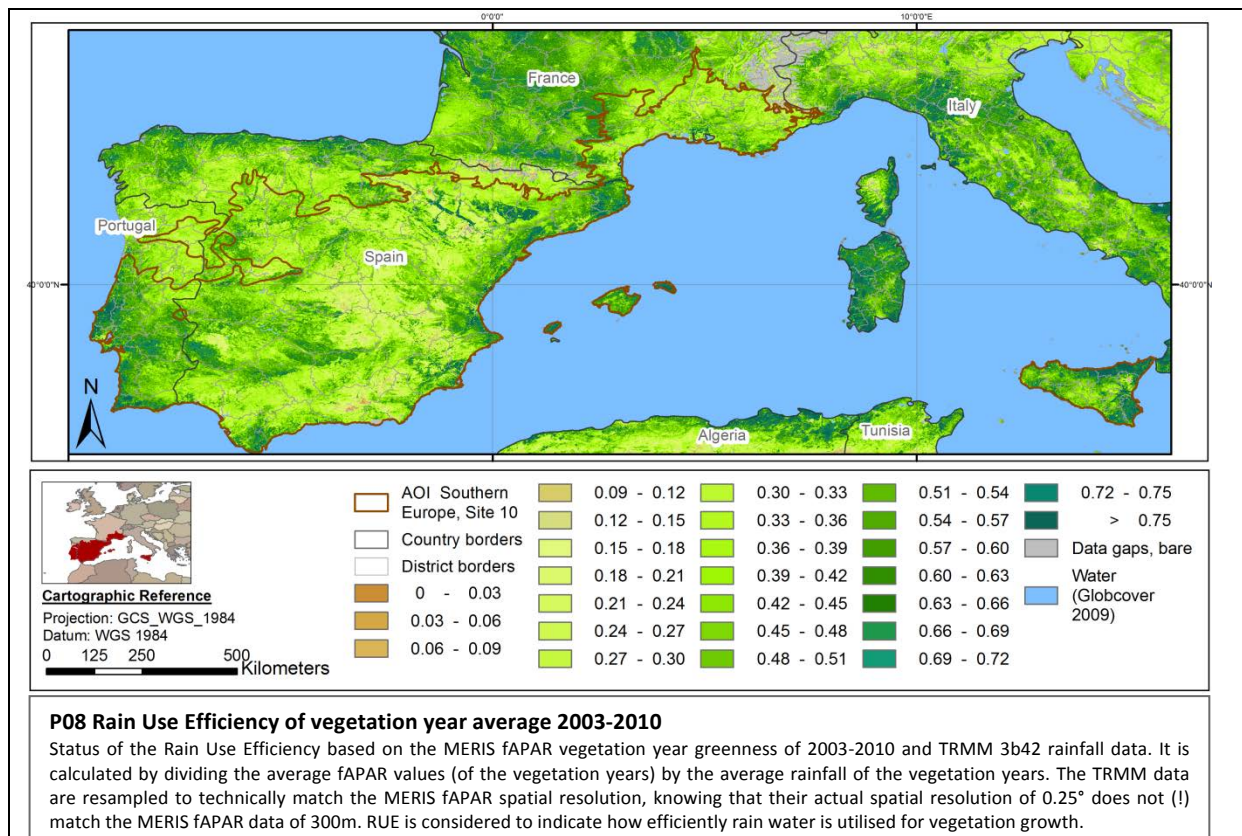
## P02 Cyclic vegetation greenness 2003-2010



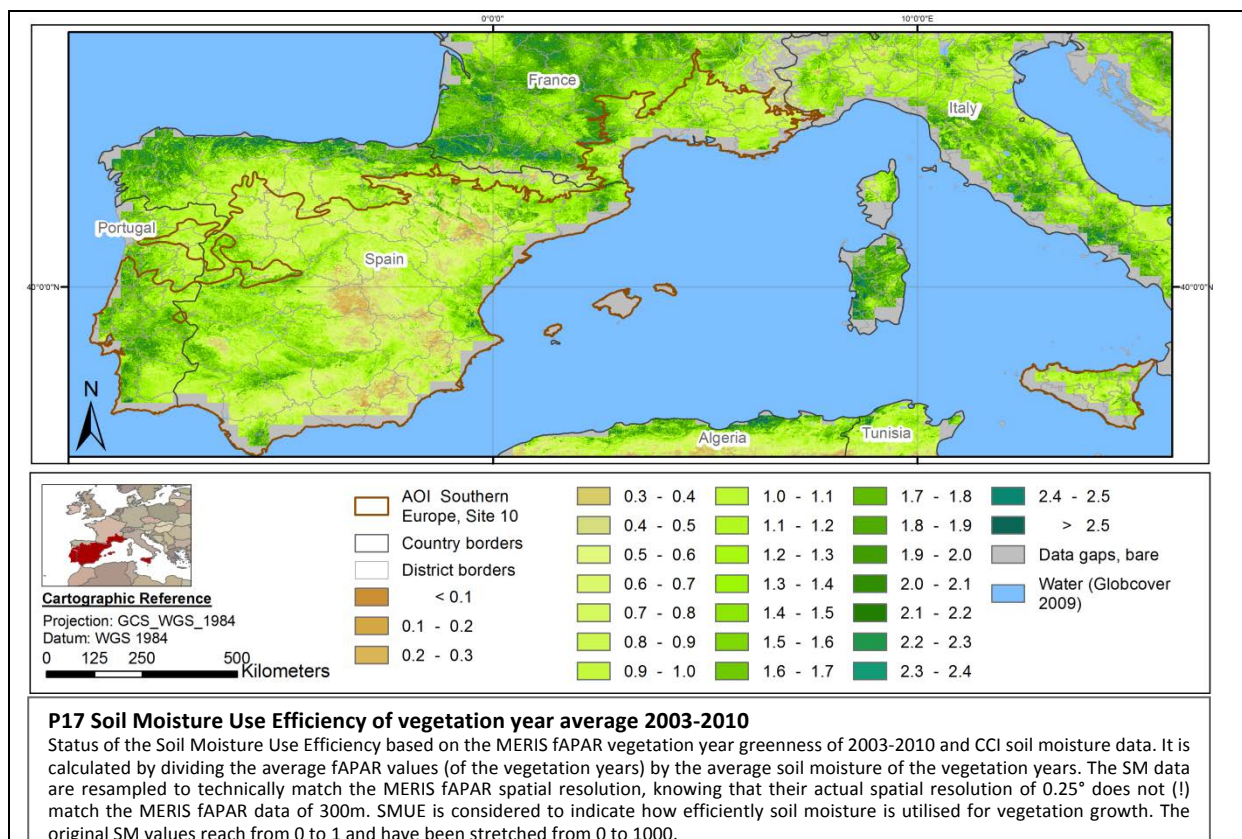
## P03 Dry season greenness 2003-2010



## P08 Rain Use Efficiency of vegetation year average 2003-2010

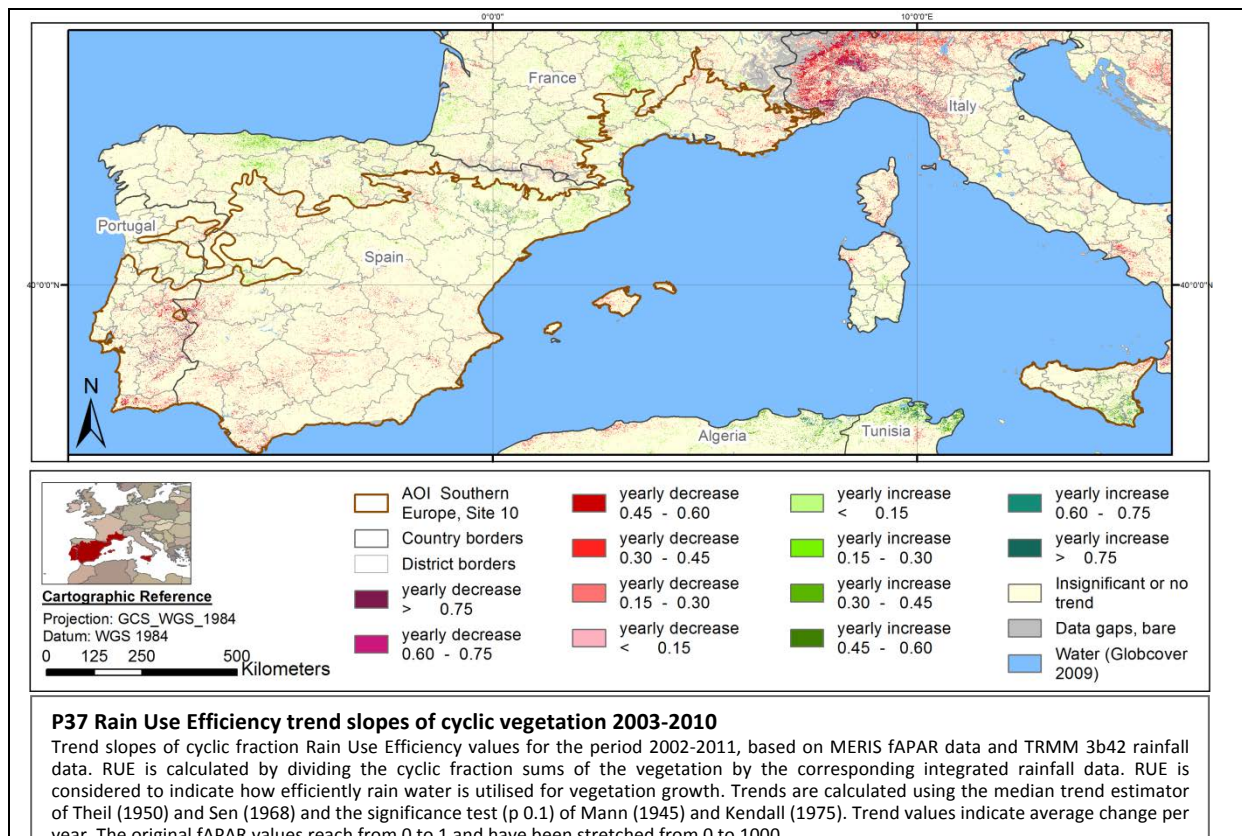


## P17 Soil Moisture Use Efficiency of vegetation year average 2003-2010

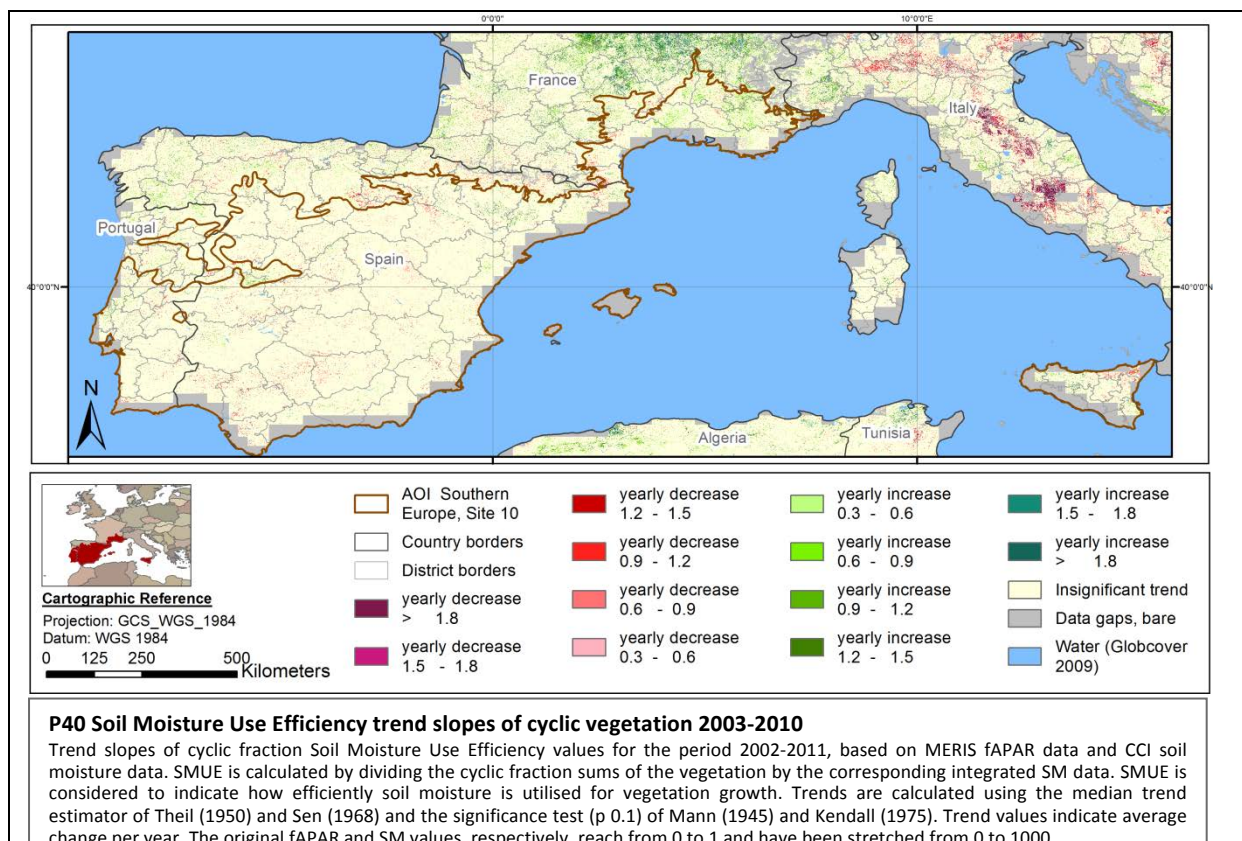




## P37 Rain Use Efficiency trend slopes of cyclic vegetation 2003-2010

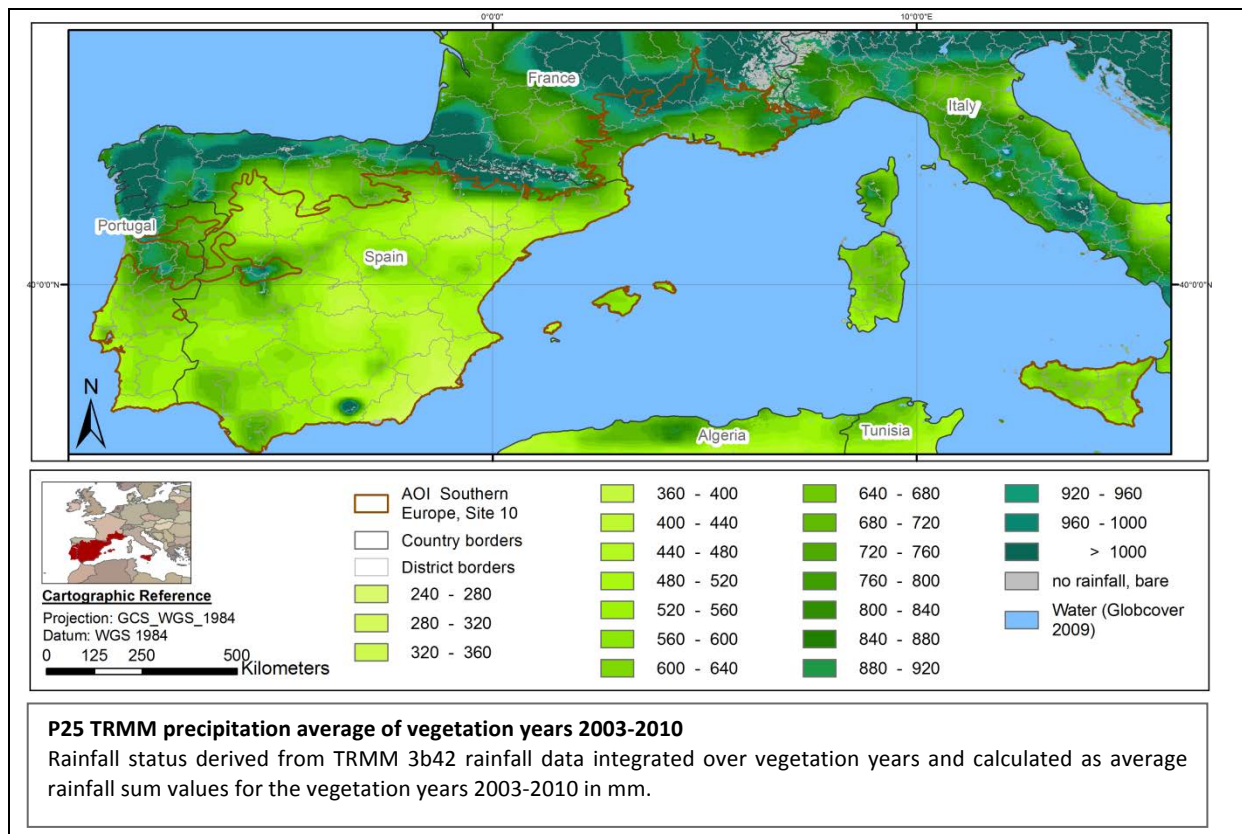


## P40 Soil Moisture Use Efficiency trend slopes of cyclic vegetation 2003-2010

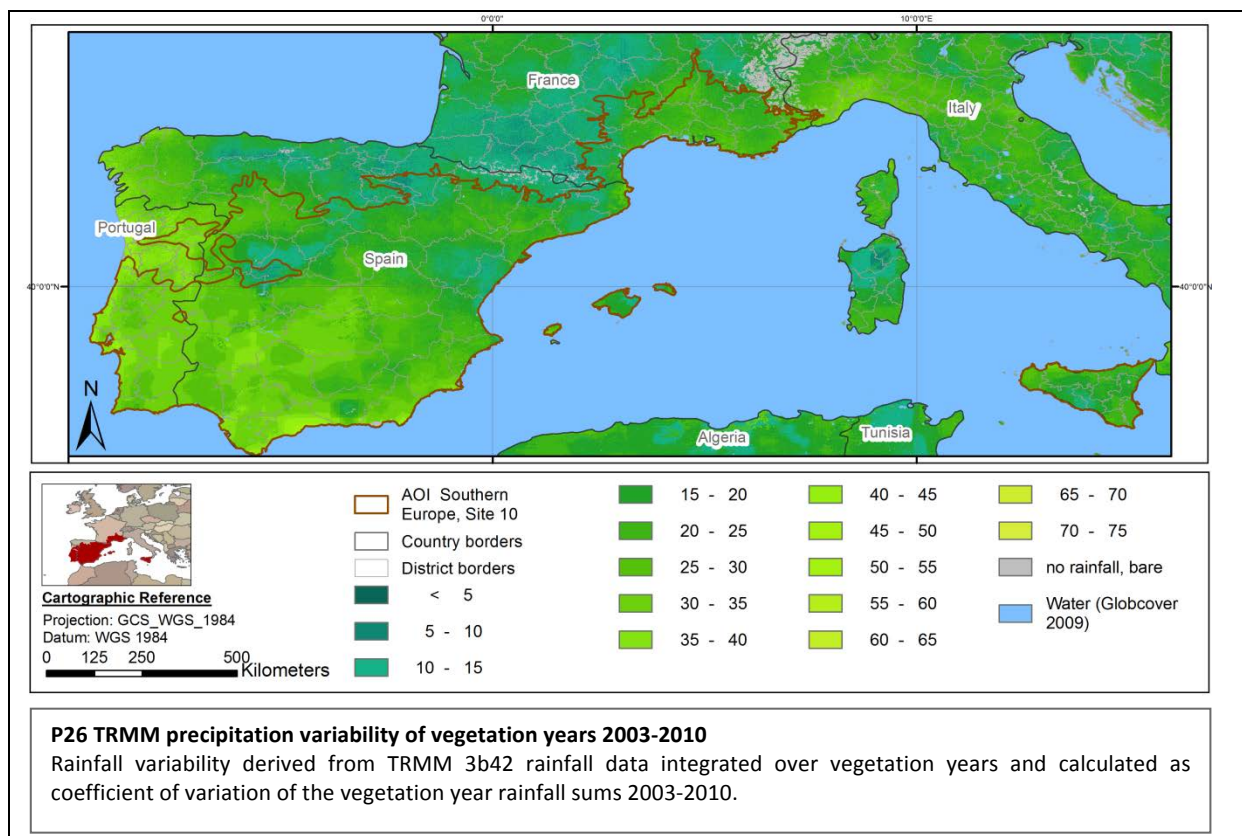




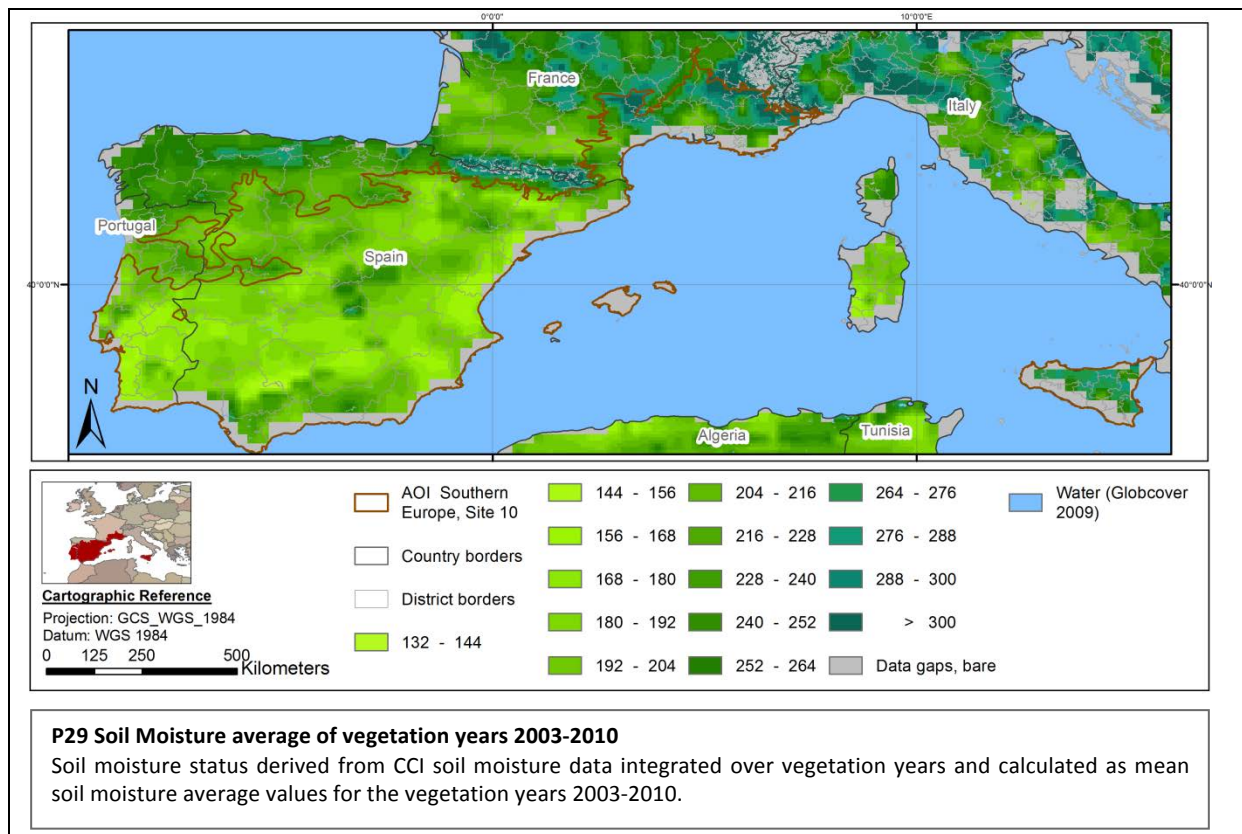
## P25 TRMM precipitation average of vegetation years 2003-2010



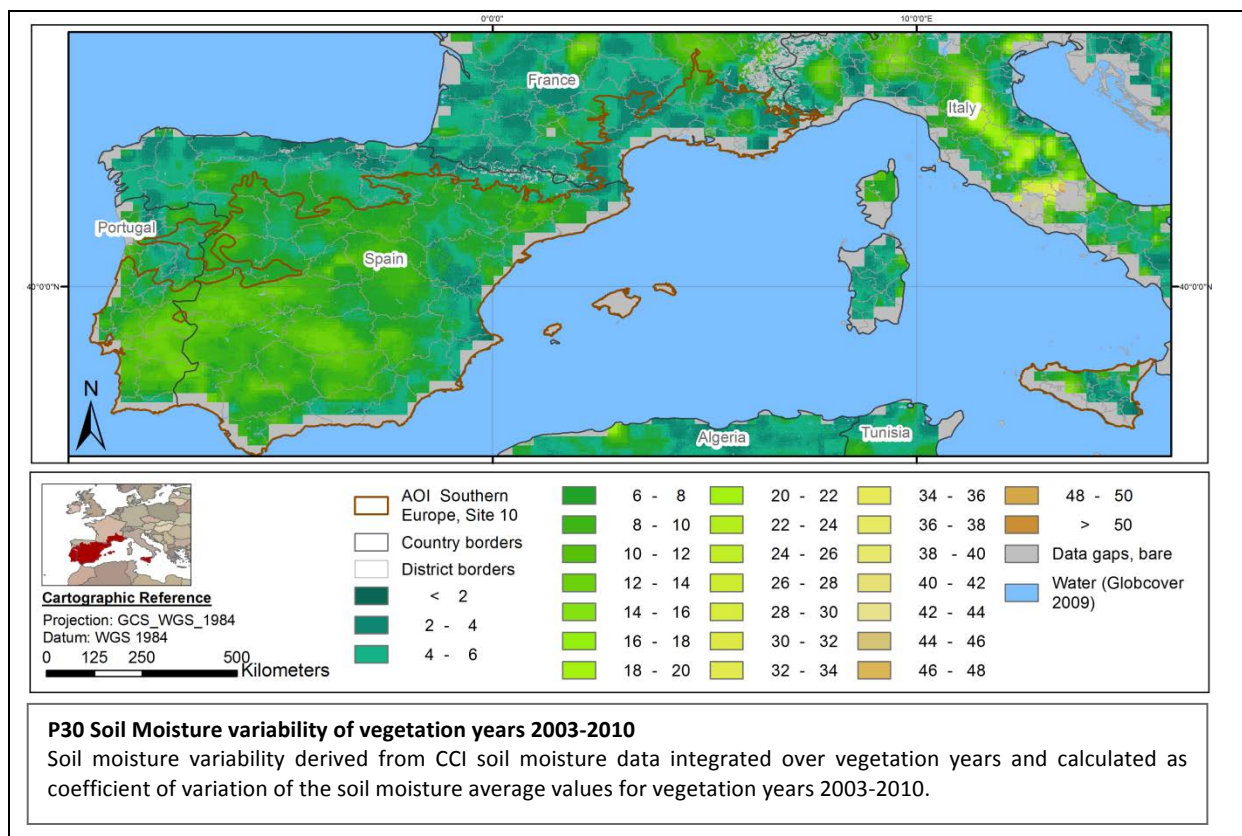
## P26 TRMM precipitation variability of vegetation years 2003-2010



## P29 Soil Moisture average of vegetation years 2003-2010



## P30 Soil Moisture variability of vegetation years 2003-2010



## 5 Generic Interpretation of the Maps

While vegetation productivity obviously 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, topography, and hydrology 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).

Biomes with rich floristic biodiversity may 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. 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](http://en.wikipedia.org/wiki/Succulent_Karoo) ). The same area is also characterised by an extended length of the green season (compared to areas with similar yearly rainfall), and a winter rain regime. Thus, phenological maps reveal important ecosystem conditions and gradients.

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, most 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 range lands is largely 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, possibly pointing to continued bush encroachment or enhanced growth and greening of existing bushes, partly related to rainfall increases. Pronounced 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.

Several indicators for the "classical" land degradation, i.e. the decrease of vegetation productivity in relation to available water have been derived in Diversity II. They include RUE and SMUE, where the latter is based on soil moisture, which is more directly reflecting available water in the root zone than rainfall. Often, RUE and SMUE exhibit different results, which is the logical consequence of the differences between the rainfall and the soil moisture data used. However, negative RUE trends are widely disputed as indicator for land degradation, mainly because RUE has been found to not consistently normalise for rainfall variability. Also the alternative RESTREND method has been challenged for this purpose (e.g. Wessels et al. 2012, Ratzmann 2014). In addition to their weaknesses related to invalid assumptions, they are lumped indicators, which do not detangle the individual developments of water availability and vegetation production. The proposed second order indicators, on the other hand (see maps P53 to [P56](#)), show both rainfall (or alternatively soil moisture) trends and NPP trends separately and synoptically.

RUE or SMUE changes and trends may be as well related to land cover/use/management changes, such as the conversion of rangeland into cropland, deforestation, etc. Especially processes such as

urbanisation or mining will lead to extreme NPP proxy and RUE decreases. Phenology helps to detangle some of the trends: for instance the clearing of shrubs, bushes and trees (e.g. for the conversion of rangeland into crop land) can be expected to lead especially to dry season NPP and RUE decreases. On the other hand, 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 also range land improvement and tree planting activities may lead to positive NPP and RUE or SMUE trends.

The derived indicators should not be directly interpreted in terms of land condition, degradation or respectively land improvement. They provide useful base information, especially when combined, but there is no single “all in one” indicator about land condition and trends. In situ knowledge about biophysical and socio-economic factors and systems (including past and present land tenure and land use practices, history of land degradation, population pressure, current policies and economic developments, etc.) is indispensable for an appropriate assessment of status, trends, and possible future developments.

Finally, the observation period is rather short, which basically hampers conclusions from derived trends. 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 certain statistical significance threshold (which has been set to 0.9 and thus relatively low in this project) to be recognised as significant trends. There may be more relevant and persistent changes going on than the trend maps for such a short period can show, and abrupt change events cannot be expected to exhibit gradual indicator developments and measurable trends. The rainfall trend maps for instance 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. Vice versa, due to the short observation period, measured significant trends may not really be part of persistent, longer term development but may already be reversed in the next epoch.

The meteorological and other environmental data used play also a significant role especially for the generation of the RUE and SMUE indicators. Compared to the MERIS data with 300m ground resolution, these datasets are extremely coarse and especially with regard to the soil moisture data by far not representative for the scale of local variability at the MERIS resolution.

For these reasons the eight vegetation years covered worldwide by MERIS are perhaps better suited for an overall assessment of the ecosystem structures and conditions, where the phenological characterisation of vegetation trends may provide hints about ecosystem functions and biodiversity. While many of the variations in vegetation production and productivity in drylands are short and medium term responses to varying water availability, the seasonal type of these responses may be taken as valuable information towards this aim.

## **6 Outlook**

The provided indicators and – if requested – the underlying continuous data can be utilised to many more analyses than those performed in the Diversity II project. Interested users may contact us for further information what else besides the project downloads has been produced in the project, or which further possibilities may exist to deepen or extend the studies.

The applied methods for the extraction of phenological and vegetation productivity parameters can be used for other sensors, such as the upcoming Sentinel 2 and especially Sentinel 3 of the ESA Copernicus program, which will be the successor of the ENVISAT MERIS data. Also SPOT Vegetation, MODIS, or Proba-V data can serve to extend the analyses of this study by applying at least the same methodology, if the data are certainly not fully comparable. Bridging the data gap between MERIS and Sentinel 3 with its first planned launch in 2015 may be achieved this way.



## 7 Description of Biodiversity

The study area considered here covers the north-western part of the Mediterranean basin, and includes the Iberian Peninsula (except for the more Atlantic influenced northwest), the Balearic Islands, southern France and the island of Sicily. The area encompasses many types of ecoregions (WWF 2013b,c,d,e,f), but overall it is characterized by either oak tree, coniferous and deciduous forest where water availability is relatively higher, or sclerophyllus shrublands in dryer regions (Derneži 2010). Altogether the area is subjected to the typical Mediterranean type climate, with cool and wet winters followed by hot and dry summers (Blondel et al. 2010). Annual average temperatures may vary between 8-19°C, and annual precipitation from 300-900 mm (WWF 2013b,c,d,e,f), although the Mediterranean basin is known for holding very distinct local microclimates, and the climatic conditions can be very unpredictable within one year and/or during successive years (Blondel et al. 2010). During autumn/winter it is quite common for torrential rainfalls to occur that can lead to violent floods, while in the summer the availability of surface water is very low and severe droughts can last for up to two months (Blondel et al. 2010).

The topography of the region certainly contributes for the climatic variability. The region contains sand dunes, cliffs and salt lagoon systems along the coastal strip, wide plains and plateaus, deep river valleys and extensive mountain chains, not to mention the many island systems (Blondel et al. 2010; WWF 2013b,c,d,e,f). In terms of the geological background, the region is predominantly composed of Mesozoic and Quaternary sedimentary rock with some extents such as the central plateau between Portugal and Spain (the Iberian massif) and areas in the Balearic Islands constituted by older crystalline rock (WWF 2013b,c,e,f). Also important to mention is the active Etna Volcano in Sicily, and consequently the volcanic rock that characterizes that area (WWF 2013d). The Mediterranean basin has a complex geological history, and the region has gone through many great scale tectonic and orogenic events, one of the most recent being the Messinian Salinity Crisis around 5.5 million years ago (Govers 2009; Blondel et al. 2010).

With such a complex geographic setting, the Mediterranean basin harbours an astonishing biodiversity. It was one of the first regions to be recognized into the 25 Global Biodiversity Hotspots (Myers et al. 2000), of which it is the third richest in terms of plant diversity (Mittermeier et al. 2004). The north-western Mediterranean vegetation is composed of a mix of evergreen, deciduous and conifer tree species, like wild olive (*Olea europaea*), oak trees (*Quercus* spp.) and pine trees (*Pinus* spp.) (WWF 2013c). Shrublands, or “maquis”, include species such as *Myrtus communis*, *Juniperus phoenicea* and *Chamaerops humilis*, while in river beds we can find *Tamarix* spp., *Fraxinus angustifolia*, *Salix* spp., among many others (WWF 2013c,f). The region includes many centres of plant diversity and endemism rates go from 10 to over 20 %. The Balearic Islands host 180 endemic plant species (out of 1450), while Sicily is home for 310 endemics (out of 2700 species) (WWF 2013d, f).

Faunal richness is also high in north-western Mediterranean. While mammals and birds are mostly of Eurasian and African origin, the amphibian, reptile and freshwater fish fauna present considerable rates of endemism (Derneži 2010; Cox et al. 2006). Rivers in the region harbour unique fish species like *Aphanius iberus*, *Anaecypris hispanica* and *Barbus microcephalus* (WWF 2013b,c). In terms of amphibians, we have the examples of the Mediterranean tree frog (*Hyla meridionalis*), the Western spadefoot toad (*Pelobates cultripes*) and the Iberian ribbed newt (*Pleurodeles waltl*) (Gasc et al. 1997; Cox et al. 2006), and for reptiles we have examples such as of the Iberian worm lizard (*Blanus cinereus* - only member of the amphisbaenians found in Europe), the Mediterranean turtle (*Mauremys leprosa*), many species of lizards (*Iberolacerta* spp., *Podarcis* spp., *Psammodromus* spp.) and of snakes/vipers (*Natrix* spp., *Vipera* spp.), among many other examples of herpetofauna (Gasc et al. 1997; Cox et al. 2006). The region is also home for emblematic endemic species of mammals such as the Iberian lynx (*Lynx pardinus*) and the rare Sicilian shrew (*Crociodura sicula*), as well as important populations of otter (*Lutra lutra*) and European polecat (*Mustela putorius*) (WWF 2013b,c,d,f). Finally, bird diversity is also tremendous, and the region constitutes an important

wintering and nesting ground for countless species. Important populations of endangered raptor species can be found in the area, like the black vulture (*Aegypius monachus*), griffon vulture (*Gyps fulvus*) and imperial eagle (*Aquila heliaca*) (WWF 2013c,f). Another endangered species present in the region is the great bustard (*Otis tarda*) (WWF 2013b). Some delta areas can harbour up to 30,000 pairs of water birds that include many ducks (*Anas* spp.), gulls (*Larus* spp.), terns (*Sterna* sp.) and countless other species (WWF 2013c). The region even holds the only European populations of flamingos (*Phoenicopterus ruber*) (WWF 2013c,e).

The Mediterranean basin is one of the richest regions in terms of biodiversity, but also one of the most threatened. For several millennia, the region has sustained some of the greatest civilization in History (Derneži 2010). So the landscape has been severely modified and nowadays very little pristine habitat spots still exist (Blondel et al. 2010; Derneži 2010). Then again, this has given time for the fauna and flora of the region to adapt to the new altered environmental settings, and some species are now dependent on the coexistence with humans, mainly in agricultural systems (Cox et al. 2006; Blondel et al. 2010). The greatest threat to biodiversity has been, without a doubt, the continuous destruction, fragmentation and modification of habitat, whether it is for agricultural use, urban or industrial development. For example, the intensification of agricultural practices has been responsible for the loss of wetlands that are essential for the survival of amphibian species (Ferreira & Beja in press). The entire Mediterranean basin is home for more than 400 million people, and future predictions show an additional increase. Furthermore, the Mediterranean countries are international tourism destinations, receiving around 200 million people per year, mainly along the coast line (Cox et al. 2006; Cuttelod et al. 2008). So establishing conservation efforts is always an arduous endeavour due to the variety of conflicts it can generate (Derneži 2010). Another major issue is water availability. The combination of dry summers, unsustainable farming practices and construction of river dams, result in dried up river beds that affect freshwater habitat species, and desertification, degradation and erosion of the land (60% of Portugal for example faces a moderate risk of desertification) (Cox et al. 2006; Cuttelold et al. 2008). All of the above pressures will become even more problematic as a result of global climate change, and forest fires and severe droughts will increase in frequency and severity (Cuttelold et al. 2008).

The Mediterranean basin is considered as one of the Global Biodiversity Hotspots (CI 2013), and fortunately in the last decades, efforts made by various institutions, from the European Union to more local forms of government, not to mention NGOs, have been responsible for the emergence of numerous conservation sites that include the Natura 2000 sites, national and regional wildlife parks and reserves (Cuttelold et al. 2008). A good example is the Doñana National Park in Spain, which holds the remaining wild population of the Iberian lynx. Additionally the test site holds one AZE site (AZE 2013) and many Ramsar sites (Ramsar 2013) and IBAs (BirdLife International 2013). Conservation sites alone do not ensure the protection of biodiversity, but together with species specific actions, continuous research and monitoring, as well as better education and communication with the general public, many species have been saved from extinction (Cuttelold et al. 2008).

## 8 Faunal Species Richness Maps

Figure 7 to Figure 10 show species richness maps of mammals, reptiles, amphibians, and all three groups as derived by Cibio with the following procedure:

Individual species distribution models (SDM) were first built at a 10x10km resolution for entire continents, using a set of eco-geographical variables (EGV) that included topography, climate and land cover. The following data sources were used:

Species presence data: GBIF ([www.gbif.org](http://www.gbif.org))

Topography: SRTM, (<http://srtm.usgs.gov/index.html>)

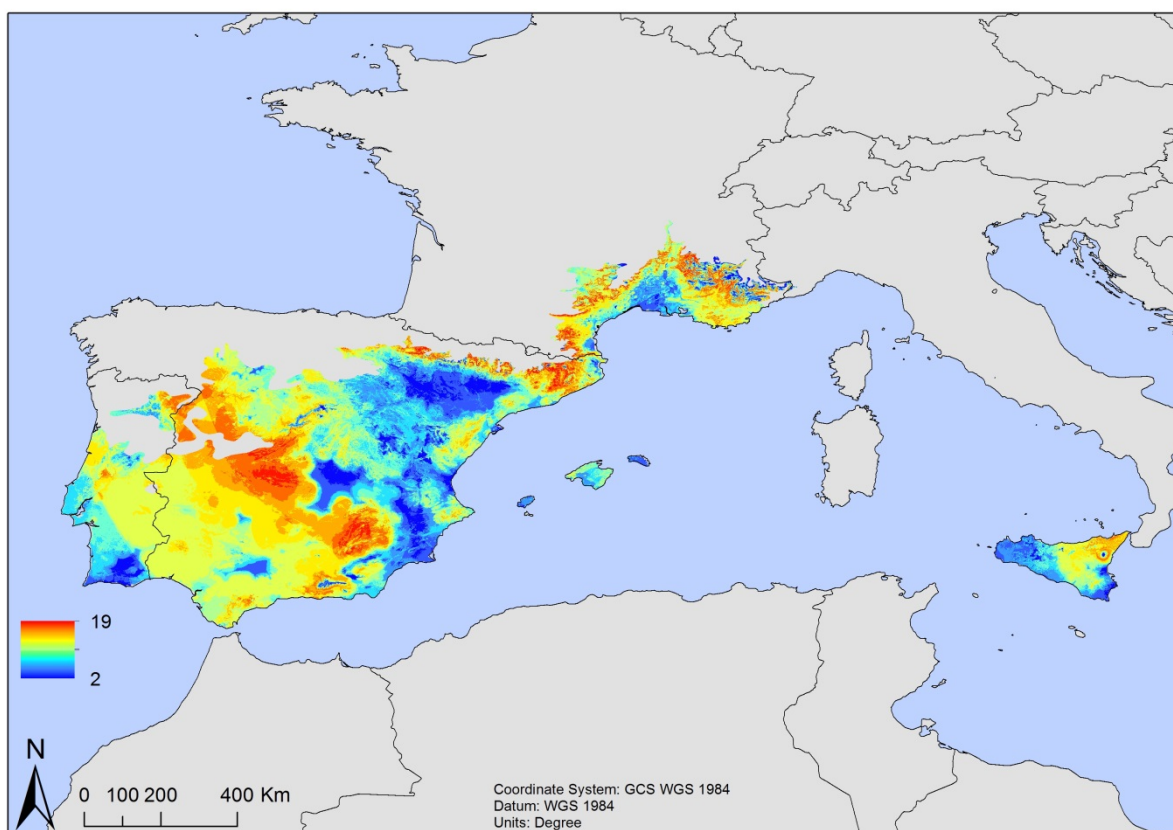
Climate variables: WorldClim (<http://www.worldclim.org/>)

Land cover: GlobCover 2009 (<http://due.esrin.esa.int/globcover/>)

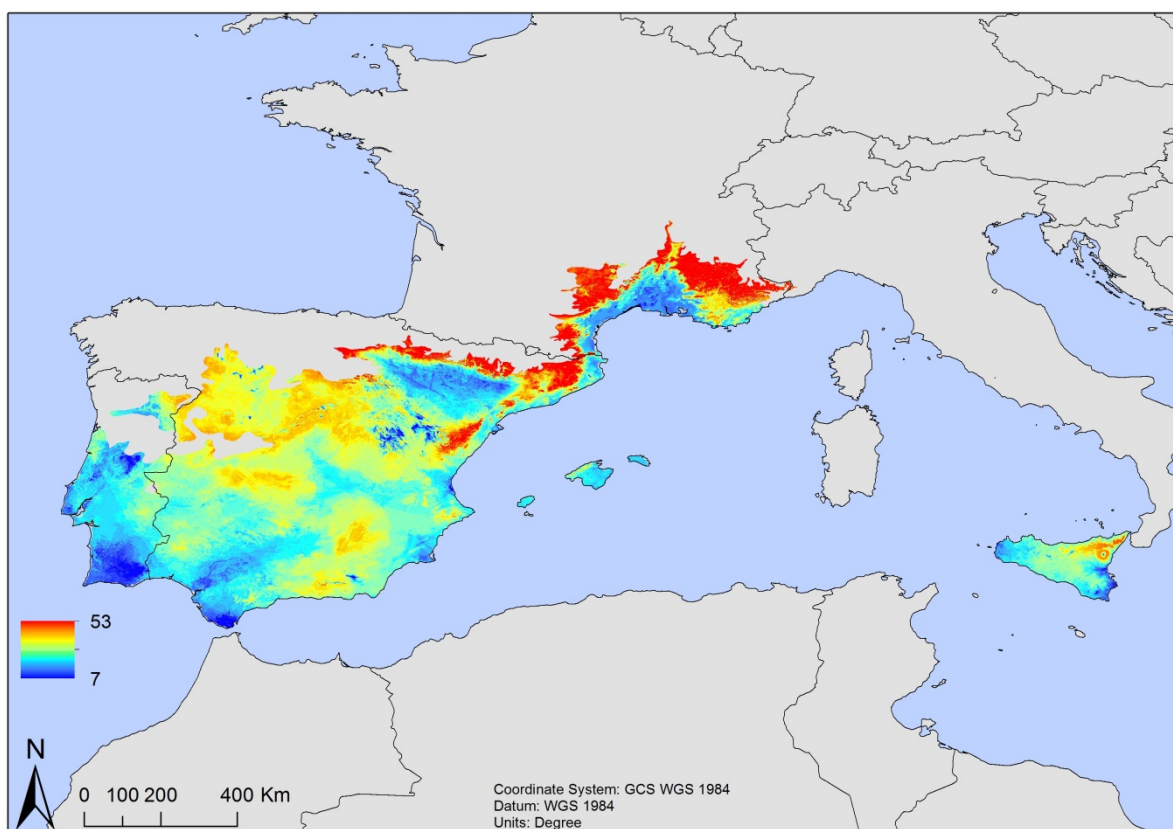
The model results were projected to the dryland test sites and gridded with a resolution of 1x1km<sup>2</sup>. All models were run with the Biomod2 package for R, based on four algorithms (GLM, ANN, GBM and MaxEnt). Probabilities of species occurrence were converted to binary values, in order for species richness to be estimated by adding the individual predictions of species presence/absence in each pixel.

By “convergence of evidence”, commonalities of the species richness maps with the derived vegetation productivity maps can be seen.

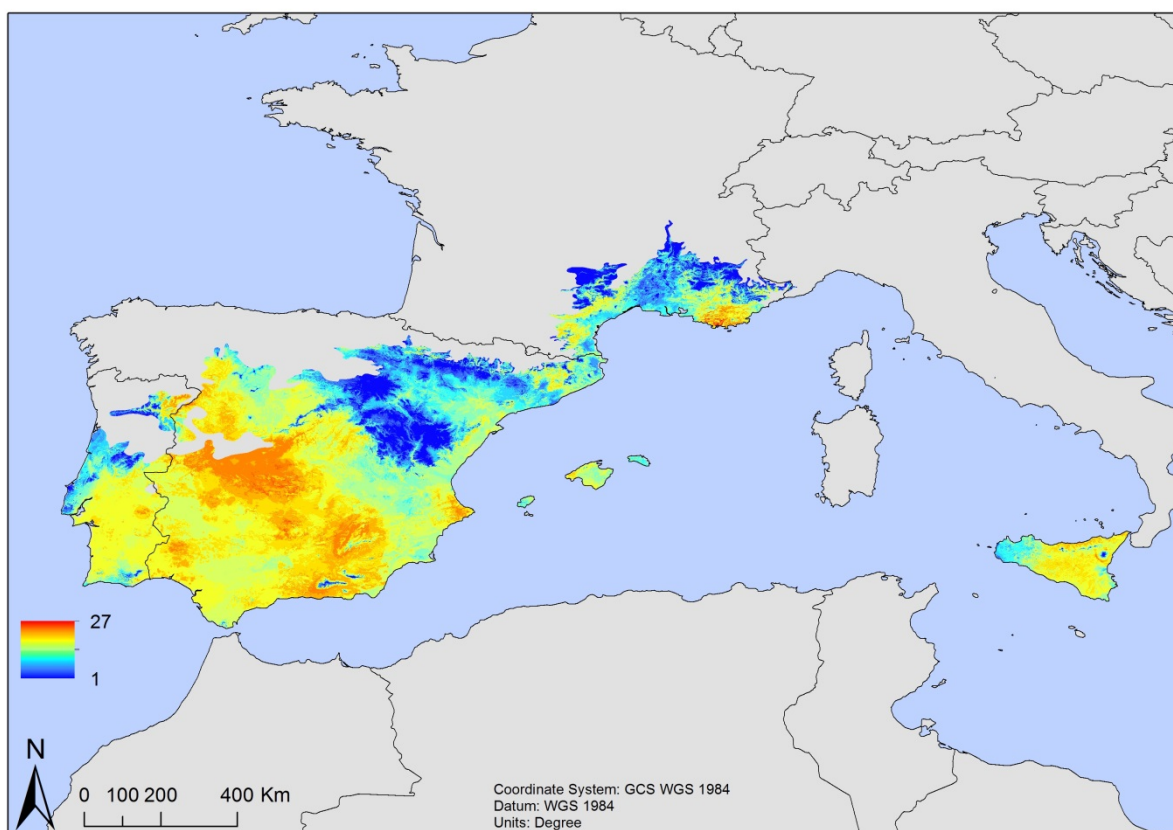




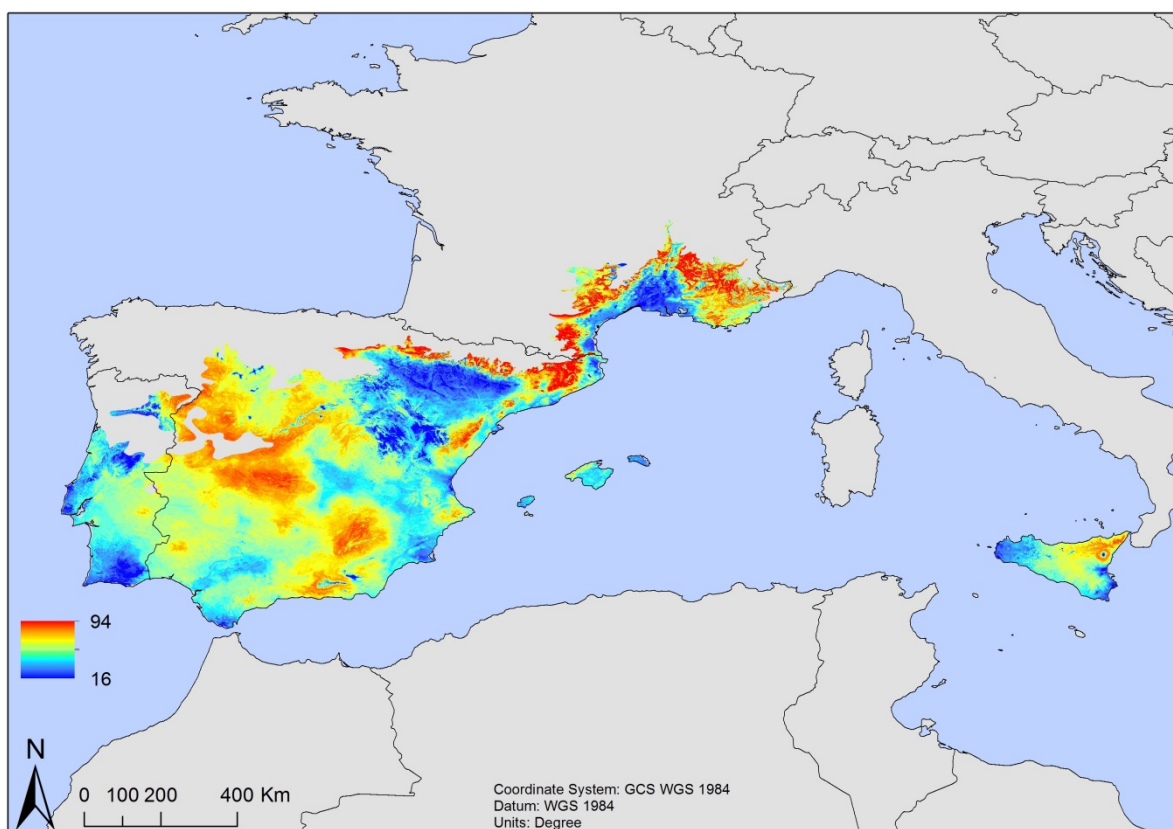
**Figure 7: Modelled species richness of amphibians**



**Figure 8: Modelled species richness of mammals**



**Figure 9: Modelled species richness of reptiles**



**Figure 10: Modelled species richness total**

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Prime contractor; project management; algorithms  
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### **GeoVille Information Systems GmbH**

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