Topic: Soil salinity assessment using Sentinel2 satellite images in irrigated rice schemes of Niger

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1. Context

- Soil salinization is a major factor in soil degradation, particularly in irrigated and arid areas (FAO, 2017).
- Salinization is dynamic, 30% of irrigated land affected (FAO., 2002)
- Niger River bassin irrigated schemes in sahel arid zone no exception (ONAHA, 2011)
- Spatial distribution and intensity of this problem in the study area not quantified

1. Context (continued)

- Research on the recognition of saline soils by remote sensing as early as the 1990s

- Two potential methods for their recognition by remote sensing (Mougenot et al, 1993)
  - Surface condition of bare soil (salt efflorescence)
  - The behavior of vegetation affected by salinity

- Classical mono-date approach (e.g. Douaoui et al., 2010 in the Chéliff valley in Algeria)

- Limits of conventional approaches
  - Detection of very saline soils but confusion of intermediate salinity classes
  - Mono-date approach
    - (1) if there is vegetation, the bare soil is unobservable
    - (2) vegetation dynamics cannot be studied

1. Context (continued)

New generation of satellites

- Fine spatial and spectral resolutions → identify salinity variations
- High Satellite pass repetitiveness → temporal monitoring

New perspectives

- Locate saline areas
- Quantifying the salinity level in space
- Monitoring changes in the salinity of agricultural land over time

1. Context (continued)

Objectives

This study aims at developing a method for assessing salinity by remote sensing using multi-temporal images from the Sentinel2 satellite

Two approaches of soil salinity detection tested:

- Observation of salinity on bare soil using salinity index (SI)
- Monitoring over time of the vegetation dynamics to detect influence of soil salinity

2. Methodology

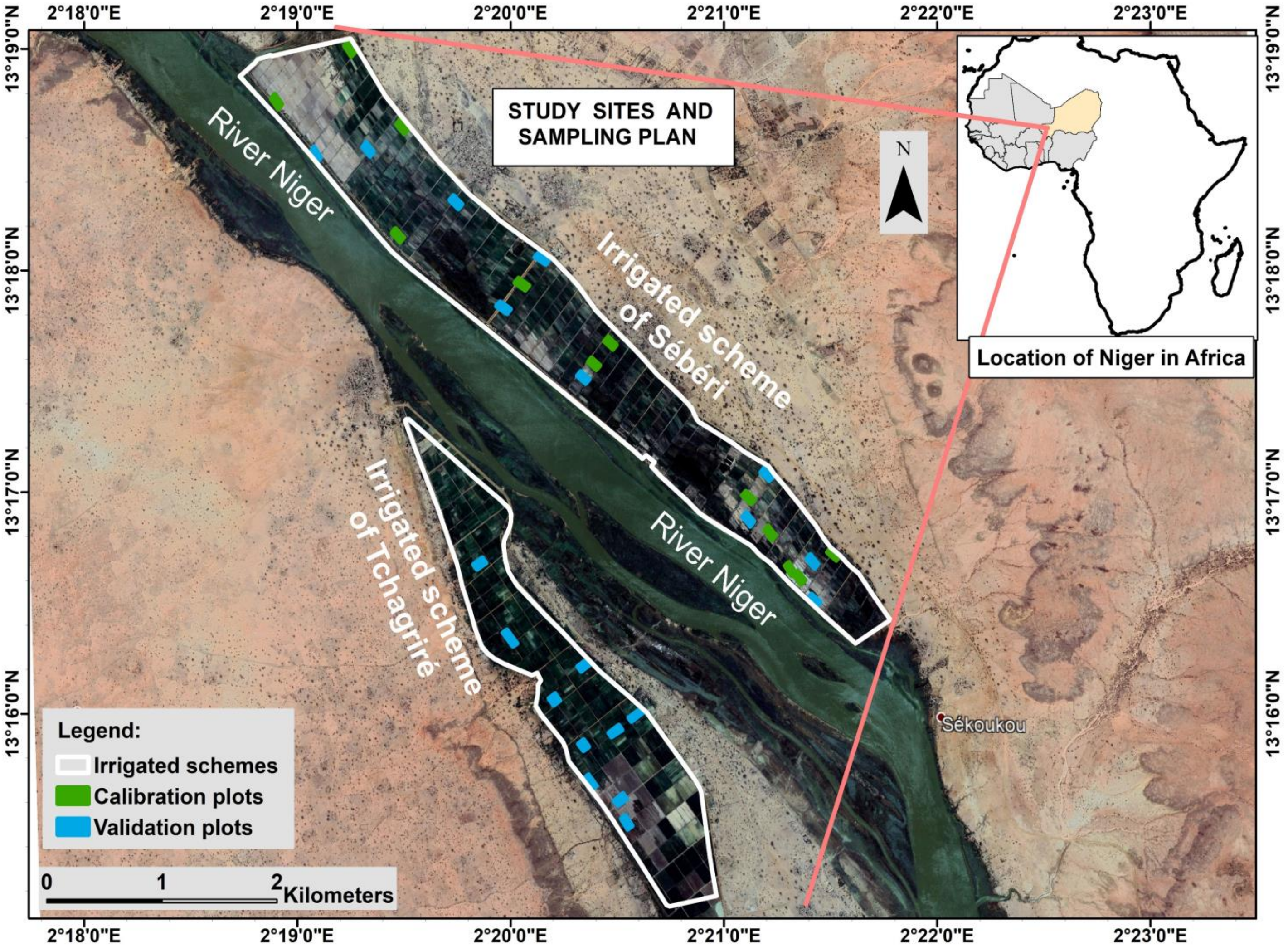


Figure 1: Location of study area and data collection plan

Study area:

- Seberi and Tchagriré irrigated scheme (= 6.5 km2) in River Niger bassin

Climate: semi-arid

- Monthly T° ranging from 25 °C to 45 °C
- Annual rainfall of 400 mm

- Rice is cultivated twice a year in dry and wet seasons.

Soil:

- Vertisol with clay content >80% marked by saline efflorescence on surface
- pH range from 3 to 5

2. Methodology

Field data collection in 2019

- Data collected from 64 plots of 0.25 ha at 4 dates in year 2019 dry season
  147 biomass samples and 64 grains yield samples collected
  118 soil samples analyzed for electrical conductivity (EC) and pH

Remote sensing data collection

- 157 pre-processed Sentinel2 images from January 2016 to December 2019
- normalized difference vegetation index (ndvi), salinity index (SI) calculated.
  NDVI = (NIR – Red) / (NIR +) (Scudero et al 2014)
  SI =(R / NIR) * 100

Download platform: https://theia.cnes.fr/

2. Methodology

Ndvi integral and mean SI calculation

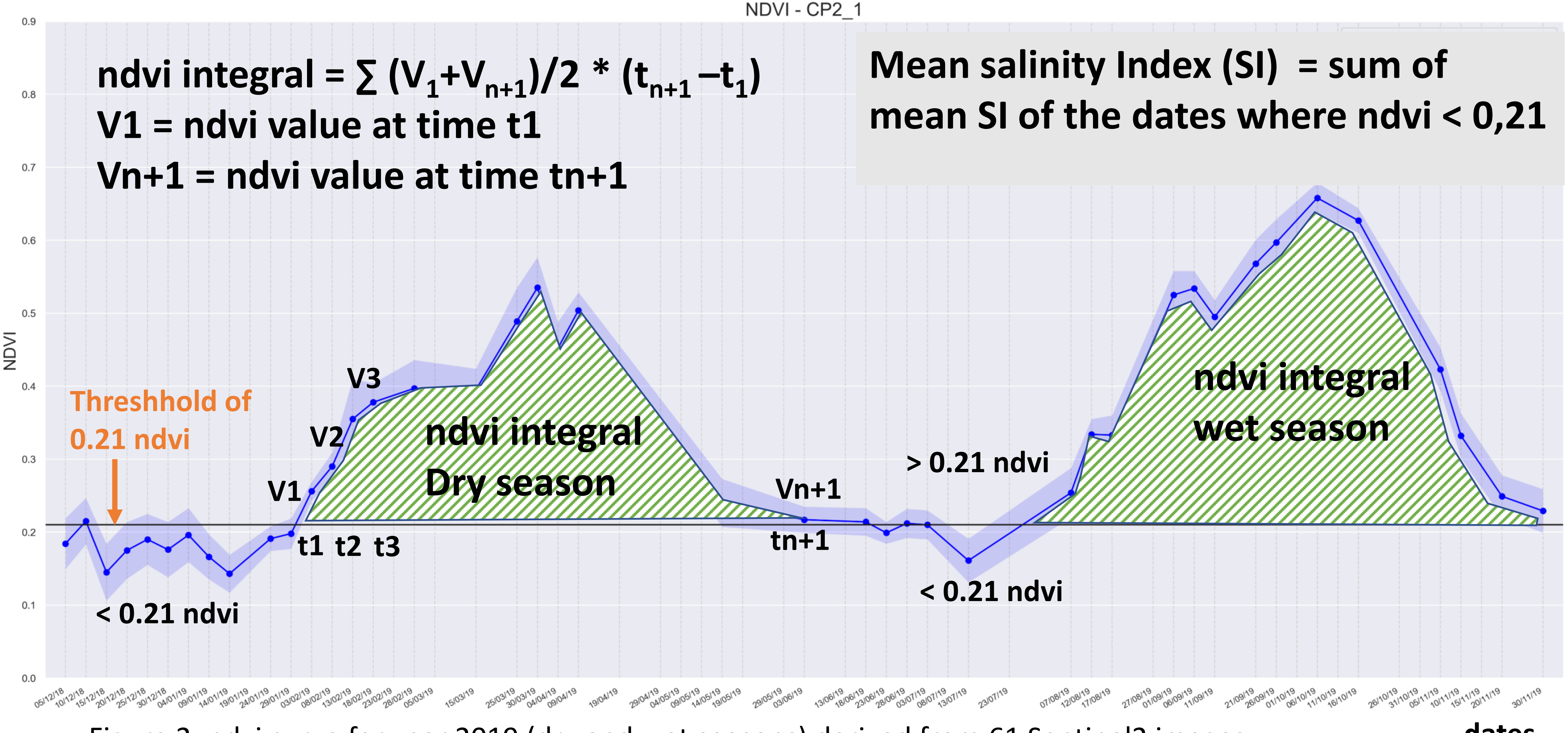


Figure 2: ndvi curve for year 2019 (dry and wet seasons) derived from 61 Sentinel2 images

Results : examples of NDVI evolution for 3 plots over 8 growing seasons

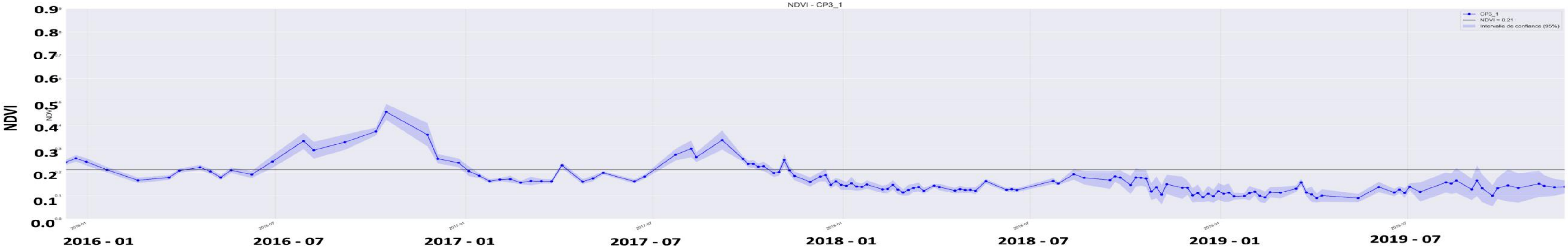


Figure 3: ndvi curve of a plot with ndvi always almost nil

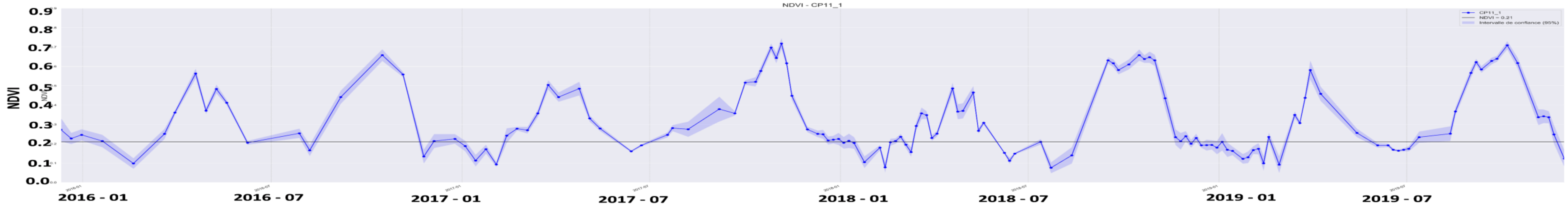


Figure 4: ndvi curve of a plot with low ndvi in dry season, higher in wet season

Figure 5: ndvi curve of a plot with high ndvi in dry season, and higher in wet season

Variation of ndvi integral at plot level for 8 growing seasons

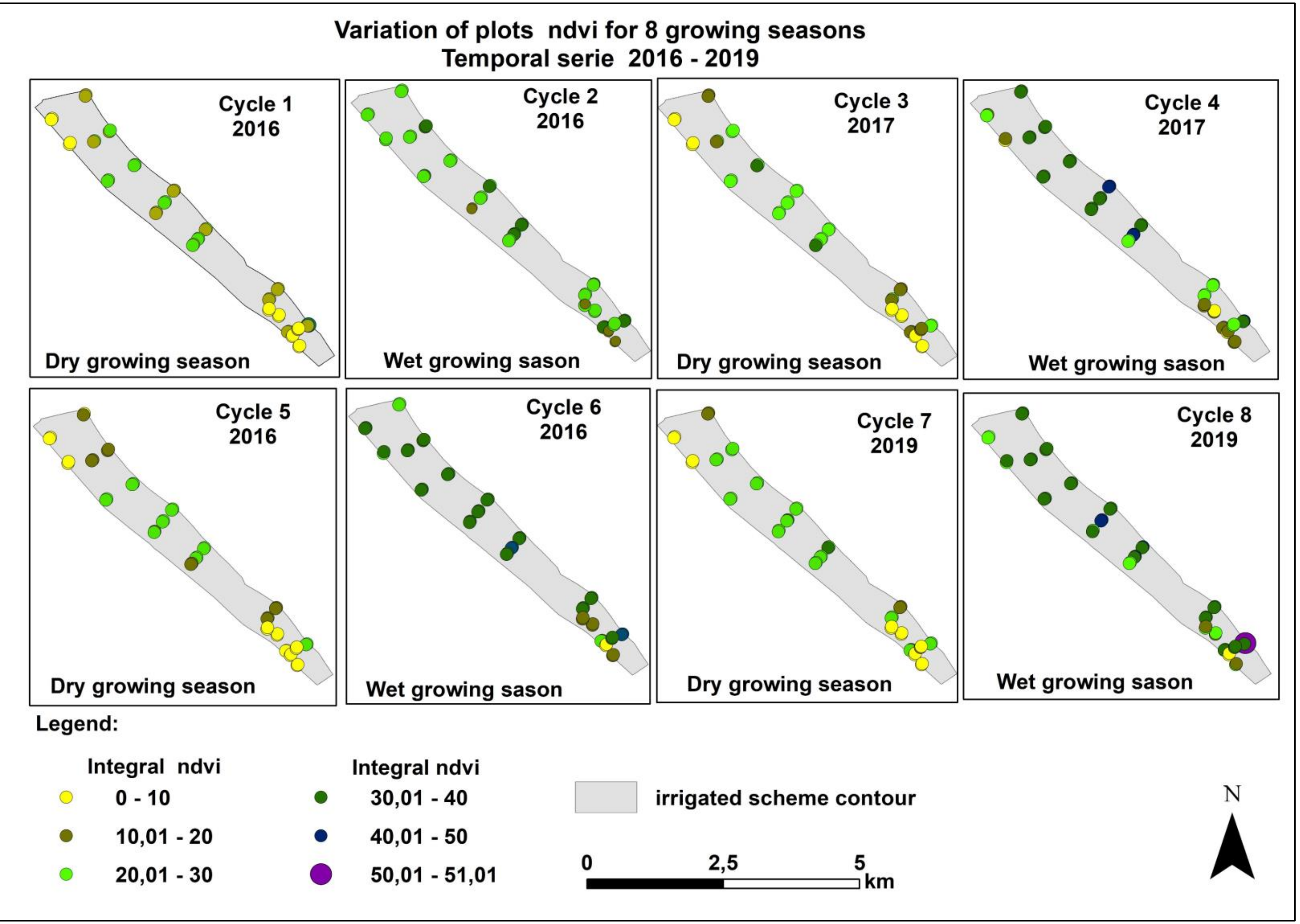
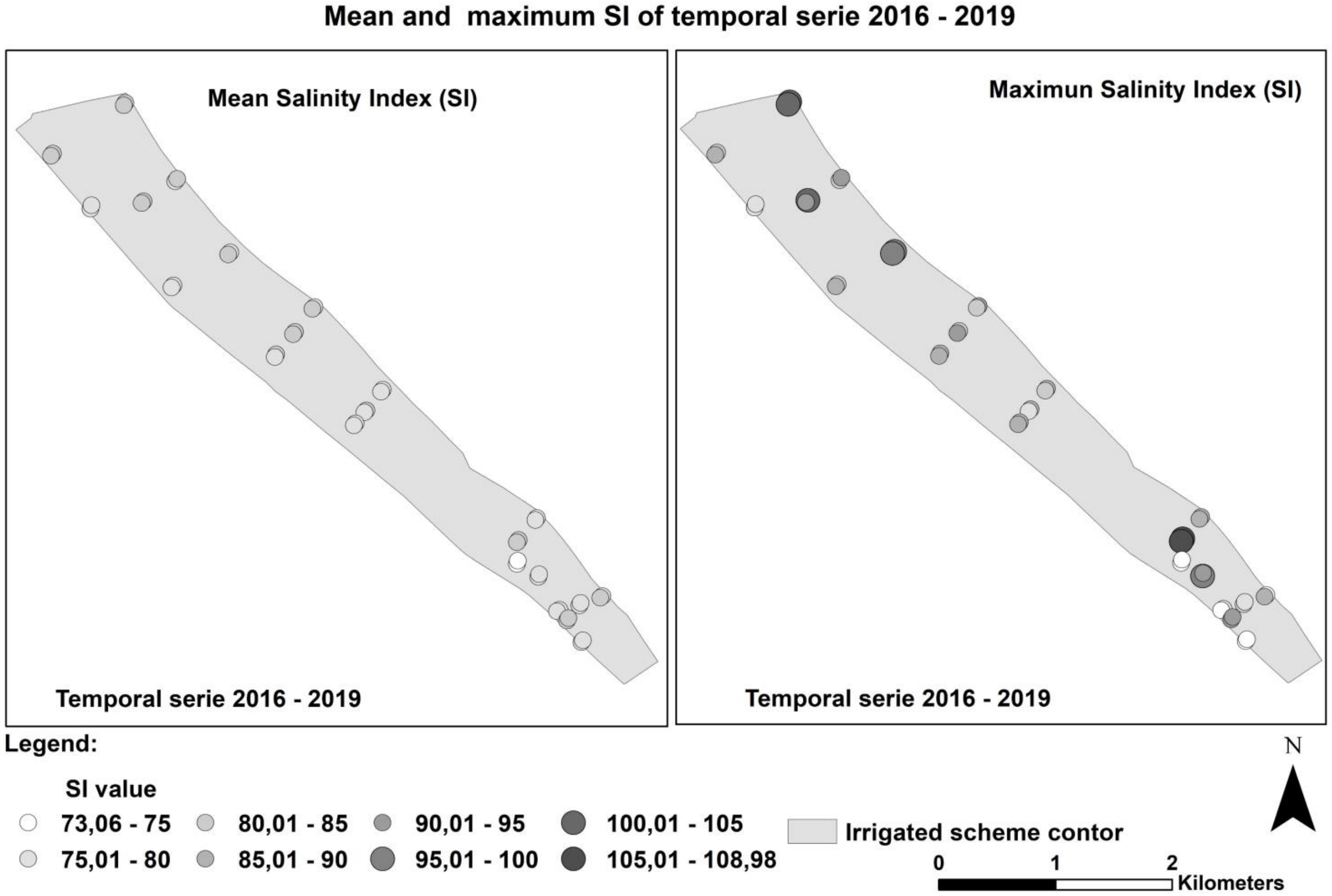


Figure 6: variation of ndvi integral between plots and for 8 growing seasons between 2016 and 2019

Dry season cycles show lower ndvi integral values than wet cycles

For a given growing season, uncultivated plots or plots cultivated with constraints (due to salinity) have lower values of ndvi

Mean and maximum salinity index over time at plot level



Mean and maximum salinity index of the plots (temporal serie 2016 – 2019)

The averages of salinity index SI within the plots do not show clear variations.

Maximum salinity index (SI) of the series are higher within plots not cultivated in all cycles of the series or at the level of plots with salinity constraints.

Summary:

ndvi integral and the maximum SI make it possible to differentiate the plots across the serie, but the mean SI does not.

PCA of spectral indices and field data variables

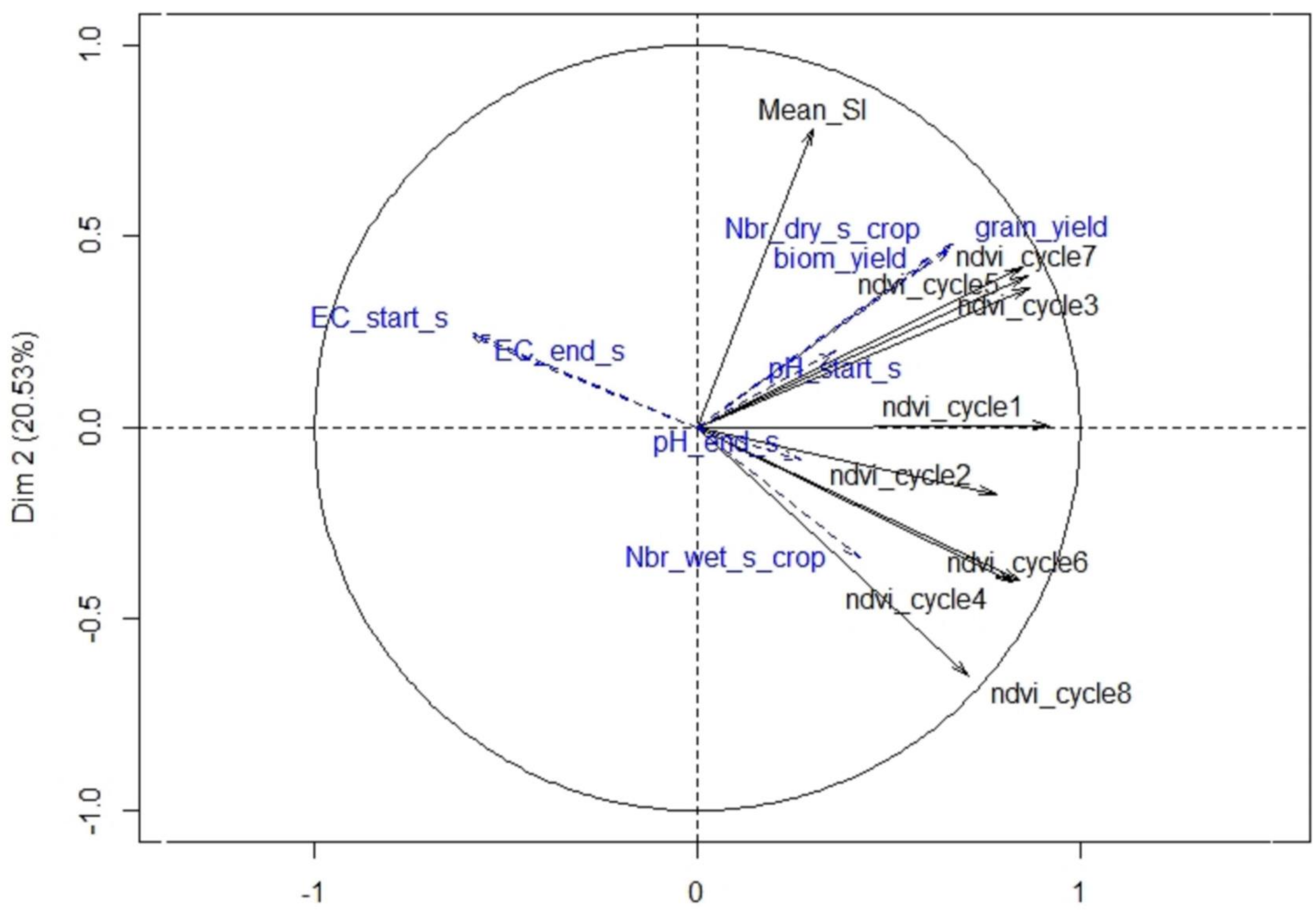


Figure 6: variables correlation circle (Dimension 1 and 2 plan of PCA)

Mean SI better linked with the dry season remote sensing and field data.

Dry cycles season remote sensing data correlated with field data

Wet season remote sensing data correlated to each other and pH of ending season.

Electrical conductivity negatively correlated with remote sensing and field data.

Typology of the spectral indices of the selected plots

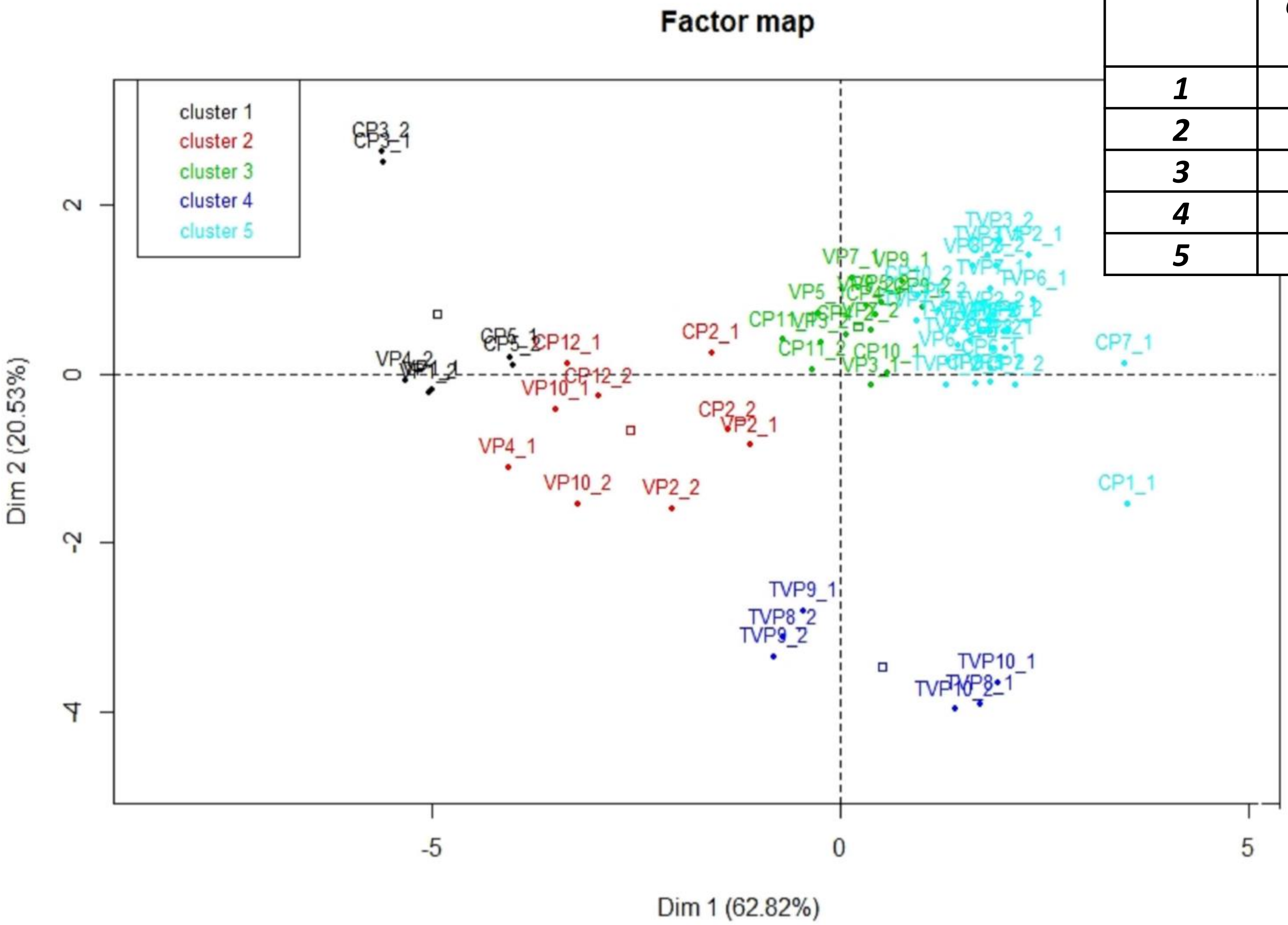


Figure 7: Plot of clusters on axis 1 and 2 of PCA plan
Based on remote sensing informations and field data 2019 dry season

Table 1: statistics of the 5 clusters

Clusters	*Mean ndvi integral dry seasons 2016 - 2019*	*Mean ndvi integral wet seasons 2016 – 2019*	*Mean salinity index SI 2016 - 2019*	*Mean EC class (dS/m2)*	*Mean pH class*
1	*1.06*	*12.78*	*73*	*2.60*	*4.96*
2	*5.24*	*25.54*	*72.5*	*0.60*	*5.50*
3	*19.68*	*30.60*	*75*	*0.02*	*5.71*
4	*10.15*	*44.57*	*70*	*0.09*	*5.19*
5	*25.38*	*35.93*	*75*	*0.06*	*5.65*

Cluster 1: non cultivated - very saline soil

Cluster 2: non cultivated areas in dry seasons - saline soils

Clusters 3 and 4: cultivated areas with stress on rice (moderate NDVI integral) - possibly slightly saline

Cluster 5: cultivated areas with good rice development (high ndvi integral for all seasons) - non saline soils

Supervised classification of the NDVI-integral clusters at scheme scale

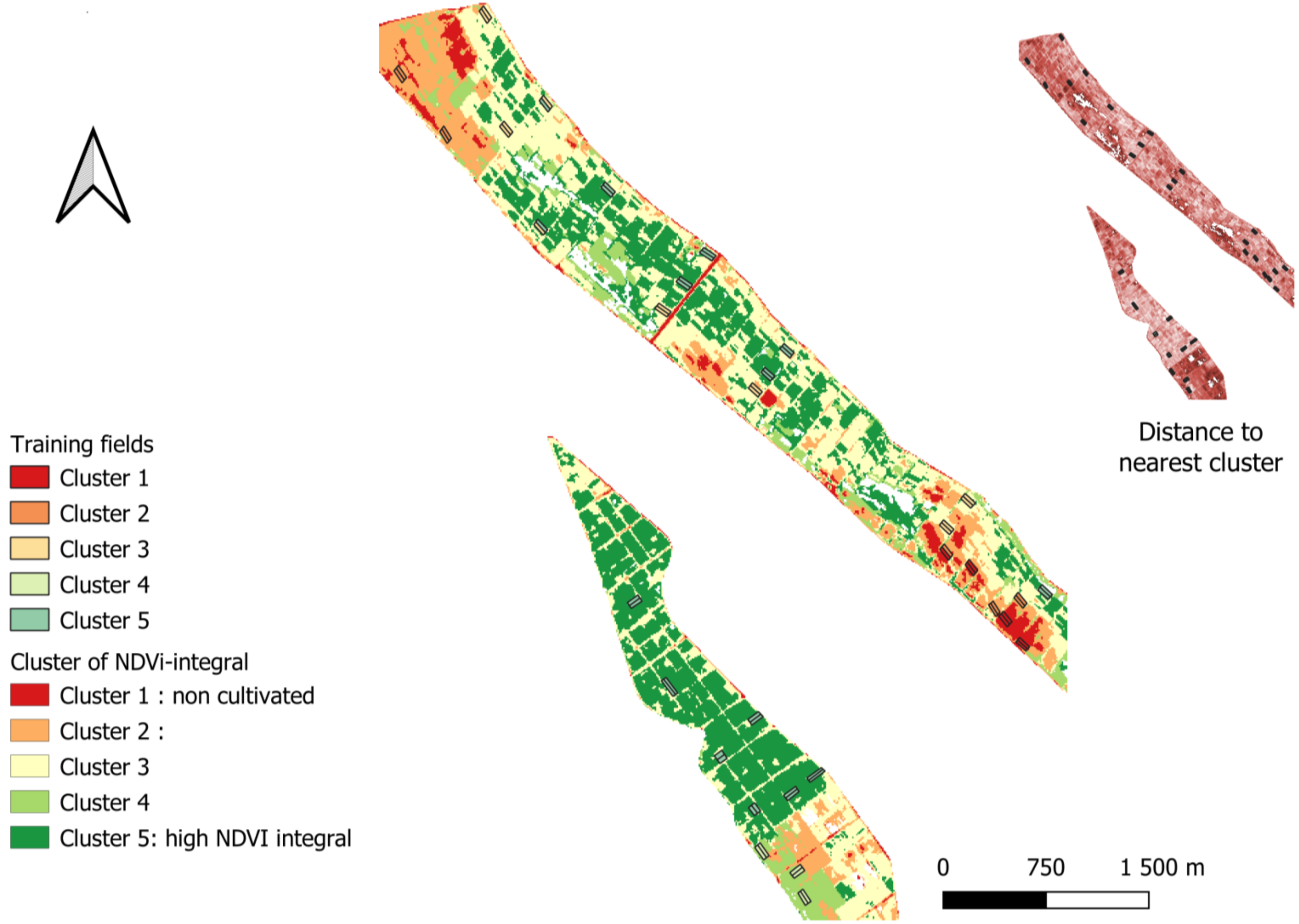


Figure 8: Classification of NDVI-integral clusters over 4 years temporal serie (2016 – 2019)

Cluster 1: non cultivated plots in very saline soils

Cluster 2: non cultivated plots in dry seasons in saline areas

Clusters 3 and 4: cultivated plots with stress in possibly slightly saline soil

Cluster 5: cultivated plots in dry and wet seasons. Well growth of rice in non saline areas

4. Conclusions

- Dense time series of Sentinel2 images over 8 growing seasons enabled to describe the rice vegetation behaviour and to distinguish areas where the crop is submitted to stresses over the growing cycles

- Periods of bare soil were limited in time and soil salinity indexes derived from Sentinel 2 images could not differentiate soil salinity levels

- Several constraints can occur in areas submitted to stresses, but can locally be linked to soil salinity by field sampling, which can be guided by NDVI-integral classification

- The approach is particularly adapted to irrigated rice schemes where monoculture prevail and NDVI variations are not linked to different crops

Thank You For Your Attention