GEOINFORMATION

in der Umweltplanung | Environmental Planning

Technische Universität Berlin

Modelling sensitivity to desertification with multi-temporal Landsat imageries in a semi-arid region on the Atlantic coast of Morocco

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Herzlich Willkommen. Welcome.

Content

- Desertification
- Study area and objectives
- Datasets and preprocessing
- Method
- Results
- Conclusion

Desertification

"land degradation in arid, semi-arid and dry sub-humid areas, resulting from various factors, including climatic variations and human activities" (UN General Assembly, 1994)

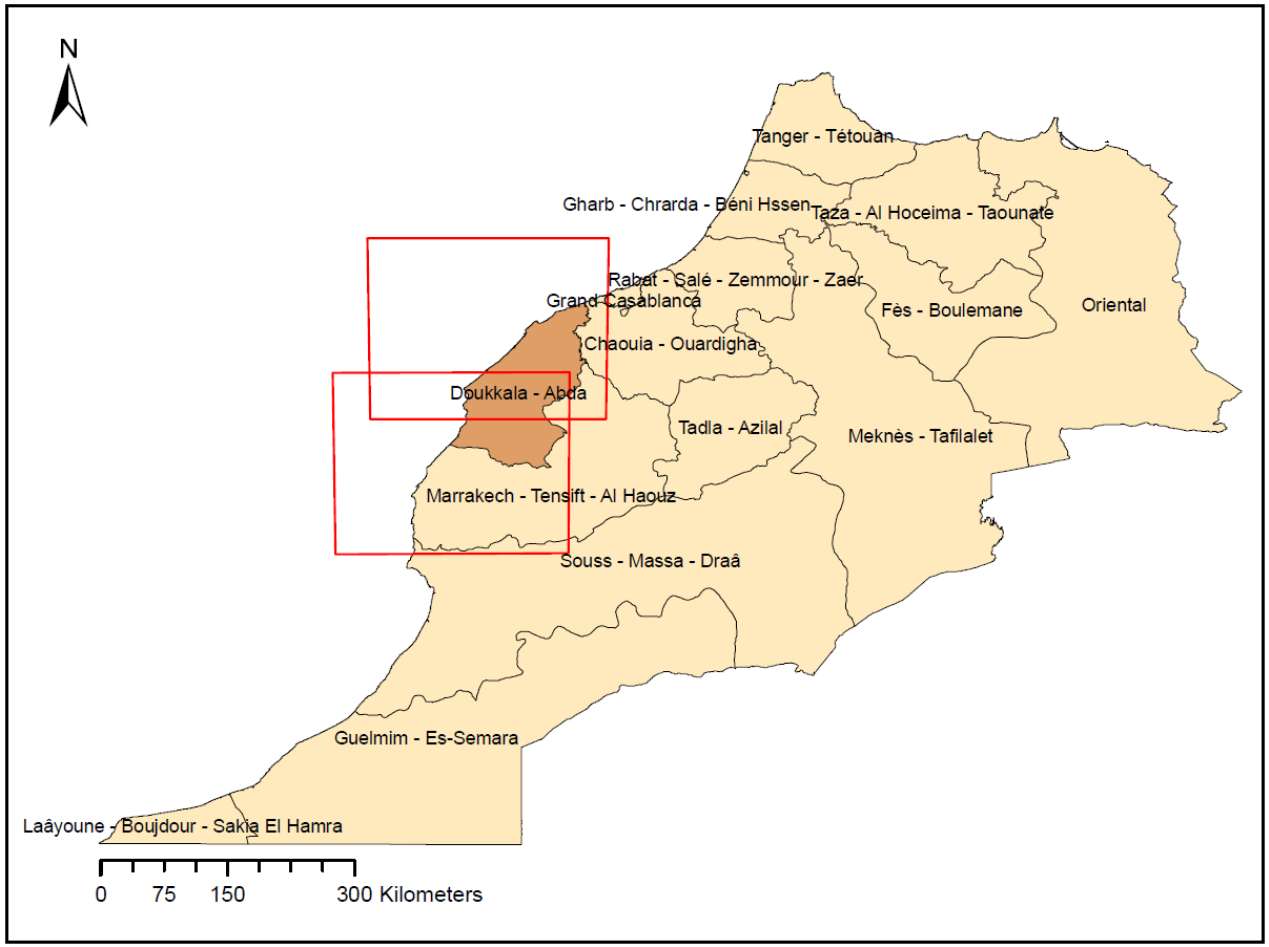
⇒ rupture of ecosystem equilibrium

deterioration of soil properties, reduction of bioproductivity

loss of natural vegetation

Study area

Province of Safi, Region Doukkala-Abda, Morocco



Climate & Flora:
mediterranean/ semi-arid,
931 species, 248 endemic

Red boxes:
Landsat path 203, rows 37 and 38

Study area

Sand encroachments

- Caused by aeolian erosion, exacerbated by excavations (urbanization, sand smugglers)
- Organic soil layer is covered

Karstification

- Caused by aeolian erosion, probably exacerbated by herding
- Soil is washed out

Objectives

1. Assessing the current **extent of desertification** in Safi and its evolution.

2. Assessing the **sensitivity** of the Province to desertification.

Datasets

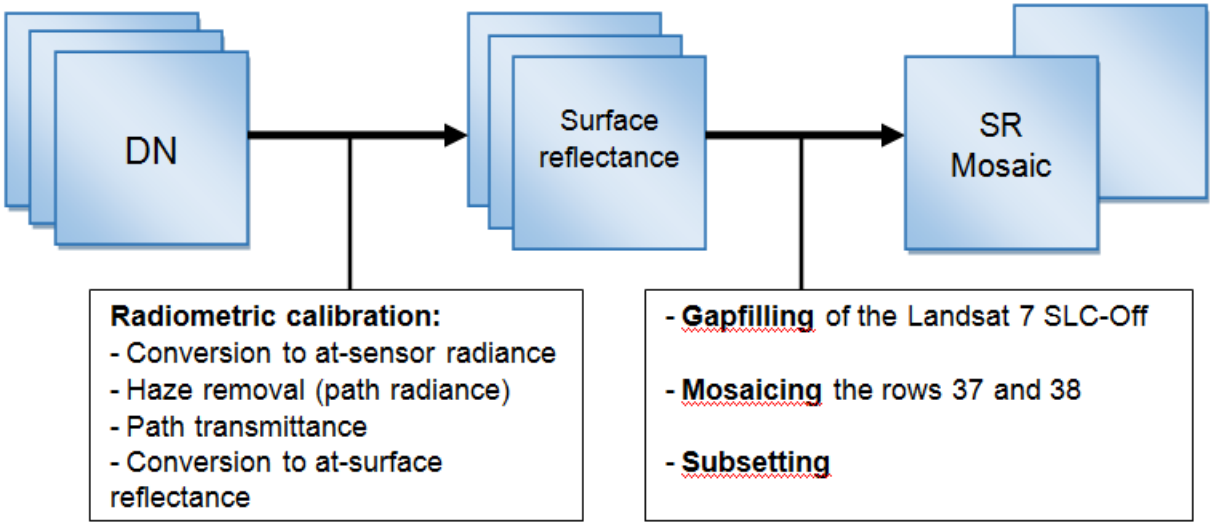
Landsat TM/ETM+:
March: 2003, 2007, 2010, 2011, 2014
April: 2002, 2005, 2008, 2009, 2011, 2013, 2014

SRTM Digital Elevation Models

UN FAO (2012) ***Harmonized World Soil Database***

Weather records from a station 30km North-East of Safi:
precipitation, temperature, evapotranspiration & wind velocity: daily 2007-2012

Preprocessing



Method: Vegetation Abundance Index

1st assumption:

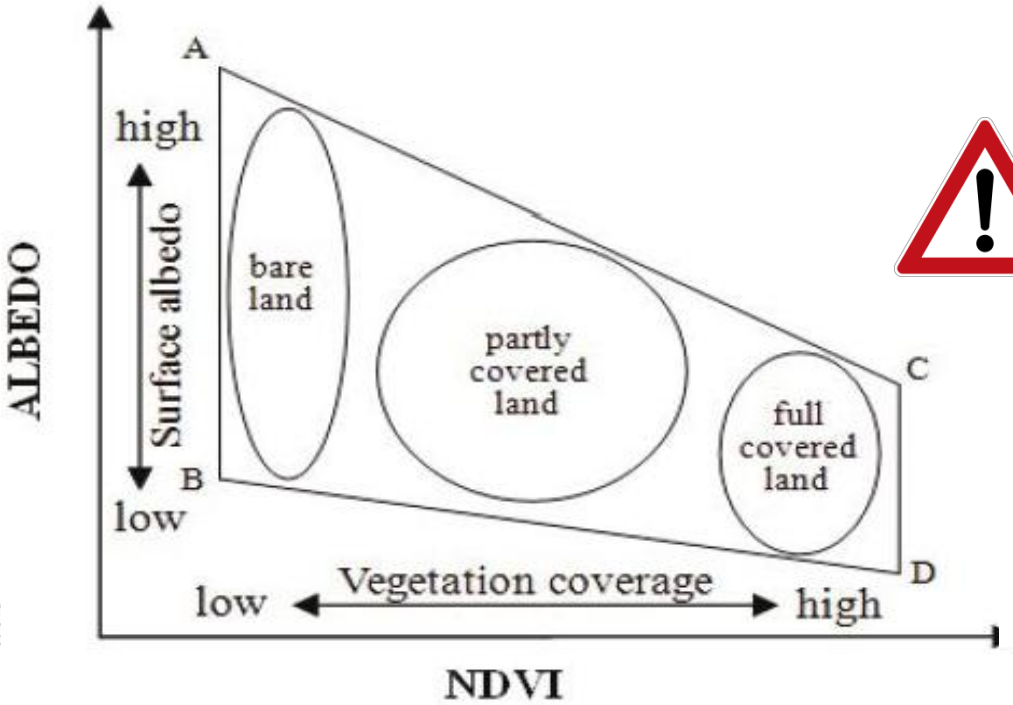
Soil water availability is the physical determinant of desertification

=> Reflected by the abundance of vegetation

2nd assumption:

Albedo increases with the exposure of dry soils

=> Negative correlation between V.I. and albedo (Ma et al., 2011)



NDVI-Albedo feature space, Ma et al., (2011)

A Vegetation Index is not a flawless proxy of land vitality (Aridification does not always affect biomass (Veron et al., 2006))

Method: Vegetation Abundance Index

Variables:

Vegetation: Fc (rescaled NDVI), NDWI

Brightness: broadband albedo, NIR-Albedo

TM bands: 1-5 and 7

⇒ Negative correlation between SWIR reflectance (B7) and vegetation (Fc)

$$\mathbf{VAI = a * Fc - B7}$$

Where *a* is the absolute value of the linear regression slope

Fig. 3: Scatterplot of Fc and Band 7

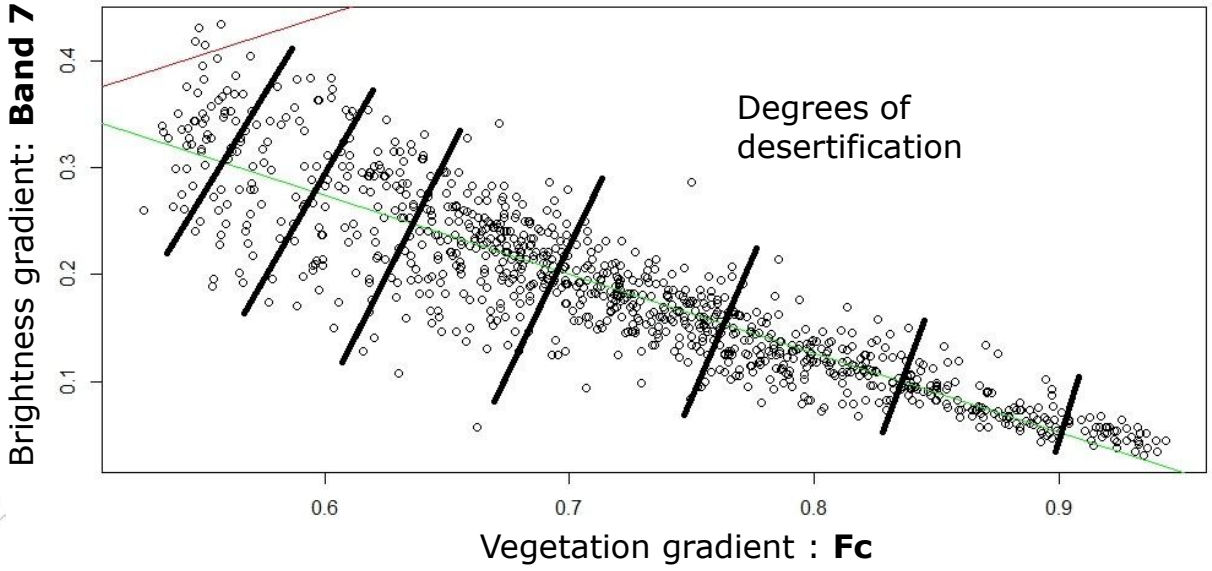
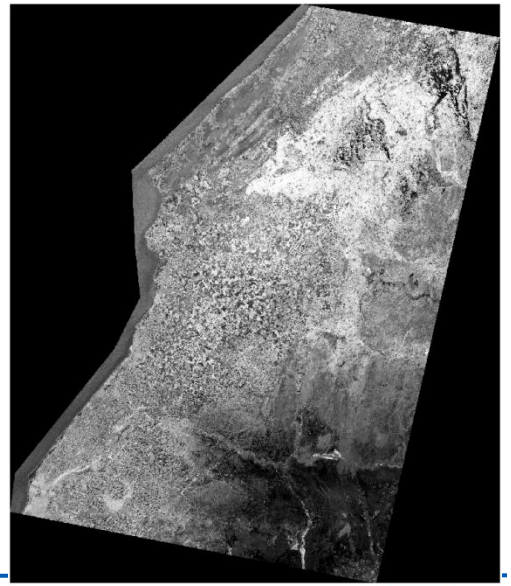


Fig. 4: VAI image



Method: Vegetation Abundance Index

Segmentation with Natural Breaks (Jenk's method)

Fig. 5: initially 7 classes reclassified into 5

Detection of change

Differences of VAI after a reclassification
in order to obtain unique identifiers of VAI change

1	1	3	7	12
-1	**2**	2	6	11
-3	-2	**4**	4	9
-7	-6	-4	**8**	5
-12	-11	-9	-5	**13**

Fig. 6: matrix for the reclassification of VAI values

Method : Greenness-Brightness Iso Cluster

Limitation of VAI: no differentiation between sandy soils and naked karst, land cover heterogeneity

Spectral endmembers: karst, sand, harvested field, growing vegetation, field vegetation

Band ratio enhancement: TM5/TM7 as brightness gradient and TM5/TM4 as greenness gradient

Fig. 7: spectral profiles of the endmembers

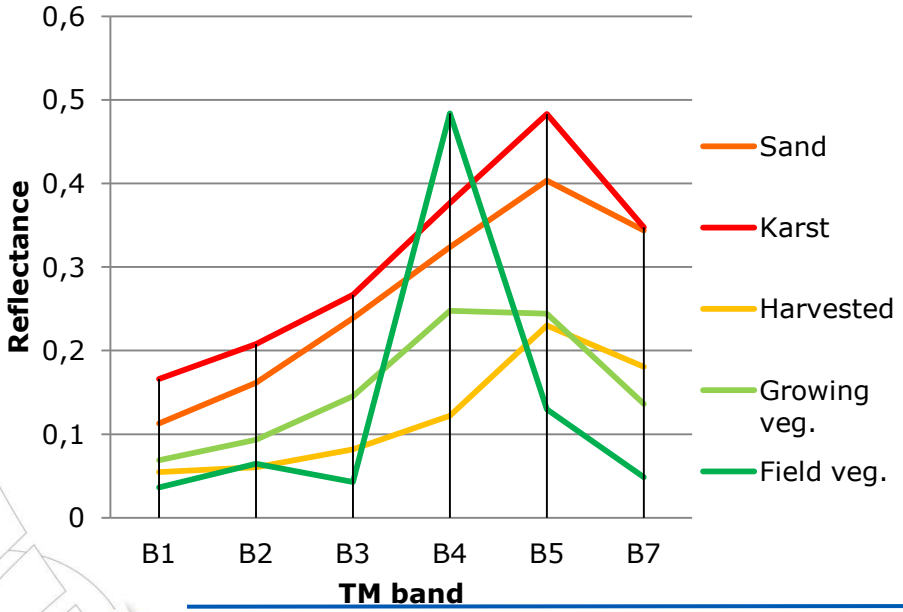
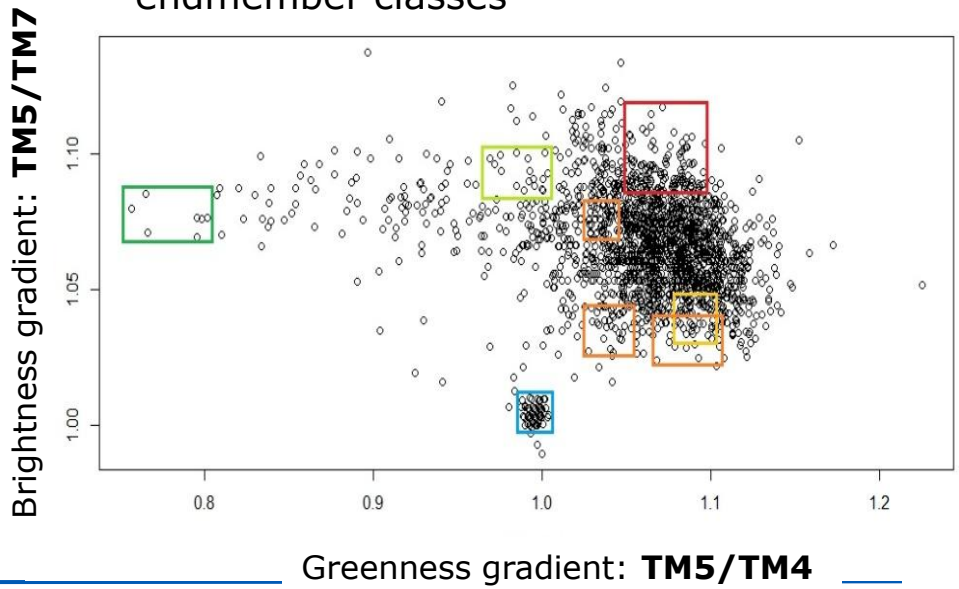


Fig. 8: scatterplot of TM5/TM4 and TM5/TM7 bands with the position of the endmember classes



Method : MEDALUS Model

Model of the physical environment

=> defines Environmentally Sensitive Areas (ESA)

Soil Quality Index
- Soil texture
- Gravel fraction
- Drainage status
- AWC
- Parent material
- Slope
- Aspect

Vegetation Quality Index
- Vegetation cover
- Erosion Protection
- Drought resistance
- Previous VAI change

Climate Quality Index
- Aridity (P/PET)

$$Index_i = (parameter_1 * parameter_2 * parameter_3 * \ldots)^{1/n}$$

Each parameter is scored from **1**: "best quality/lowest sensitivity" to: **2** "worst quality/highest sensitivity". Example:

Slope	**< 6%: gentle**	**1**
	6-18%: not very gentle	**1.33**
	19-35%: abrupt	**1.66**
	> 35%: very abrupt	**2**

Method : MEDALUS Model

Desertification Sensitivity Index:

$$DSI = (SQI*VQI*CQI)^{1/3}$$

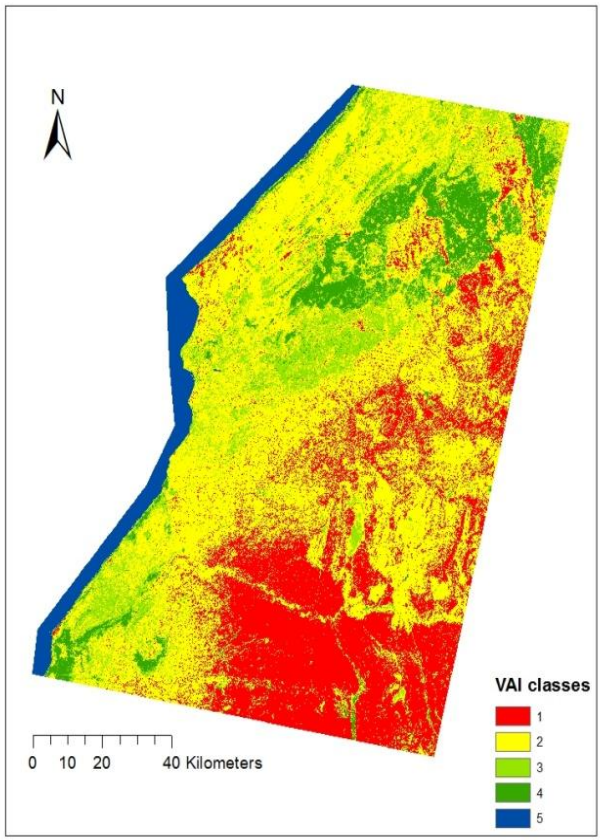
reclassified into ESA classes:

ESA Class	DSI Range	Description
1	DSI < 1.2	Area not affected by desertification
2	1.2 < DSI < 1.3	Low sensitivity to desertification
3	1.3 < DSI < 1.4	Medium sensitivity to desertification
4	1.4 < DSI < 1.6	High sensitivity to desertification
5	DSI > 1.6	Extreme sensitivity to desertification

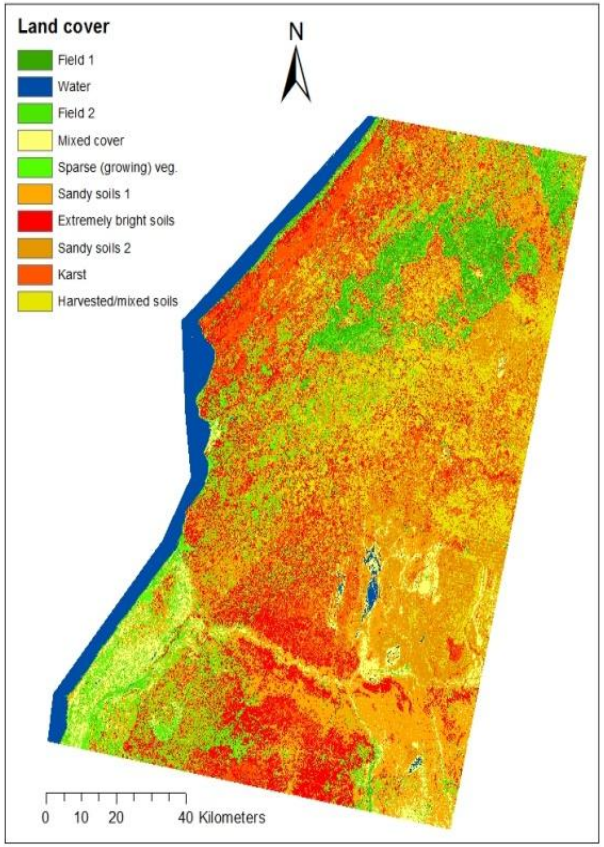
(Gad and Lotfy, 2008)

Results 1 - Desertification

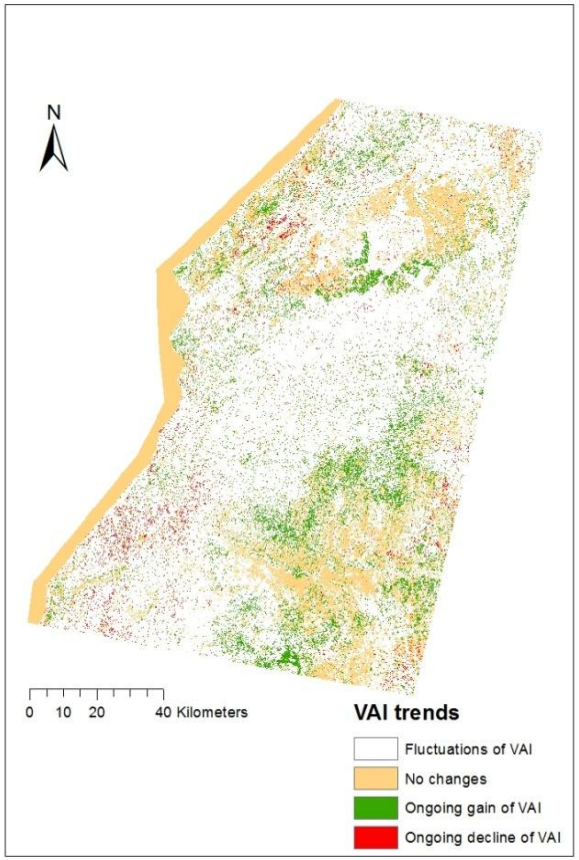
VAI classification of April 2005



ISO Cluster Classification of Brightness-Greenness of April 2005



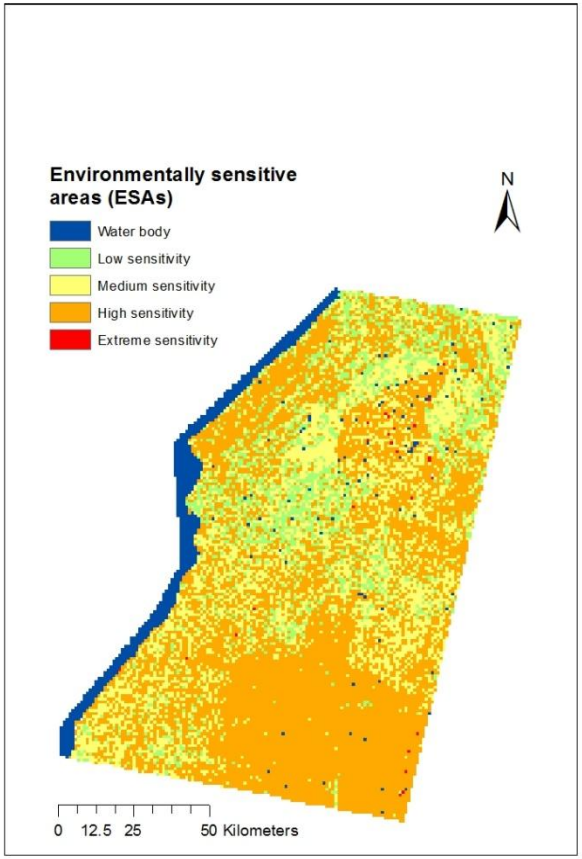
Intersection of VAI differences per direction for the April group



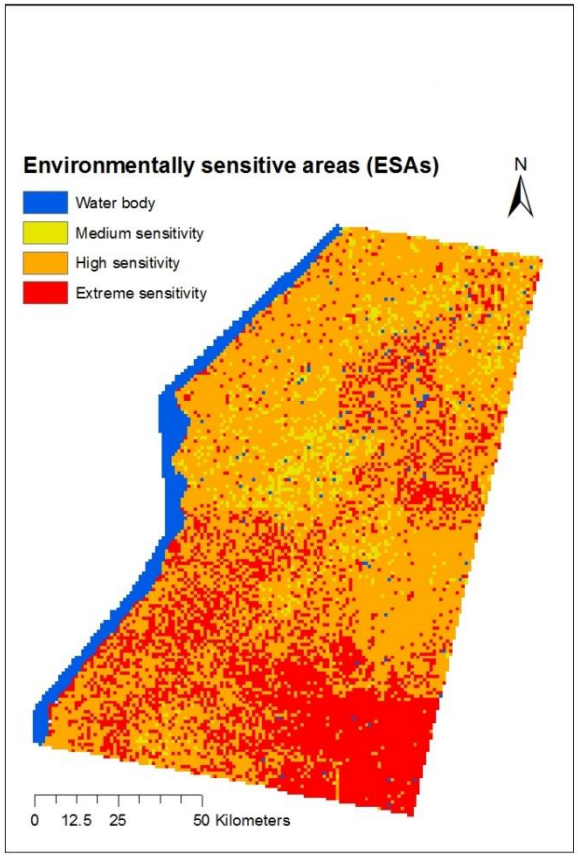
Overall accuracy: VAI: 78%; Iso Cluster: 88%

Results 2 - Sensitivity

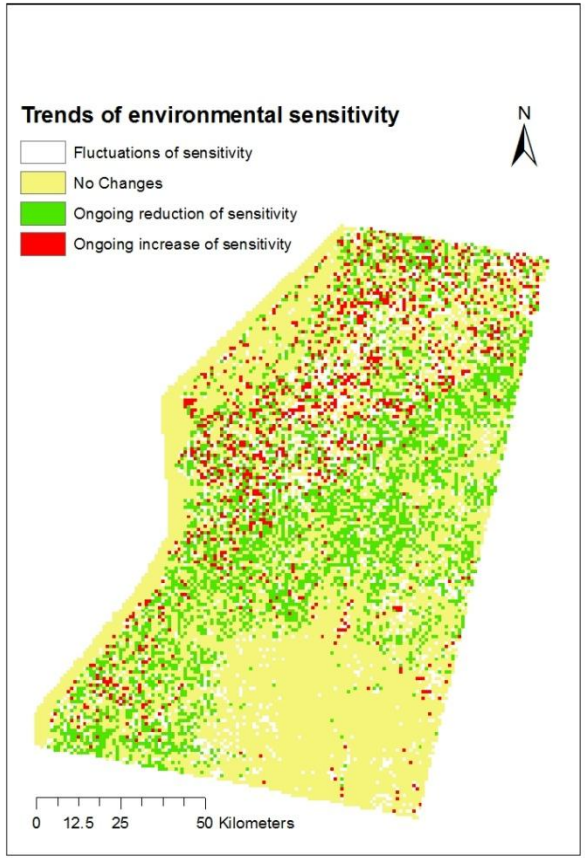
Environmentally sensitive areas of 2011 based on annual DSI



Environmentally sensitive areas of 2011 based on summer DSI



Intersection of ESA differences per direction for the years 2008, 2009 & 2011



Discussion

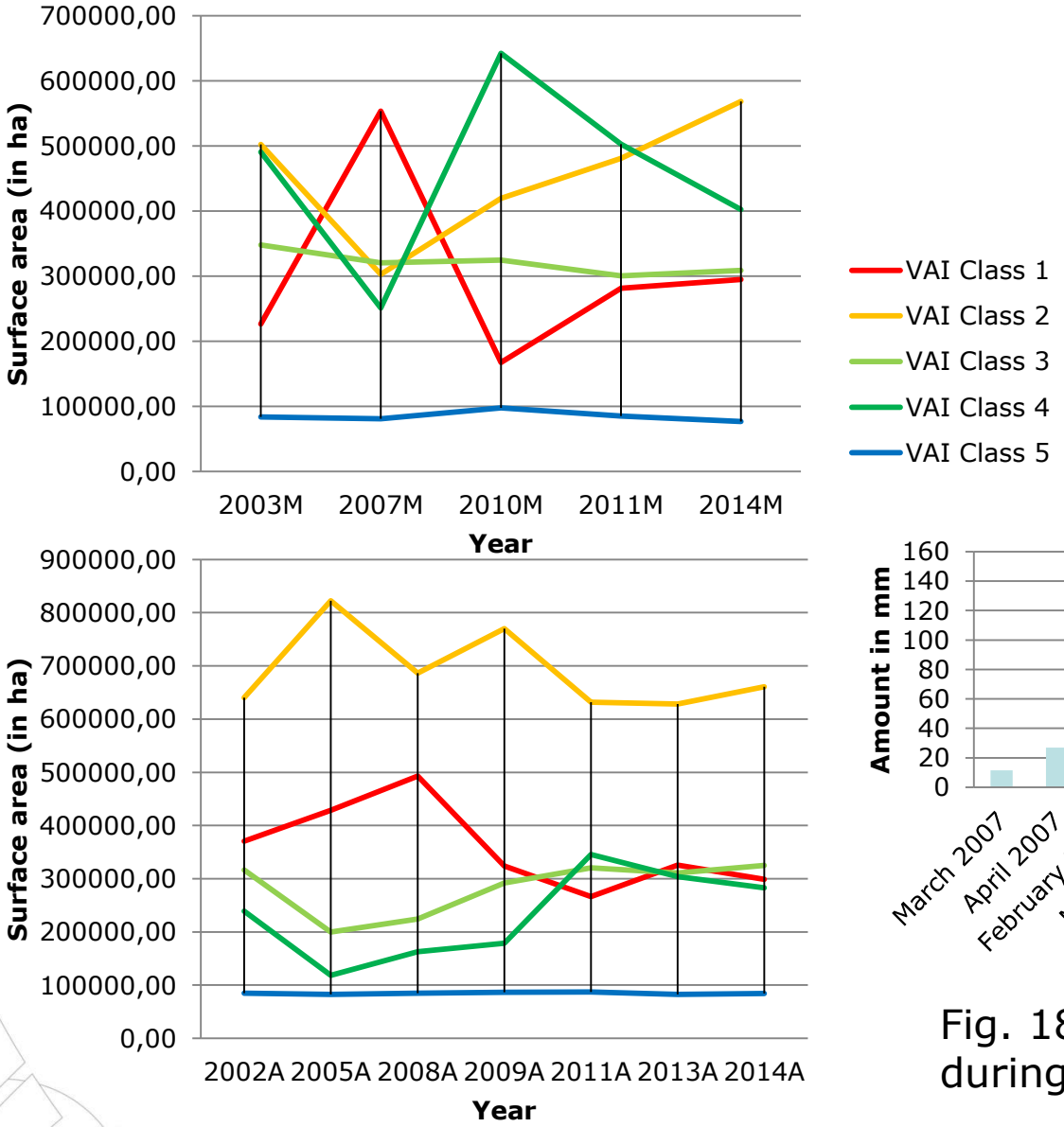


Fig. 16 and 17: variations of the VAI class surfaces. March series above and April series below.

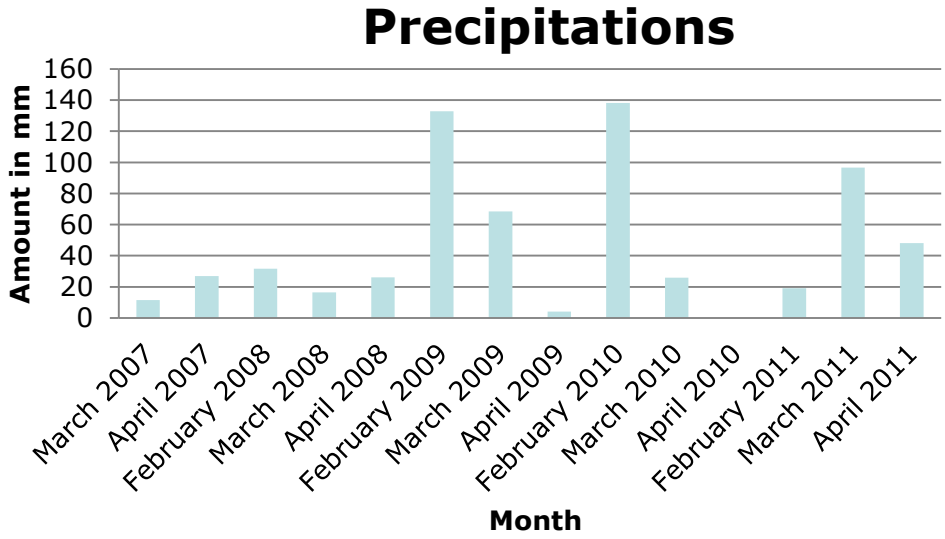


Fig. 18: Precipitation levels for the period during and before the satellite overflight

Discussion

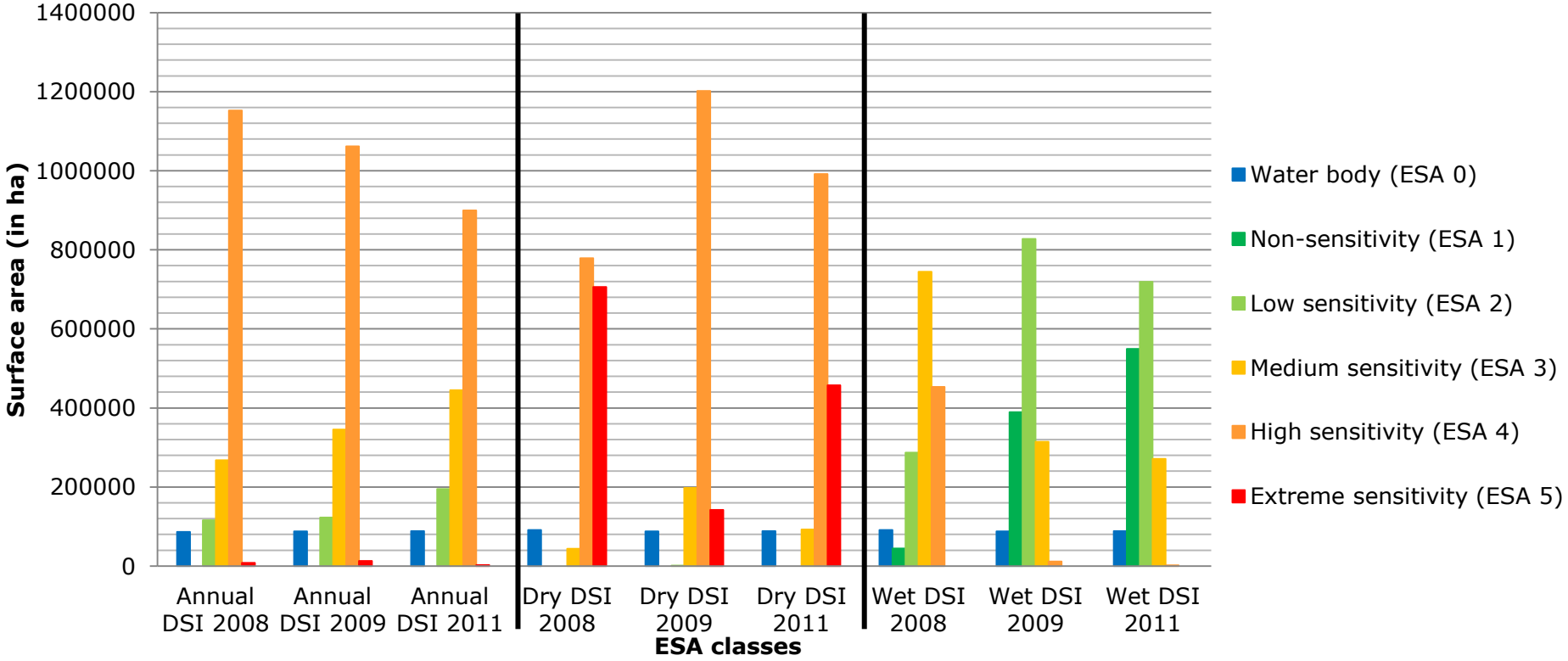


Fig. 19: : the surface area of all ESA classes per year according to the annual, dry season and wet season DSI calculations

Accuracy assessment: correlation of VAI decline and environmental sensitivity?

⇒ Observed VAI fluctuations do not correlate with the level of environmental sensitivity

- Irrigation disconnects the vegetation growth from rainfall and soil conditions?
- Observed non-vegetation is the result of crop rotation and harvest, but does not signify increased sensitivity

Conclusion and Outlook

- **Desertification?** Neither a large-scale decline of land vitality nor any trends during the decade
- **Sensitivity** „bursts" in summer but has been stable on annual average

- Probably the first assessment of this type for Safi
- Method: **alternative** to the SMA in heterogeneous landscapes when not all LCs are known

- In the future: data for a **Management Quality Index** and for a **wind parameter** are required
- Also: better accounting for **harvested** fields in the classification

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Thank you!

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Appendix: conversion to surface reflectance

Image-based absolute radiometric correction:

$$\rho_\lambda = \pi * D^2 * (L_{\lambda sensor} - L_{\lambda haze}) / (TAUv * Esun_\lambda * \cos(\theta_z) * TAUz)$$

Where:

- ρ_λ is the reflectance at the surface for band λ,
- D is the Earth-Sun distance in astronomical units (AU), **=>** Provided by NASA
- $Esun_\lambda$ is the exo-atmospheric solar irradiance for band λ,
- $L_{\lambda sensor}$ is the apparent at-satellite radiance for band λ **=>** Calibration factors and sun elevation angle in header file
- θ_z is the solar zenith angle
- $L_{\lambda haze}$ is the path radiance for band λ, **=>** IDOS and relative scattering model (Chavez, 1996)
- $TAUv$ is the atmospheric transmittance (ground to sensor) **=>** set to 1
- $TAUz$ is the atmospheric transmittance (sun to ground) **=>** estimated from the haze values (Song et al., 2001)