A joint analysis of crop production trends in Sahel using MODIS NDVI time series, crop modeling and statistic data

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Background of the study

Food security in West Africa

West Africa is characterized by:

- A strong climate variability in space and time
- High population growth rates

⇒ Impacts on agricultural production and on food security

**Challenge of West Africa**: Enhance knowledge on crop production dynamics both at regional and local scale
Background of the study

Agricultural monitoring in West Africa

Remote Sensing

- Crop conditions and trends
- Crop area
- Crop type

Crop area from MODIS land Cover

Potential millet yields for the rainy season 2012 (Agrhyrmnet, August 2012)
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- Crop conditions and trends
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Agricultural statistics
- Crop production
- Surface harvested yield

Aggregated data!

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- Crop conditions and trends
- Crop area
- Crop type

Agricultural statistics
- Crop production
- Surface harvested yield

Crop modeling
- Yield prediction
- Biomasse prediction
- LAI ...

Crop area from MODIS land Cover

Potential millet yields for the rainy season 2012 (Agrhymet, August 2012)
Question addressed:

What are the crop production dynamics in Sahel?
Objectives of the study

Question addressed:

What are the crop production dynamics in Sahel?

By performing a joint analysis of:

1. NDVI trends from remote sensing within the crop domain
2. Yield and biomass output trends from a crop model
3. Statistic data
Normalised Difference Vegetation Index : NDVI

Data

- NDVI product : MODIS MOD13Q1
- Sensitive to vegetation and its conditions
- Correlated to LAI, FAPAR and vegetation primary production

\[ \text{NDVI} = \text{proxy for vegetation greenness and biomass production} \]

Hypothesis : NDVI increase with green plant biomass
Normalised Difference Vegetation Index : NDVI

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Methods

1) Extraction of the crop domain : Application of an averaged crop mask (MODIS Land Cover Product) on annually integrated NDVI time series

2) Trends analysis by OLS (Ordinary Least Square Regression)

3) Anomalies
In situ observations from crop model and statistic data – Case study of the Kollo department (Niger)

**Statistic data**

**Millet Yield** – Aggregated at the Kollo department scale: 2000-2010 (AGRHYMET)
In situ observations from crop model and statistic data – Case study of the Kollo department (Niger)

**Statistic data**

**Millet Yield** – Aggregated at the Kollo department scale: 2000-2010 (AGRHYMET)

**Crop model: SARRA-H (Baron et al., 2005)**

- Suited for the analysis of climate impact on cereal growth and yield in dry environment
- Operating at daily time step
- Simulates attainable yields and biomass at the field scale under **climatic constraint**

![Graph](sarra-h.teledetection.fr)
In situ observations from crop model and statistic data – Case study of the Kollo department (Niger)

Crop model: SARRA-H (Baron et al., 2005)
**In situ observations from crop model and statistic data – Case study of the Kollo department (Niger)**

**Crop model: SARRA-H** *(Baron et al., 2005)*

**Data & Methods**

**Regional scale**

- **Type of soils**
  - Deep Sandy

- **Level of fertilization**

- **Seeding date**
  - Automatically simulating

- **Cultivated species and varieties**
  - Pearl Millet Hainy Kire

**Local scale**

- **Rainfall**
  - Rain gauge measurements
    - AMMA-CATCH (7 stations, 2000-2010)

- **Other climatic variables**
  - Humidity, temperature, wind, insolation

- **Climatic data**
  - AGRHYMET
    - (1 station, 2000 – 2010)

**SARRAH**

- **Attainable Yield**
  - Day of year

- **Attainable Biomass**
  - Day of year
What does vegetation monitoring by remote sensing tell us about crop production dynamics?
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**NDVI anomalies between 2000 and 2012**

**Regional scale**

**NDVI anomaly 2002**

**NDVI anomaly 2006**

**NDVI anomaly 2010**

**NDVI anomaly 2012**

Strong spatio-temporal variability of biomass production within the crop domain:

\[ \rightarrow \text{vegetation stress} \approx \text{decrease in biomass production} \]
What does vegetation monitoring by remote sensing tell us about crop production dynamics?

**NDVI trends between 2000 and 2010 in West Africa**

**NDVI MODIS trends – significant at 90%**

- **Stable overall trend**
What does vegetation monitoring by remote sensing tell us about crop production dynamics?

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- Identification of areas with:
  - a significant increase in biomass production
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- Identification of areas with:
  - a significant *increase* in biomass production
  - a significant *decrease* in biomass production
- North/South effect
- East/West effect
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**Study area**

- Centered on 13.5°N and 2.5°E
- Area of 10,000 km²
- Rainy season from June to September
  - 200-400mm/year
  - Sahelian climate
- Rainfed agriculture dominated by **pearl millet** (low input and low yield)

*Site instrumented since 1990’s: availability of climate and meteorological daily time series*
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NDVI trends between 2000 and 2010 in the Kollo department.
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NDVI trends between 2000 and 2010 in the Kollo department
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NDVI trends between 2000 and 2010 in the Kollo department

0 10 20 km
Are the SARRA-H simulated yields and biomass in agreement with estimation from remote sensing?
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At the site scale? *Between 2000 and 2010*
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NDVI trends between 2000 and 2010 in the Kollo department

R=0.08
R=0.19
R=0.28
Are the SARRA-H simulated yields and biomass in agreement with estimation from remote sensing?

NDVI trends between 2000 and 2010 in the Kollo department

- R = 0.08 (Strong negative trend)
- R = 0.19 (Moderate negative trend)
- R = 0.28 (Low negative trend)
- R = 0.53 (Moderate positive trend)
- R = 0.42 (Strong positive trend)
Are the SARRA-H simulated yields and biomass in agreement with estimation from remote sensing?

NDVI trends between 2000 and 2010 in the Kollo department

Data & Methods

Regional scale

Local scale
Are the SARRA-H simulated yields and biomass in agreement with estimation from remote sensing?

NDVI trends between 2000 and 2010 in the Kollo department

Poor agreement between simulated data and remote sensing at the site scale.
Are the SARRA-H simulated yields and biomass in agreement with estimation from remote sensing?

At the Kollo department scale? Between 2000 and 2010

Data aggregation of 7 stations

- No significant trends (pvalue>0.10)
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Both satellite and simulation observations show no significant trends

Good overall agreement
What do the statistics data say? Comparison between NDVI, simulated data and yields from AGRHYMET
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Comparison at the Kollo department scale - Between 2000 and 2010

- Statistic data show a positive but no significant trend of millet yields
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Comparison at the Kollo department scale- Between 2000 and 2010

- **Statistics vs Satellite**: Opposite trends
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Comparison at the Kollo department scale - Between 2000 and 2010

- Statistics vs Satellite: Opposite trends
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Comparison at the Kollo department scale - Between 2000 and 2010

- **Statistics vs Satellite**: Opposite trends
- **Statistics vs Simulation**: Overall the same year-to-year variability but opposite trends
What do the statistics data say? Comparison between NDVI, simulated data and yields from AGRHYMET

Comparison at the Kollo department scale- *Between 2000 and 2010*

- Moderate correlation between NDVI VS Yield statistics

\[ R = 0.30 \]
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Comparison at the Kollo department scale - Between 2000 and 2010

- Moderate correlation between NDVI VS Yield statistics

- No correlation between simulated data VS Yield statistics
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Opposite trends but no significant agreement
Conclusion and Perspectives

At regional scale

• Satellite observations show an overall stable dynamic of the crop vegetation between 2000 and 2010
  ✓ Limitations: Only 10 years of data
  ✓ What about the long term crop vegetation trends? (NDVI GIMMS3g)
Conclusion and Perspectives

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  BUT good agreement at the Kollo department scale.
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  - Use a crop mask with a better spatial accuracy
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    ✓ Use spatial rain data rather than local data
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- Poor agreement with statistic data
  - Weakness of aggregated statistic data: lack of spatial representativeness
Thank you for listening...