Workshop
Sustainable agro-pastoral systems: concepts, approaches and tools
Milano | Italy | 27 March 2012

Analysis of time series satellite imagery to monitor vegetated ecosystem dynamics in Sahel

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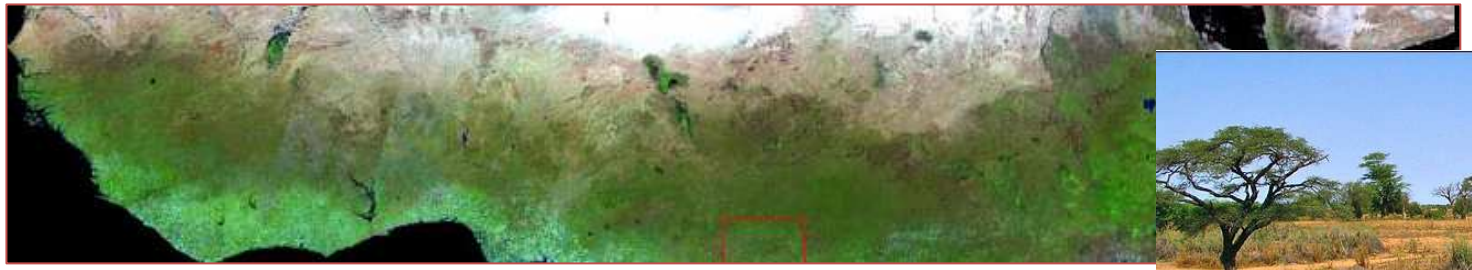
Framework

- **Developing countries** are particularly vulnerable to the ongoing **climate changes**, and **Africa,** due to its weak adaptive capacity, is likely to be the **most vulnerable** (IPCC 2007)
- The **growing population**, with a projection to double in the next twenty years, will exacerbate existing problems and impacts on food production, safe water provision, and natural-resource-based livelihoods
- Climate exerts a significant **control on the day-to-day economic development** of Africa (particularly for the agricultural and water-resources sectors).
- Monitoring of the **natural environmental resources** and early warning of drought are crucial components of disaster **mitigation plans**.

Sahel fragile ecosystem



SAHEL: dynamic eco-region

Sahel is a **transition zone** between the arid Sahara in the North and the sub-humid tropical savannas in the South, and is marked by a steep North-South gradient in mean annual rainfall.

The **borders** of the Sahel are often identified with the boundaries of pastoral and agro-pastoral activities (thus relying on human activities), or with the **limits of rainfall isohyets** (150-550 mm)

From 1960 to early 80s the area experienced **dramatic food crisis**, caused by prolonged drought, resulted in tensions and armed conflicts

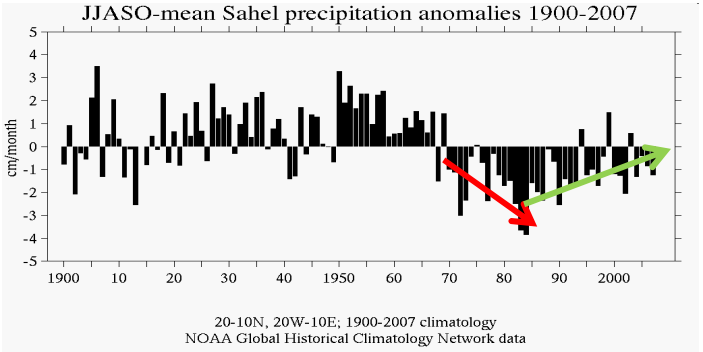
Sahel: Re-greening vs humanitarian crisis

Several studies aimed to seek explanations (climatic or human) of the drought phenomena.

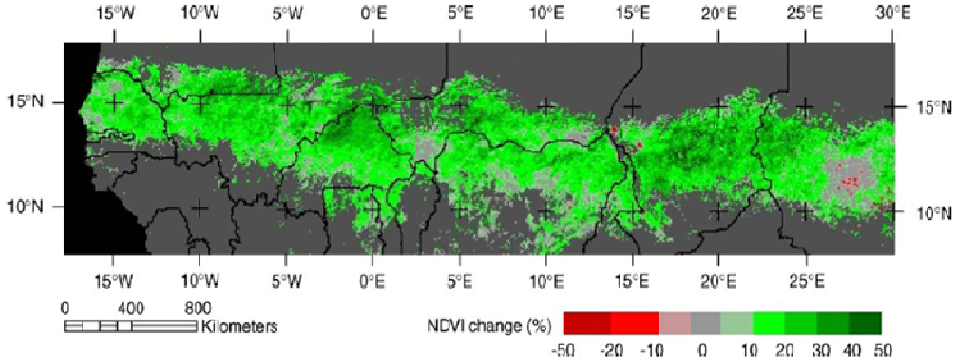
- **Charney (1975)** attributed to **human mis-management** of land resources the year-to-year persistence of drought
- **Lamprey (1988)** stressed an **"irreversible and progressive desertification of the Sahel"** as effect of long-term droughts

- **Anyamba et al. (2005)** and **Hermann et al. (2005**) showed that from the 80's a **re-greening is visible** in **satellite images** analysis

Precipitation anomalies (1900-2007)



Vegetation trend (1982-2003)



(Herrmann et al, 2005)

Context and Objectives

EU and **AU Commission** jointly promoted different initiatives **exploiting Earth Observation Satellite,** in order to **improve the lives and prospects** of people in Africa, and whose livelihoods depend heavily on their environment

2007 - 2013 GMES geoland 2

CIS NARMA
Natural Resources Monitoring in Africa

AMESD

African Monitoring of the Environment for Sustainable Development

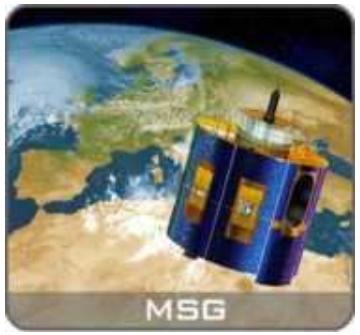
Exploitation of time series of satellite imagery

- **Timely provision of information** on the natural resources conditions, mainly vegetation cover, using environmental indicators derived from satellite data

- **Highlight critical situations** (hot-spots) where inter-annual vegetation behavior is not explained by climate variability (rainfall pattern and dynamics)

Respect to previous published research we focus
on the **last 13 years up to 2010 using 1 km resolution** satellite data.

From EO Data towards Information



EUMETCAST receiver

MSG Every 15 min
Spot/VGT Every 10day

Time series

Vegetation index NDVI 1998 - now

Water Index NDWI 1998 – now

Leaf Area Index LAI 2007 – now

Albedo BBDHR

Land Temperature LST

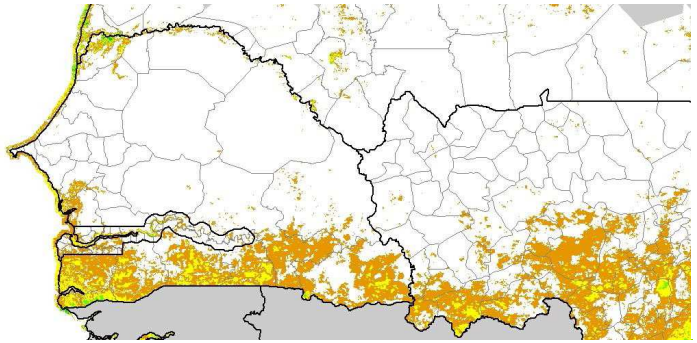
…

Environmental Indicators

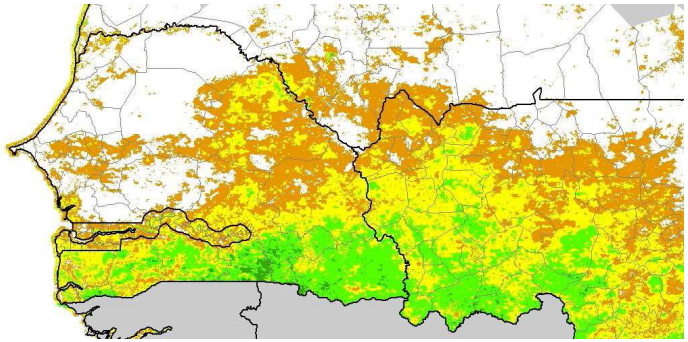
sNDVI	Standardized NDVI
VCI	Vegetation Condition Index
NGI	Normalized Growth Index
VPI	Vegetation Productivity Index
fCover	fractional vegetation Cover
LST	Land surface temperature
TCI	Temperature Condition Index
VHI	Vegetation Health Index
SWB	Surface Water Body

NGI seasonal evolution: 2009

June 1st dekad



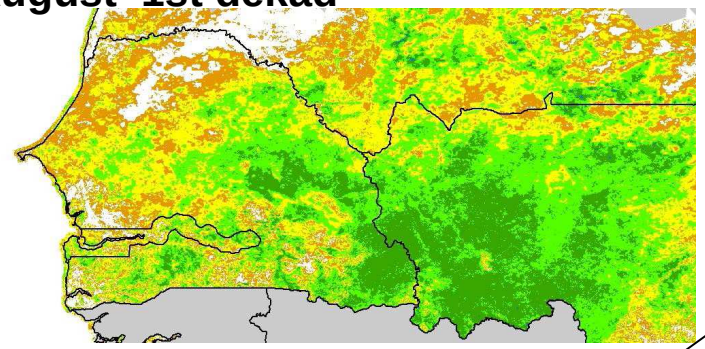
July 1st dekad



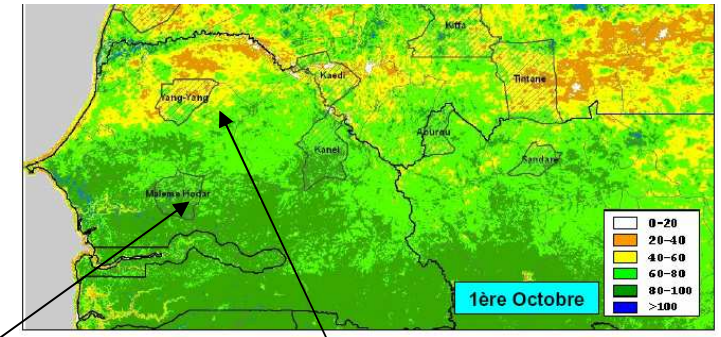
In **Senegal** and western **Mali** agro-pastoral season 2009 very favorable.

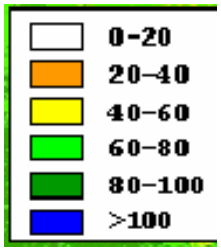
In **Mauritainia**, exceptional 2009 rain season

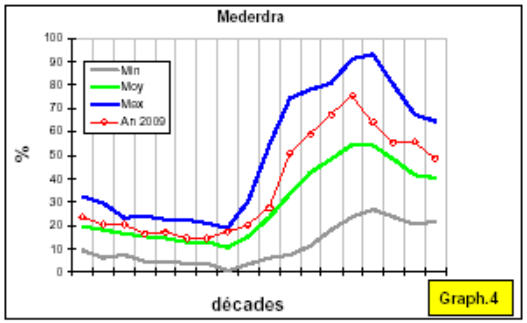
August 1st dekad

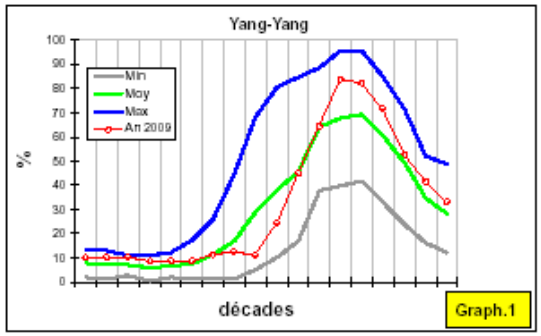


October 1st dekad



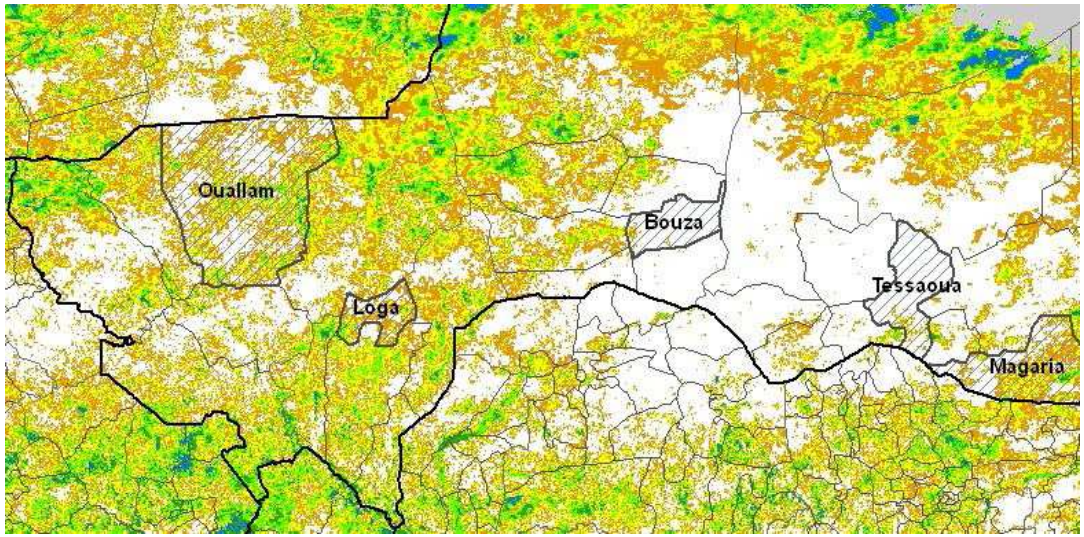




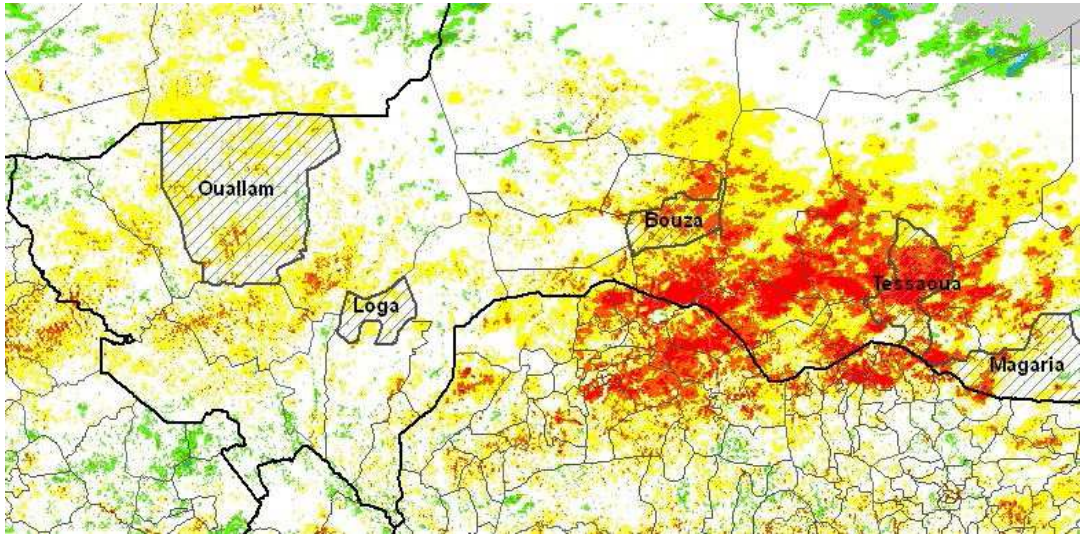


Seasonal NGI profile averaged per Administrative Unit

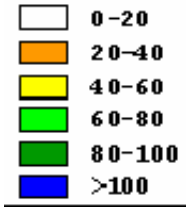
VCI and sNDVI indicators



October 1st dekad

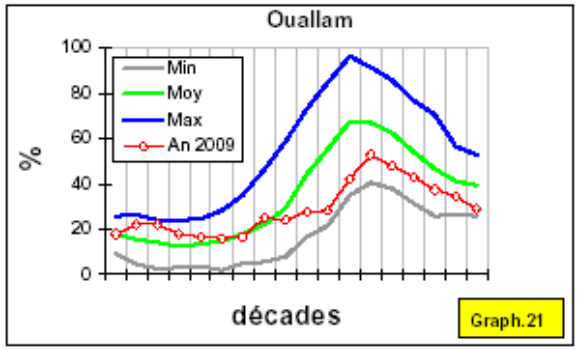


VCI



In **Niger** the second part of rainy season was characterized by an early stop of rains (end of August) mainly in the Eastern part of the country.

NGI



sNDVI

GeoLand-2 NARMA satellite products:

- **RFE** derived by FEWS NET were used to characterized rainfall variability

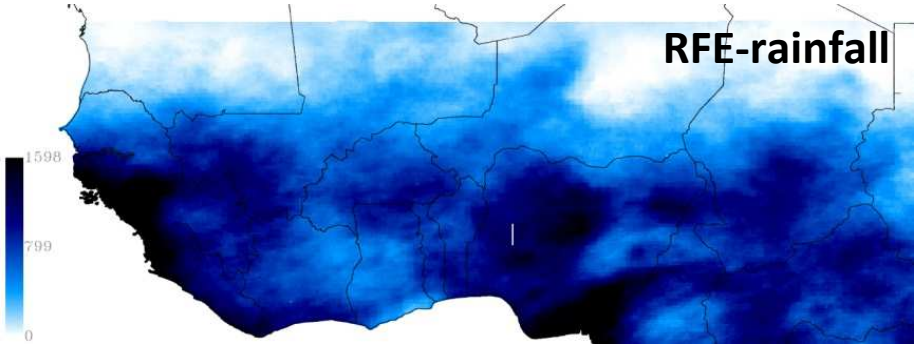
  8 km spatial 10-day data (1998-2010)

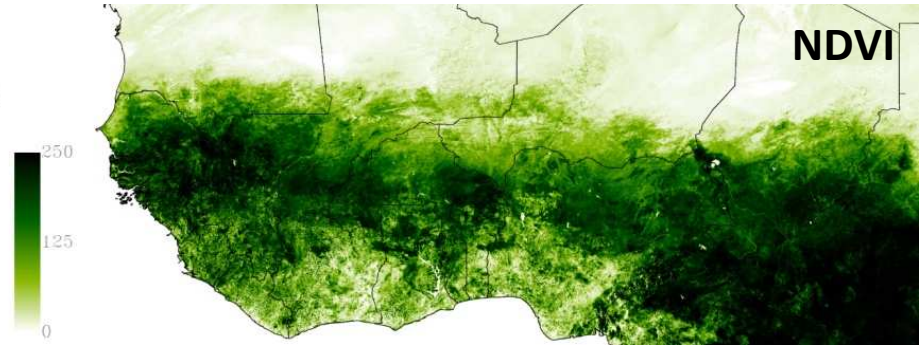
- **NDVI** from SPOT-Vegetation (VGT) were used as proxy of vegetation production

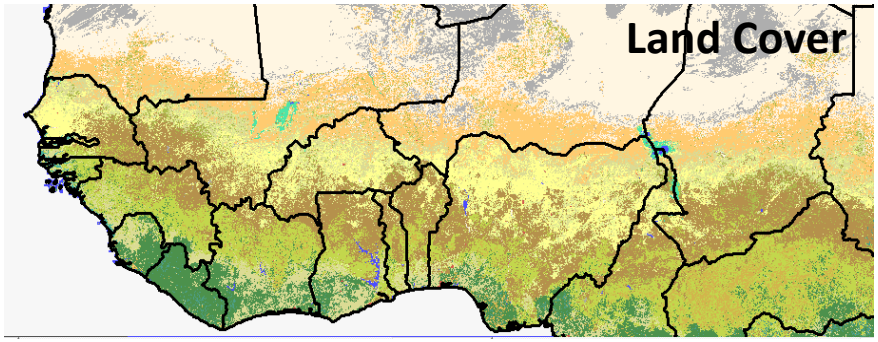
  1 km spatial 10-day data (1998-2010)

- **Glob Cover (GC)** was used to analyze behavior in different land cover classes

  300m spatial (MERIS data, Year 2005)







Analysis of anomalies

– Pre-processing of EO product

- **ΣNDVI** : 10-day NDVI values were cumulated for the period JASO proxy of annual (net and gross) primary productivity (Price, 1991).
- **Y-Rain**: annual cumulated rainfall which is considered as the most influential parameter on plant production in the study areas.

– Normalization by Z-score calculation

$$\text{Anomaly}(i, j) = \frac{DN(i, j) - \bar{X}(i, j)}{\sigma(i, j)}$$

DN = annual value of NDVI (or rainfall);

$\dot{X}$ = mean value for the period 1998-2010;

σ = standard deviation for the period 1998-2010.

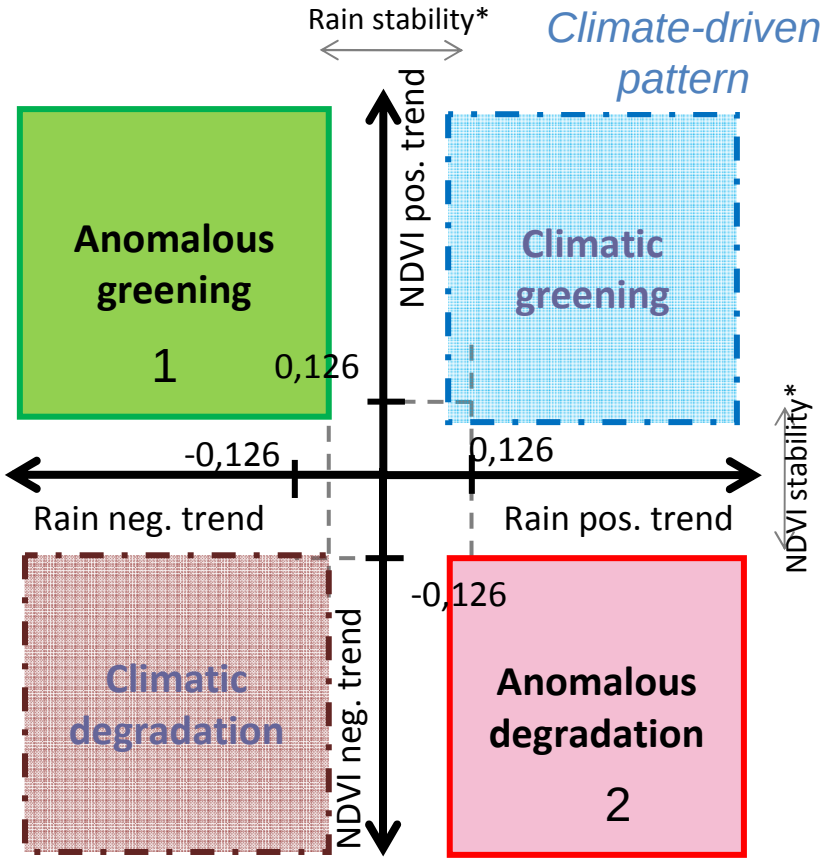
i, j - indicates pixel coordinates (samples and lines)

– Temporal trend

- **Trend significant**: Mann–Kendall non parametric test used to identify monotonic increase/decrease in the Z-score time series
- **Trend Magnitude**: slope of the trend was calculated using the Sen's non-parametric method

Conceptual model and Interpretation scheme

Long-term trends of both variables were analyzed together according to the interpretation scheme



X = Rain trend slope Y = NDVI trend slope

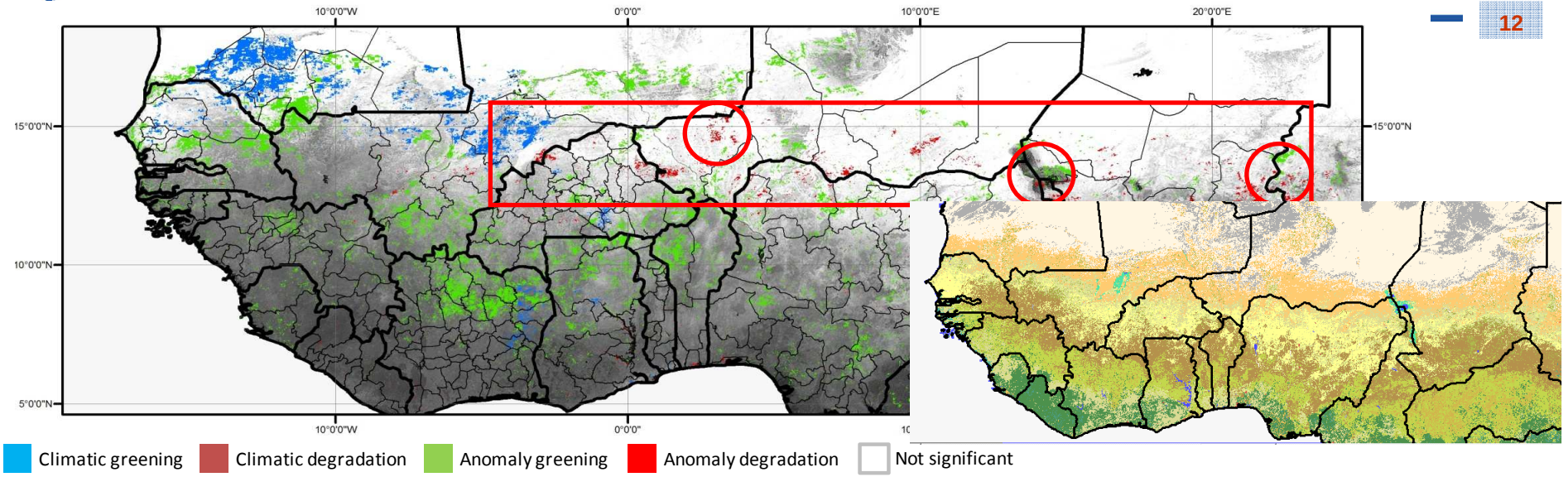
* not significant trend or low slope trend

- **Climatic** processes only when significative change in rainfall are detected (P< 0.1) with a sensible magnitude (sl > 0.126 ↑ or sl < -0.126 ↓)

- **Anomaly** condition when NDVI trend present significative slope (P< 0.1) and magnitude (sl > 0.126 ↑ or sl < -0.126 ↓) even in condition of stable rain

- **Unclassified** when ΣNDVI trends are not significative (P< 0.1) or present very low magnitude

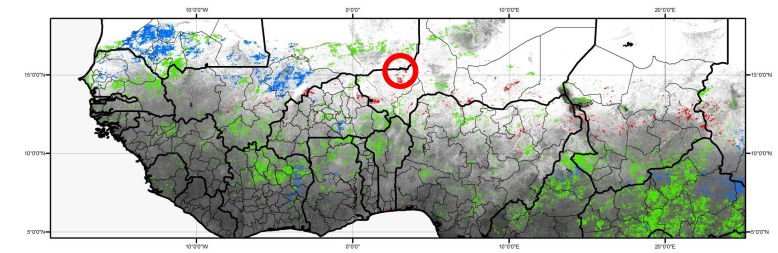
Hot spot map

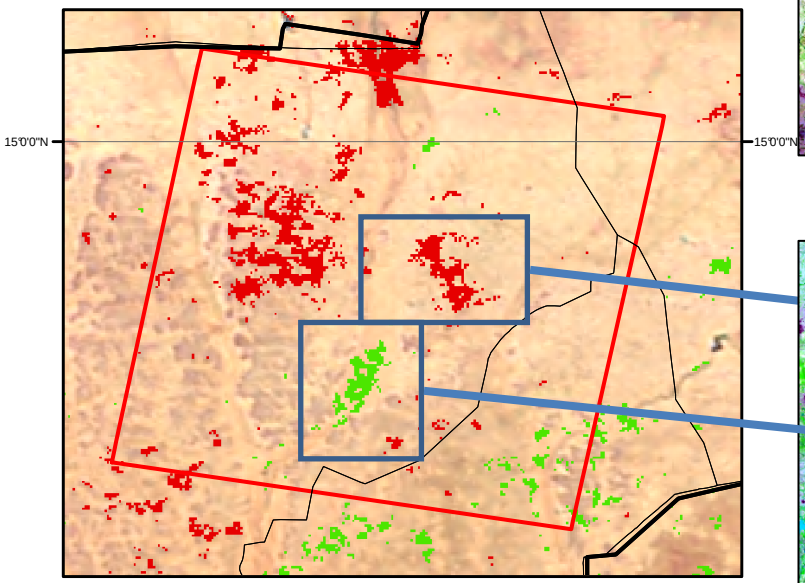


- Most of the areas present a **stable situation** at least in the last 13 years.
- **Climatic greening** can be identified north west (Mauritania , Senegal)
- **Climatic degradation** can not be appreciated at regional scale (1% in Nigeria).
- **Anomalous greening** mainly in the North-west part of Sahel (Mauritania and north Mali), central part of West Sudanian savanna (rain > 800 mm) and forested areas of East Sudanian savanna.
- **Anomalous degradation** located in the **central part of Sahel (**annual rainfall between 200 and 400 mm). **Niger and Chad hot spots** fall in the "Sahel's fragile high-risk zone" (ECOWAS 2006) suffering from both persistently low and very unpredictable rainfall.

For Niger in these areas livelihood crisis reported (FEW-NET, GIEWS) in the last ten years (2000, 2004, 2005 and 2010) suggesting likely **chronic environmental unfavorable conditions**.

Hot spot at Landsat TM: NIGER





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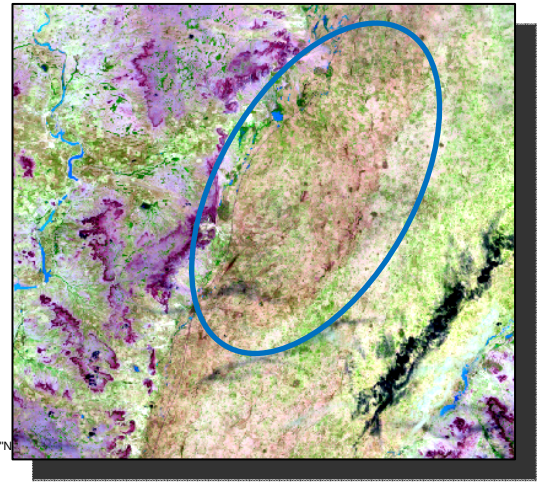

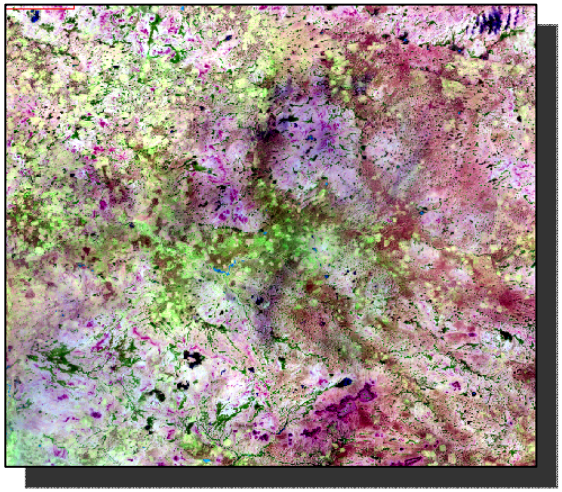

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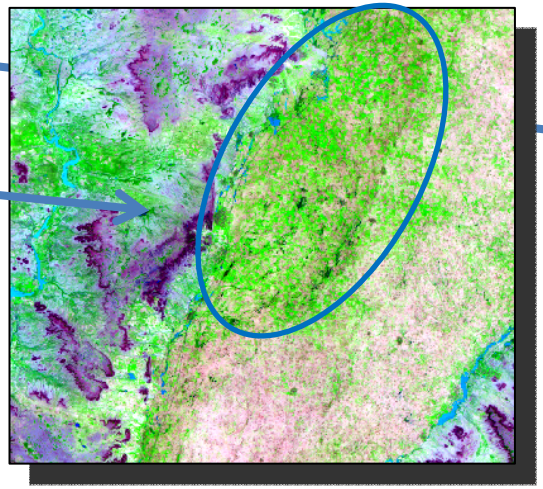
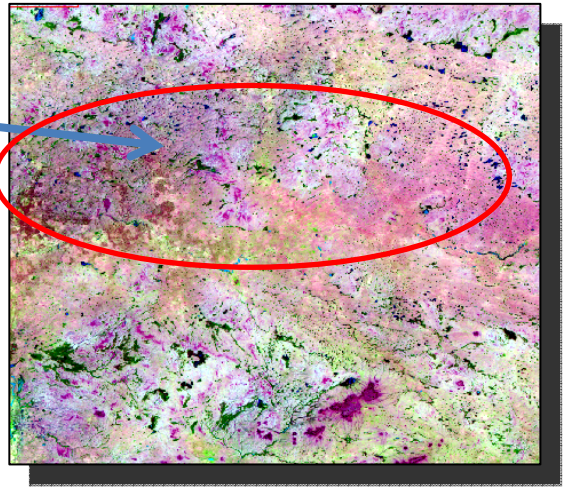
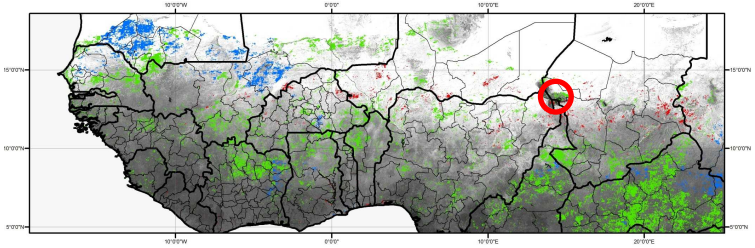
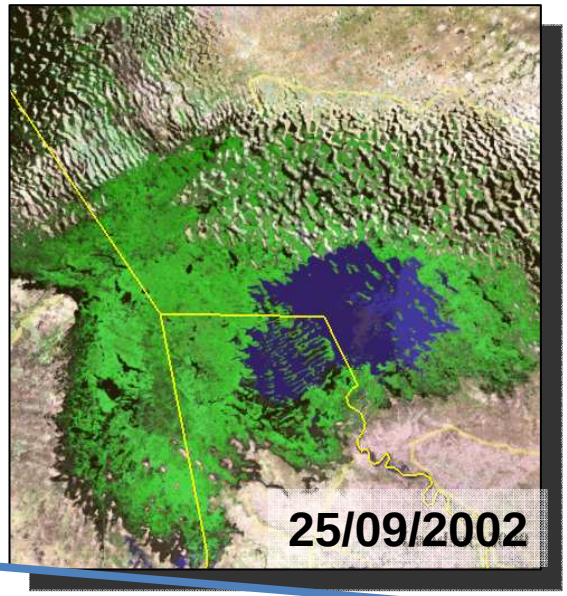
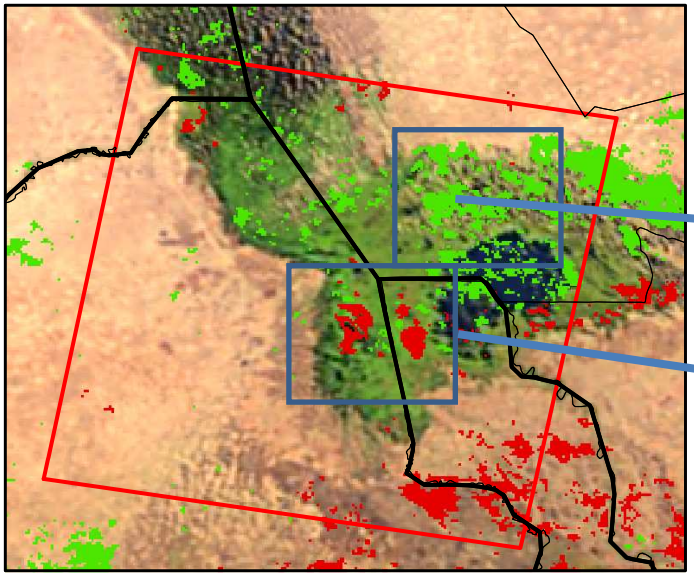


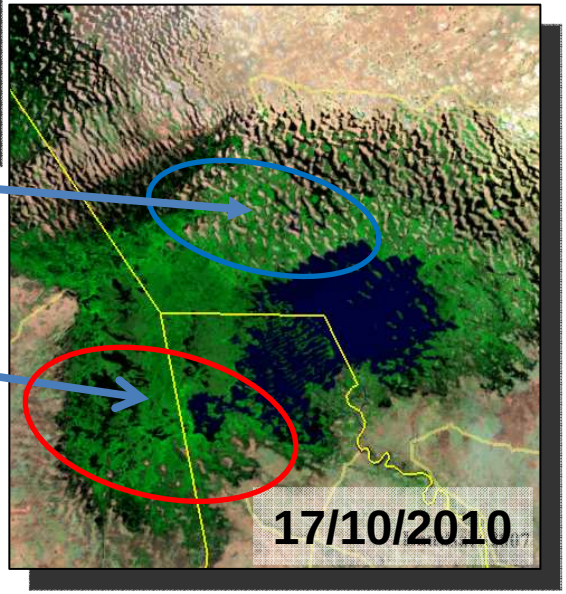


Hot spot at Landsat TM: Lake Chad



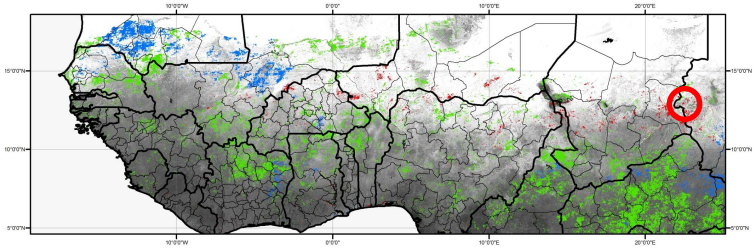


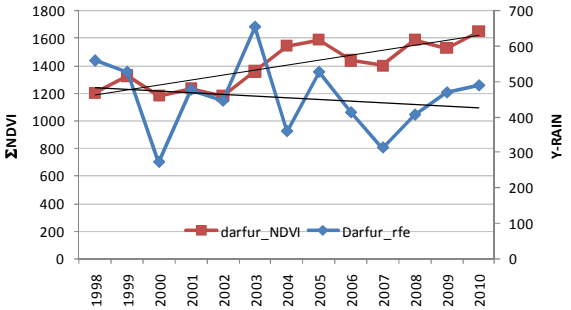


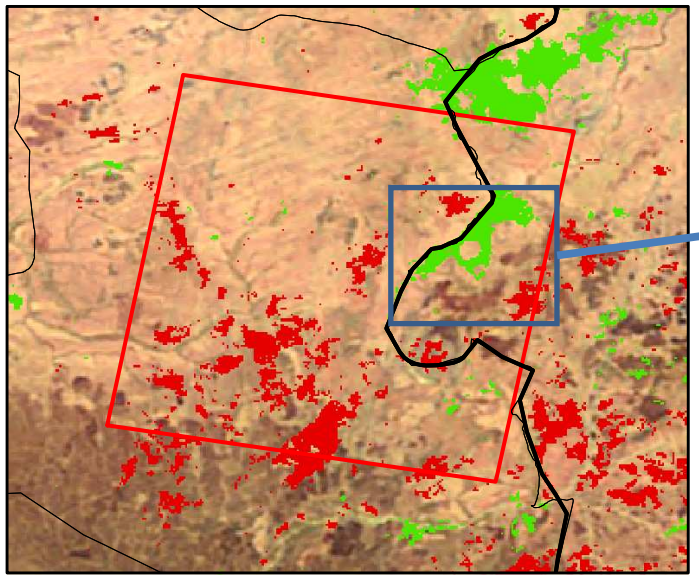


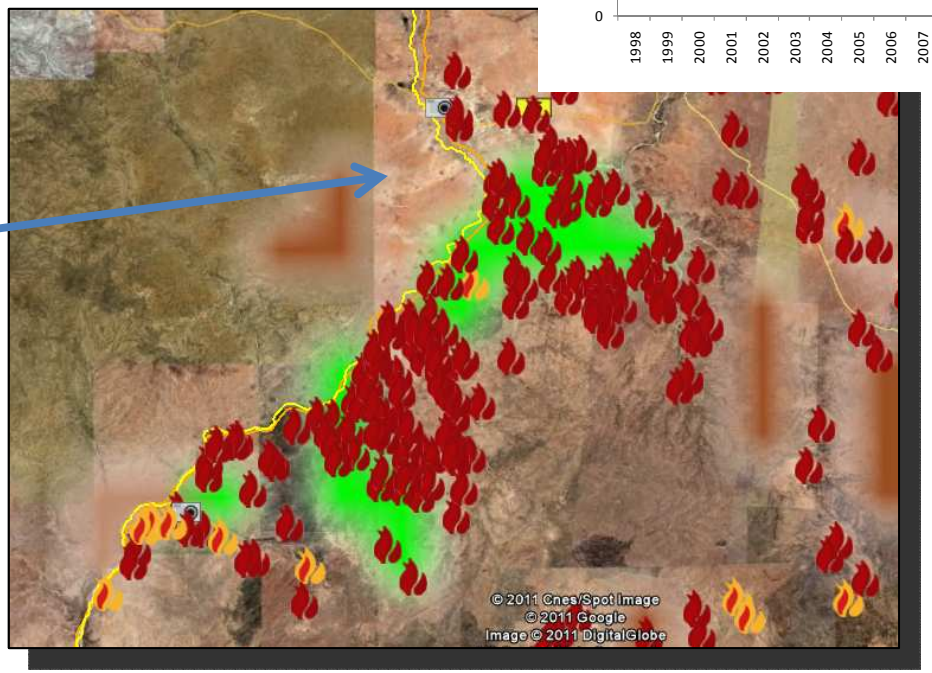
Anomalous greening in Darfur

Anomalous greening occurring after the 2004 -2006 Darfur crisis









Conclusions

Despite the documented occurrence of **re-greening** (1980-2000) the Sahel area continuously (recently) experienced **humanitarian crisis**.

• Our analysis (1998-2010) shows that **precipitations** are mainly **stable** and large portion of the **vegetation depends on climatic variability** (NDVI driven by changes in rainfall pattern).

• An **anomalous greening** (increase of NDVI where rains stable) was observed In the Southern part of the study area

• This phenomenon may be explained by improvement in management of cultivated areas by local populations in favorable climatic condition (*Closed to open scrubland* (GC) presents an expansion of agriculture in the period of analysis)

Hot spots of anomalous degradadtion are located mostly in agricultural-grazing areas of Niger and Chad (mixture of crop and grassland land cover classes)

✓ Locations where **vegetation** development is driven by factors other than climate (which interfere in the dynamics of plant development) are **more common in pasture** areas than in cropland.

✓ **Satellite derived maps** were found in good agreement **with humanitarian crises db** (critical areas identified in Niger are all within the crisis boundaries).

Thank you for your attention !

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