CEOS Recovery Observatory

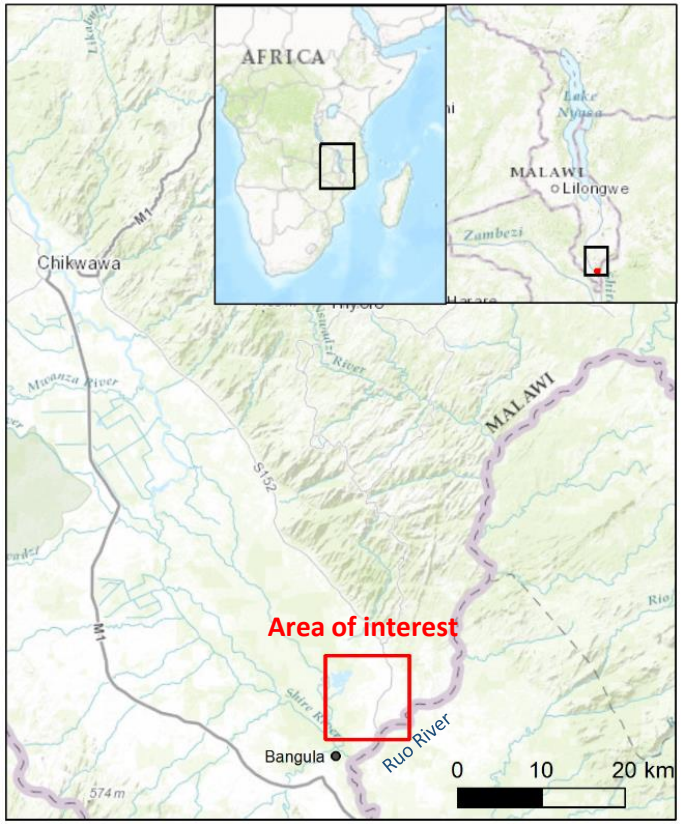
MALAWI DEMONSTRATOR – October 2016

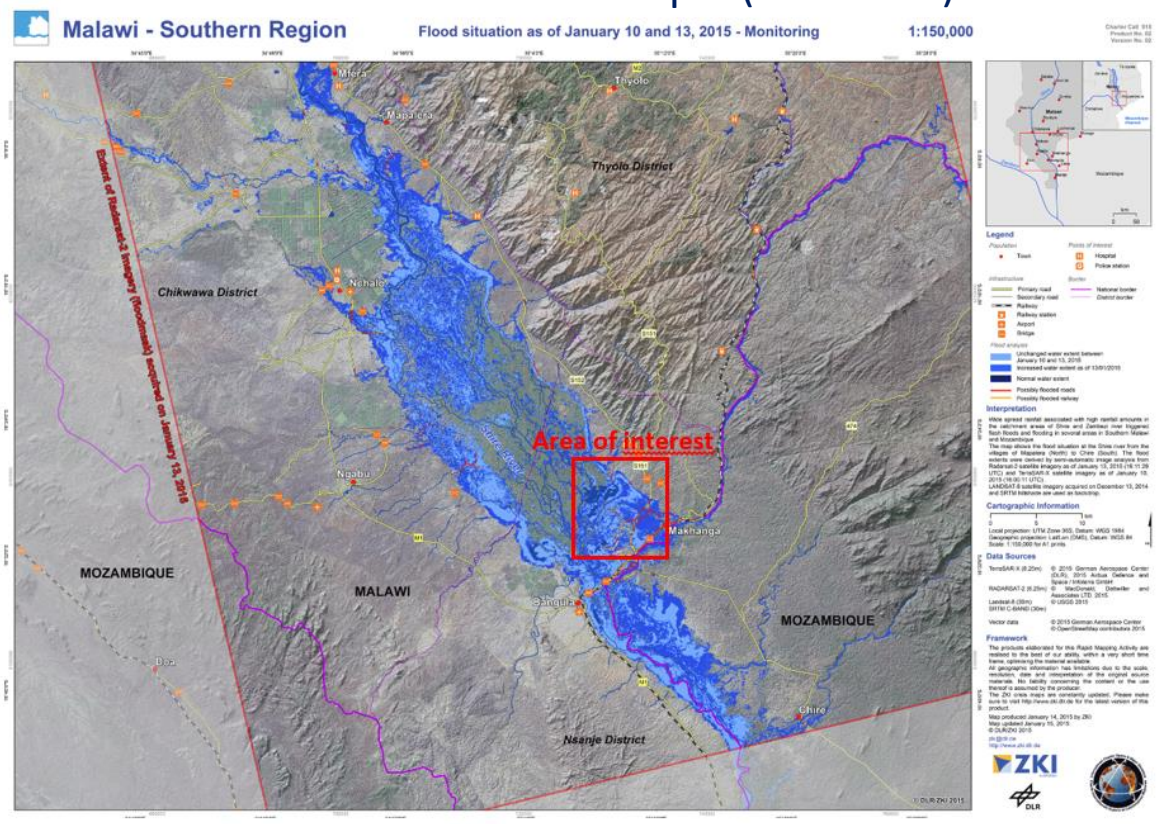
Agriculture monitoring in the Elephant Marsh area between 2013 and 2016

1. Context and overview of the study

Area of interest

- January 2015, severe rainfall caused historical flooding in Malawi
- Charter is triggered the 8th of January by the Department of Disaster Management Affairs of Malawi
- Elephant Marsh : wetland where the fishery and agriculture are crucial livelihoods for the local communities
- Area 10 km x 10km at the border between Malawi and Mozambique (Ruo River)





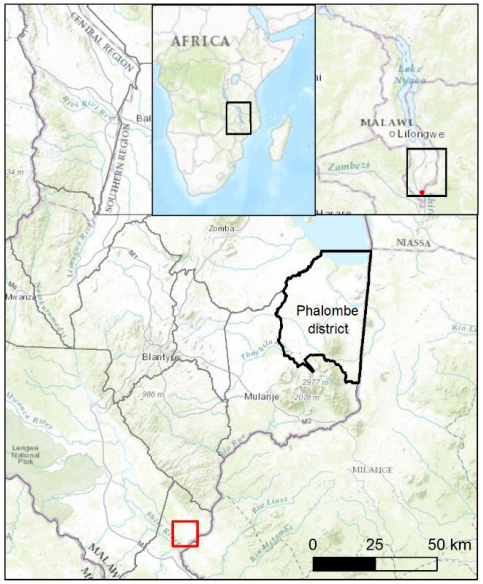
What the landscape in the abandoned agricultural area looks like.
Alluvial deposits and traces of crops in still humid areas are clearly visible (19th March 2015).

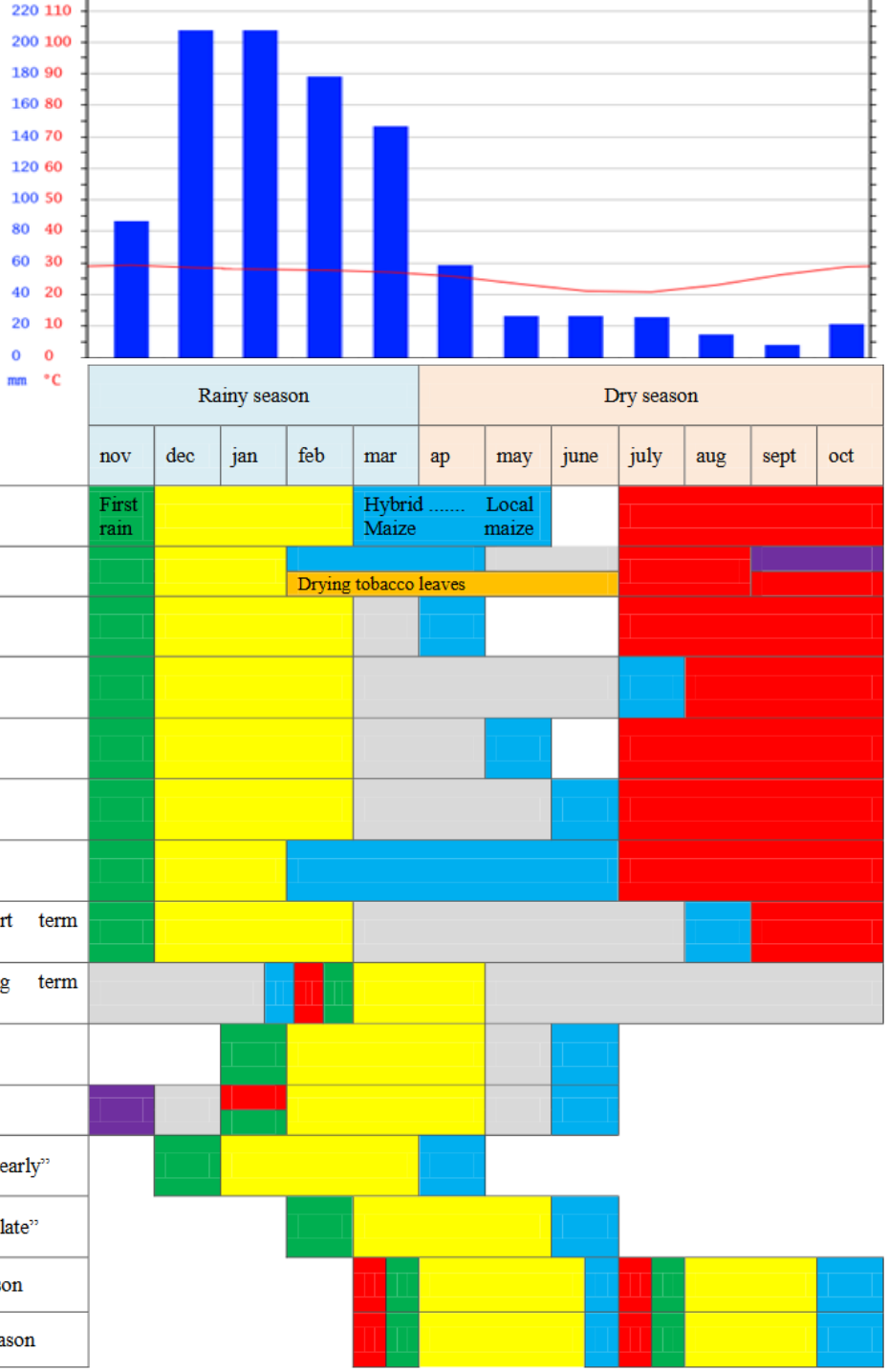
1. Context and overview of the study

Agriculture in the area

- Small-scale farm sector
- Subsidence agriculture

Crop calendar in the Phalombe District





1. Context and overview of the study

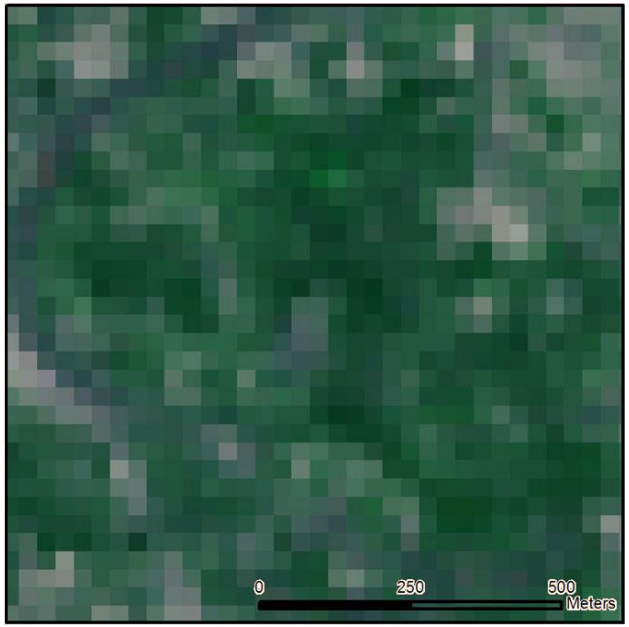
Imagery used

SPOT-6
Pixel size: 6 m
25/07/2015

PAN 1.5 m
MS 6 m (3 VIS, 1 NIR)
Tasking on-demand

Sentinel-2
Pixel size: 10 m
30/07/2016

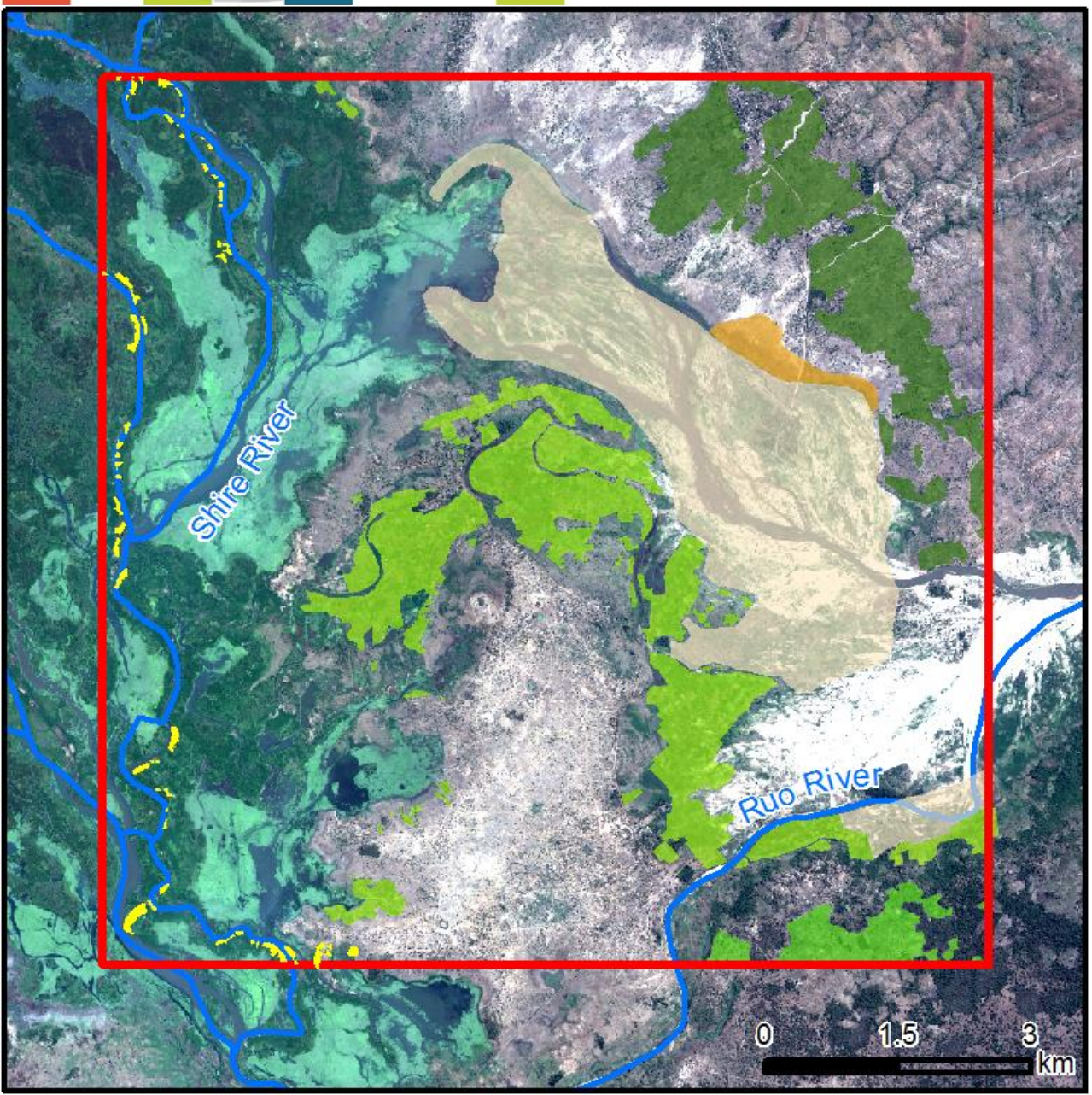
MS 10 m (3 VIS, 1 NIR)
MS 20 m (4 NIR, 2 SWIR)
MS 60 m (1 VIR, 1 NIR, 1 SWIR)
Systematic acquisition



Landsat-8
Pixel size: 30 m
25/07/2015

PAN 15 m
MS 30 m (4 VIS, 1 NIR, 2 SWIR)
MS 100 m (2 TIRS)
Systematic acquisition

2. Delineation of agricultural areas (SPOT-6)



Interpretation

- Small isolated agricultural area
- Large agricultural areas. High density foliage and geometric patterns
- Large agricultural areas. No active vegetation but geometric patterns.
- Large agricultural areas in Mozambique. No active vegetation but geometric patterns. Isolated trees. Forest clearings
- Large area of abandoned agricultural land, covered by alluvial deposits. Agricultural area most affected by the 2015 floods
- Small abandoned irrigated area (rice)

3. Studying flood impact on agricultural areas (L8)

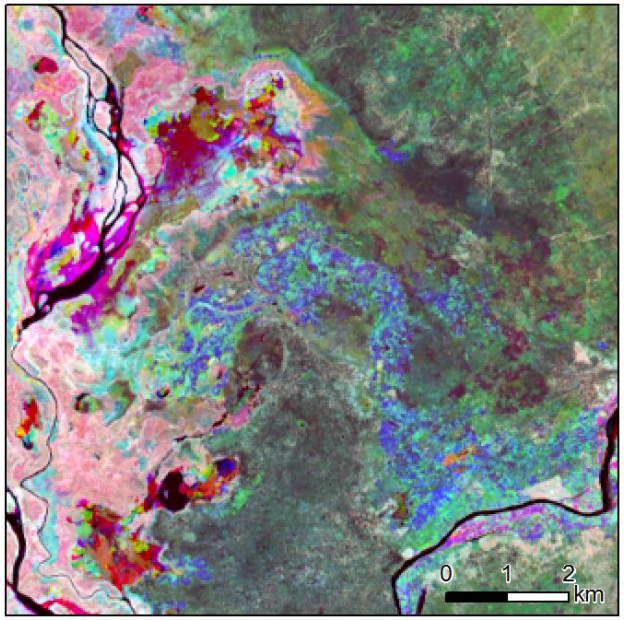
Data selection

- Selection of consistent dates between agricultural seasons to facilitate the comparison between them

	Observation 1	Observation 2	Observation 3
2013 - 2014	10/12/2013	04/06/2014	07/08/2014
2014 - 2015	13/12/2014	07/06/2015	25/07/2015
2015 - 2016	14/11/2015	24/05/2016	27/07/2016

3. Studying flood impact on agricultural areas (L8)

Processing



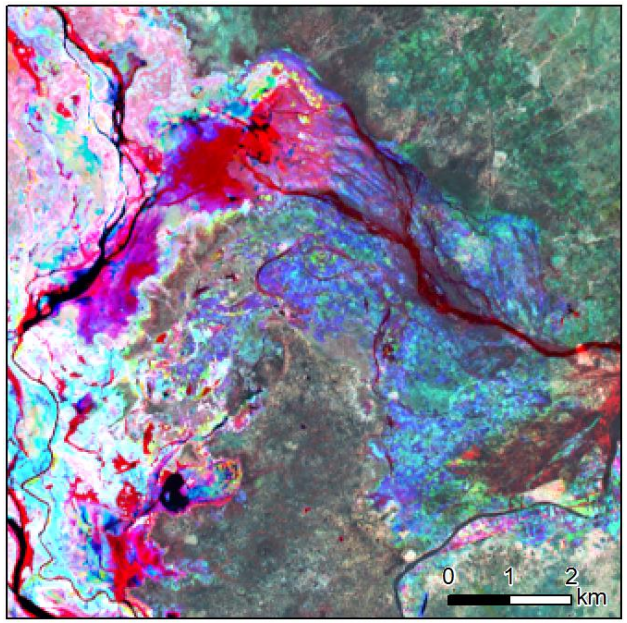
Season 2013 - 2014

Coloured composition

Blue band : 10/12/2013

Green band : 04/06/2014

Red band : 07/08/2014



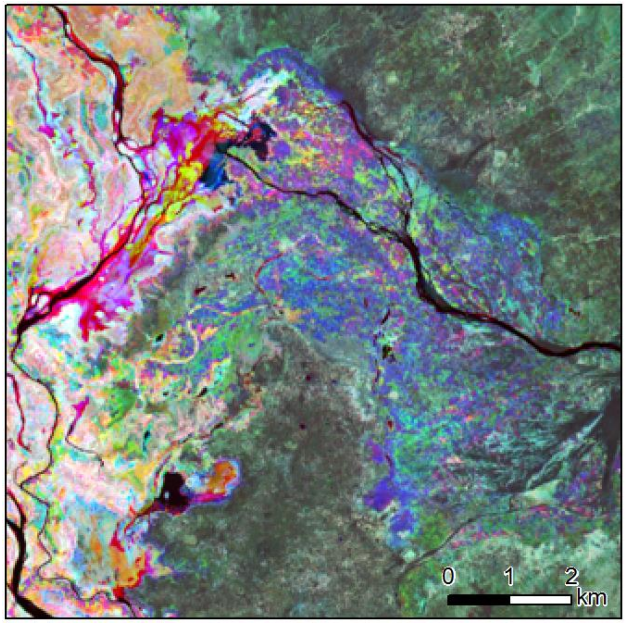
Season 2014 - 2015

Coloured composition

Blue band : 13/12/2014

Green band : 07/06/2015

Red band : 25/07/2015



Season 2015 - 2016

Coloured composition

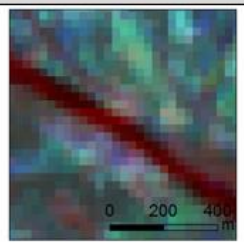
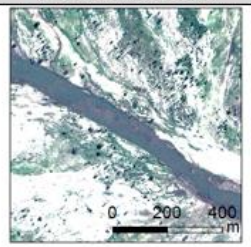
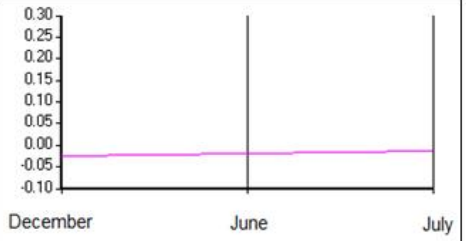
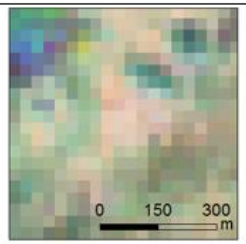
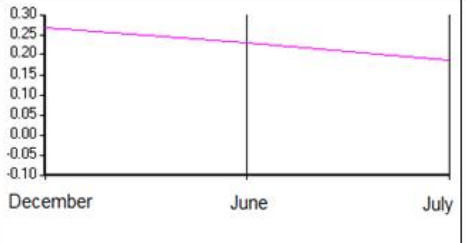
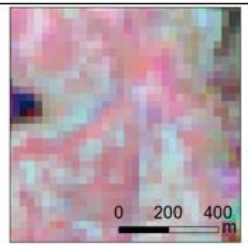
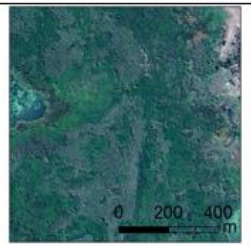
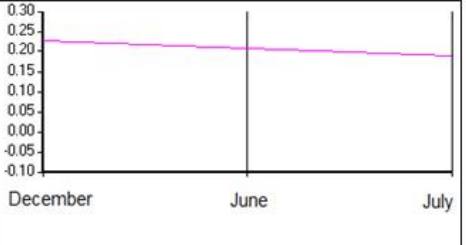
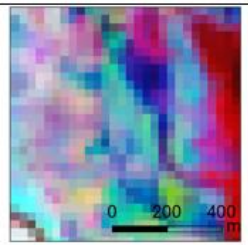
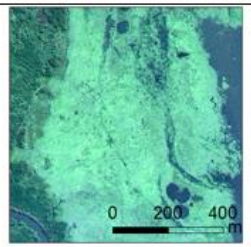
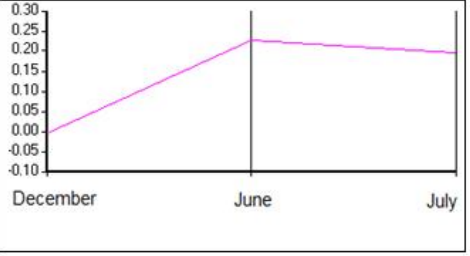
Blue band : 14/11/2015

Green band : 24/05/2016

Red band : 27/07/2016

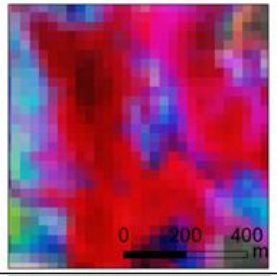
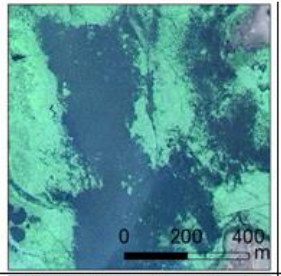
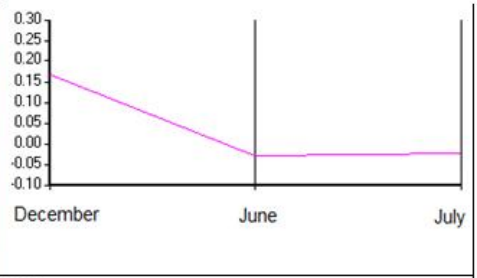
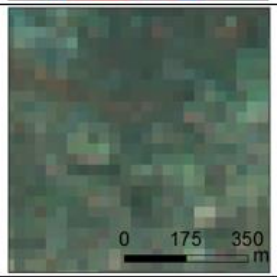
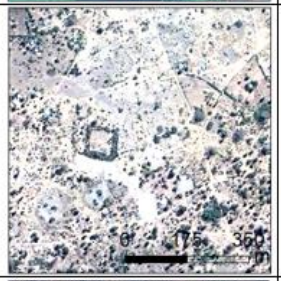
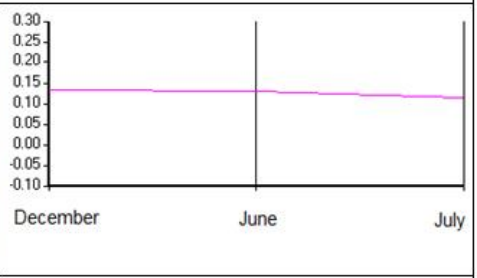
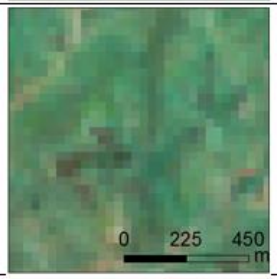
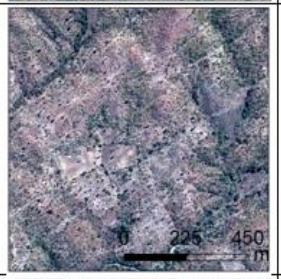
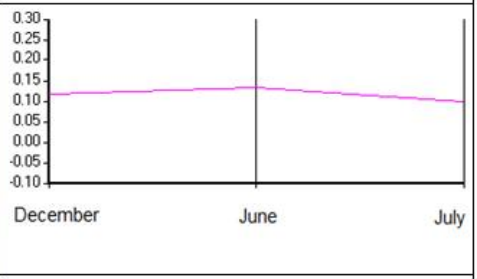
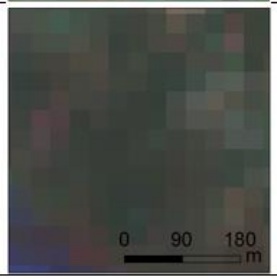
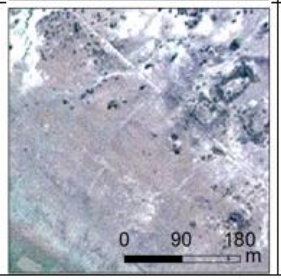
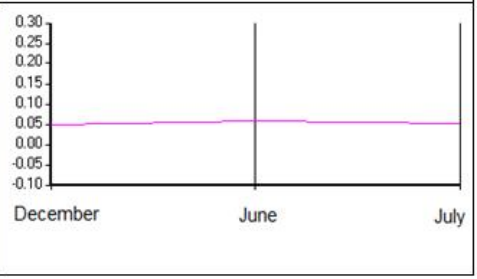
3. Studying flood impact on agricultural areas (L8)

Land-use description

ID	Short name	Description	As seen on Landsat 2014 - 2015 time series	As seen on SPOT-6 imagery (natural colours)	Typical temporal profile of Landsat 8 EVI's
0	PERMWA	Permanent water. Water seen on all 3 images in the agricultural season			
1	FOREST	Forest			
2	WETLAND	Wetland (not cultivated)			
3	SUBMER1	Wetland observed submerged on 1 image per season			

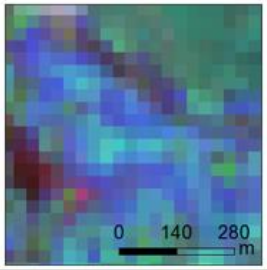
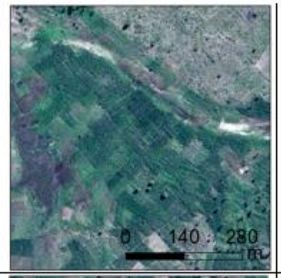
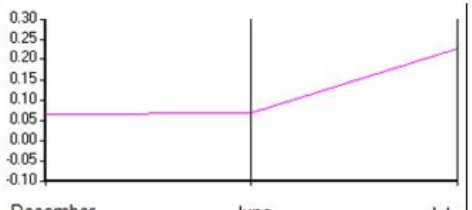
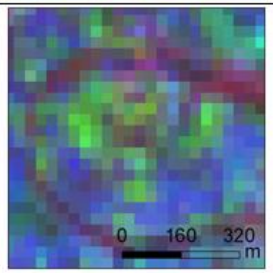
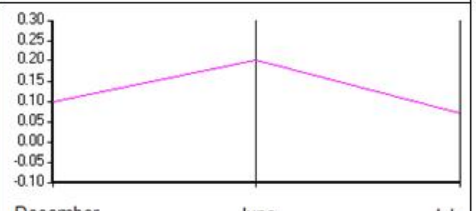
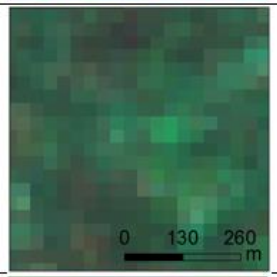
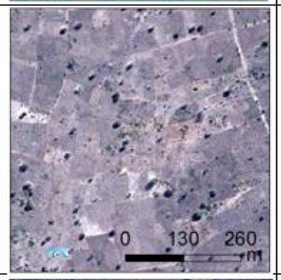
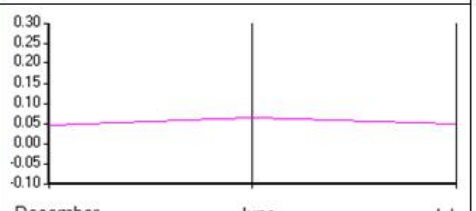
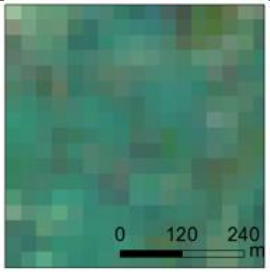
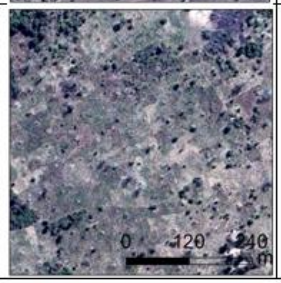
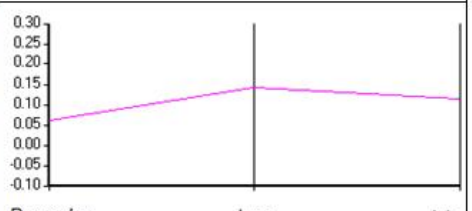
3. Studying flood impact on agricultural areas (L8)

Land-use description

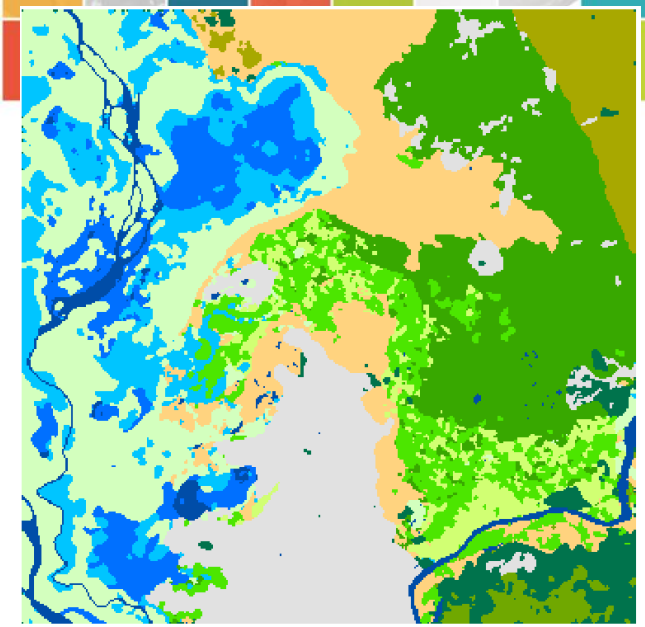
4	SUBMER2	Wetland observed submerged on 2 images per season			
5	POPULA	Sparsely populated area			
6	BUSH	Bush			
7	SOIL	Heterogeneous area, majority of bare soil and alluvial deposits			

3. Studying flood impact on agricultural areas (L8)

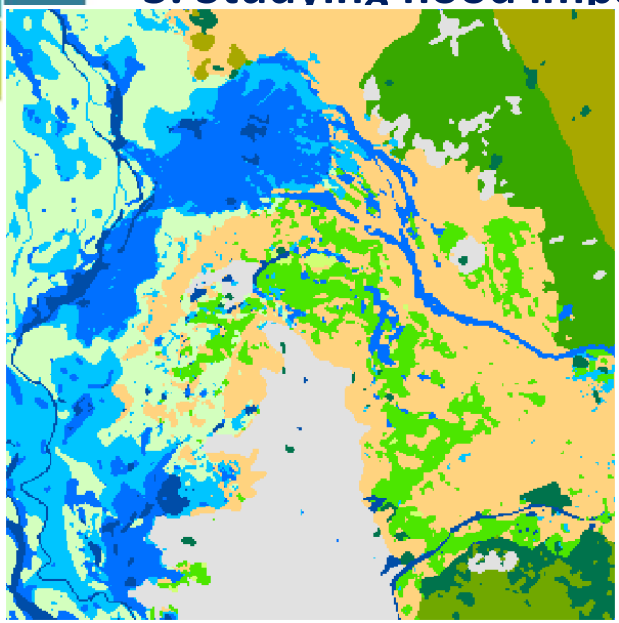
Land-use description

8	CROPS1	Crops type 1			
9	CROPS2	Crops type 2			
10	CROPS3	Crops type 3			
11	CROPS4	Crops type 4			

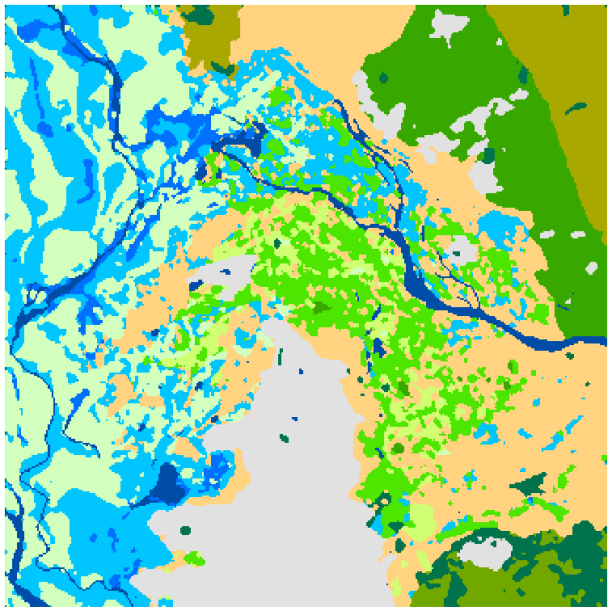
3. Studying flood impact on agricultural areas (L8)



Season 2013 - 2014
Baseline



Season 2014 - 2015
Critical flooding early 2015



Season 2015 - 2016
Severe drought

Large variations are the trends to focus on

			Area (ha)		
ID	Short name	Description	2013 - 2014	2014 - 2015	2015 - 2016
0	PERMWA	Permanent water	271	269	304
1	FOREST	Forest	355	248	243
2	WETLAND	Wetland (not cultivated)	1812	1321	1483
3	SUBMER1	Wetland observed submerged once	913	1062	1665
4	SUBMER2	Wetland observed submerged twice	642	1155	233
5	POPULA	Sparsely populated area	1319	1286	1340
6	BUSH	Bush	391	405	452
7	SOIL	Heterogeneous area, majority of bare soil and alluvial deposits	1320	2420	2127
8	CROPS1	Crops type 1	709	770	855
9	CROPS2	Crops type 2	399	22	286
10	CROPS3	Crops type 3	1723	836	824
11	CROPS4	Crops type 4	126	185	166
		Total	**9980**	**9980**	**9980**

3. Studying flood impact on agricultural areas (L8)

Cross-tabulated land-use statistics

- Changes between 2013-2014 and 2014-2015 seasons - Flooding period

< 5 %
>= 5 % and < 10 %
>= 10 % and < 25 %
>= 25 % and < 50 %
>= 50 % and < 75 %
>= 75 % and < 95 %
>= 95 %

13-14 \ 14-15	0 PERMWA	1 FOREST	2 WETLAND	3 SUBMER1	4 SUBMER2	5 POPULA	6 BUSH	7 SOIL	8 CROPS1	9 CROPS2	10 CROPS3	11 CROPS4
0 PERMWA												
1 FOREST												
2 WETLAND												
3 SUBMER1												
4 SUBMER2												
5 POPULA												
6 BUSH												
7 SOIL												
8 CROPS1												
9 CROPS2												
10 CROPS3												
11 CROPS4												

3. Studying flood impact on agricultural areas (L8)

Cross-tabulated land-use statistics

- Changes between 2014-2015 and 2015-2016 - Recovery period

	< 5 %
	>= 5 % and < 10 %
	>= 10 % and < 25 %
	>= 25 % and < 50 %
	>= 50 % and < 75 %
	>= 75 % and < 95 %
	>= 95 %

14-15 \ 15-16	0 PERMWA	1 FOREST	2 WETLAND	3 SUBMER1	4 SUBMER2	5 POPULA	6 BUSH	7 SOIL	8 CROPS1	9 CROPS2	10 CROPS3	11 CROPS4
0 PERMWA												
1 FOREST												
2 WETLAND												
3 SUBMER1												
4 SUBMER2												
5 POPULA												
6 BUSH												
7 SOIL												
8 CROPS1												
9 CROPS2												
10 CROPS3												
11 CROPS4												

3. Studying flood impact on agricultural areas (L8)

Cross-tabulated land-use statistics

- Changes between 2013-2014 and 2015-2016 - pre/post flooding

	< 5 %
	>= 5 % and < 10 %
	>= 10 % and < 25 %
	>= 25 % and < 50 %
	>= 50 % and < 75 %
	>= 75 % and < 95 %
	>= 95 %

13-14 \ 15-16	0 PERMWA	1 FOREST	2 WETLAND	3 SUBMER1	4 SUBMER2	5 POPULA	6 BUSH	7 SOIL	8 CROPS1	9 CROPS2	10 CROPS3	11 CROPS4
0 PERMWA												
1 FOREST												
2 WETLAND												
3 SUBMER1												
4 SUBMER2												
5 POPULA												
6 BUSH												
7 SOIL												
8 CROPS1												
9 CROPS2												
10 CROPS3												
11 CROPS4												

3. Studying flood impact on agricultural areas (L8)

Cross-tabulated land-use statistics

These results should be taken with caution:

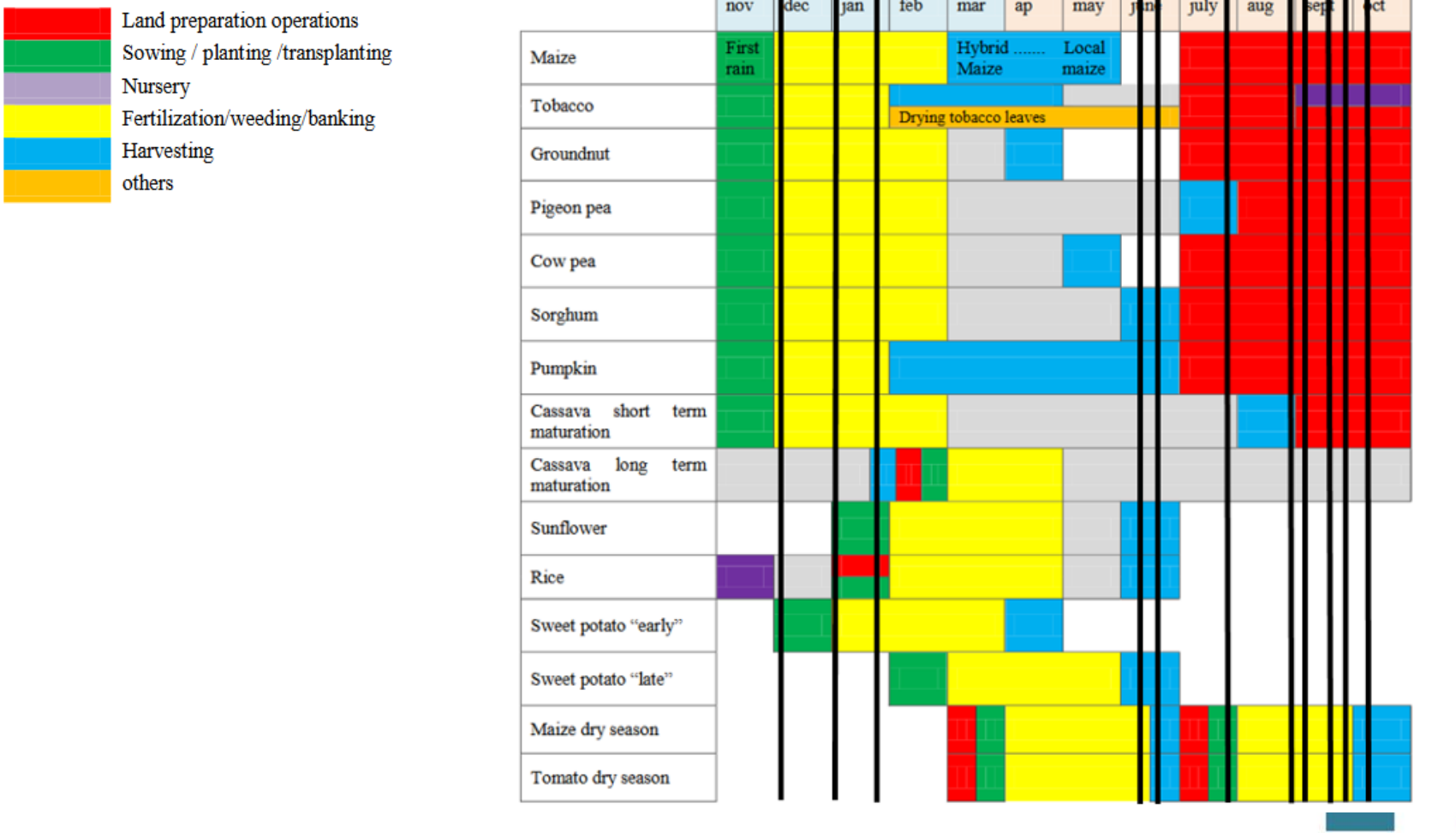
- Spatial resolution of Landsat-8 (30 m)
- Number of images used in the time series
- Absence of ground truth / validation

In particular, the surfaces classified as CROPS1 north of the new riverbed on the 2015-2016 season are abandoned.

<u>Large variations are the trends to focus on</u>

4. Crop-wise analysis for the 2015-2016 season (S2)

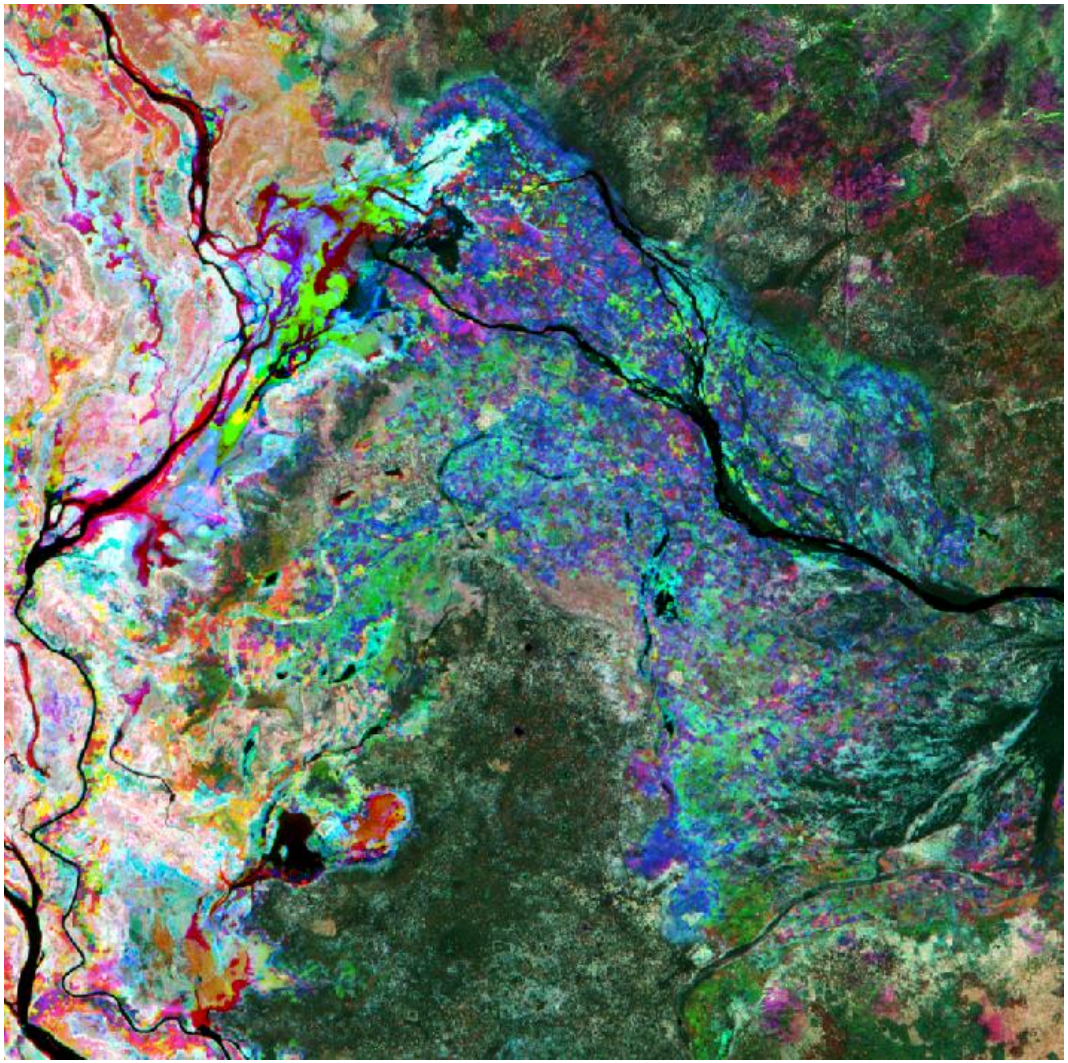
Data inventory and selection

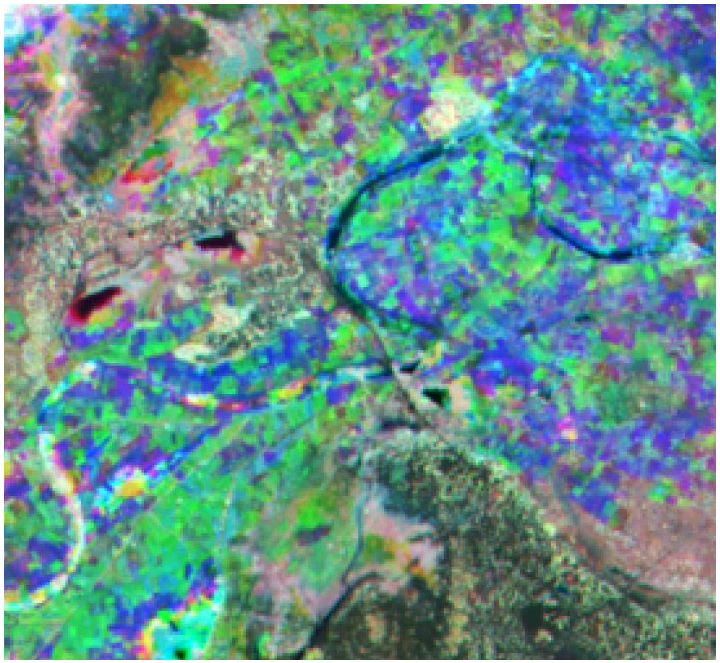


4. Crop-wise analysis for the 2015-2016 season (S2)

Processing

- Enhanced Vegetation Index calculated from surface reflectance images
- Layer stack of EVI layers per agricultural season





Season 2015 - 2016

Coloured composition

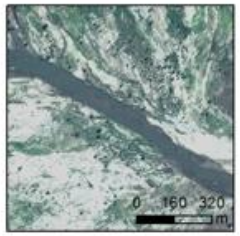
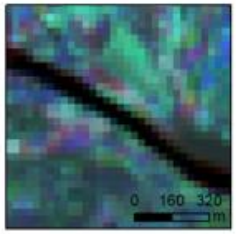
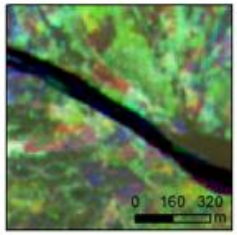
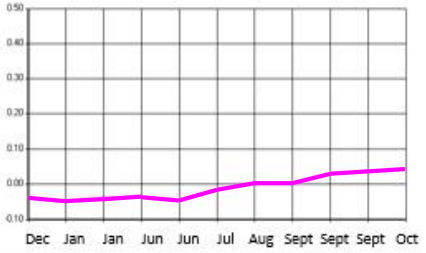
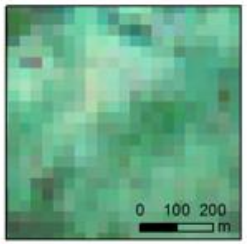
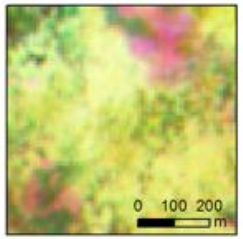
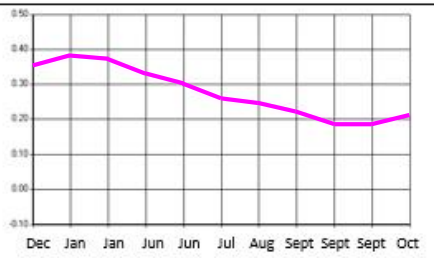
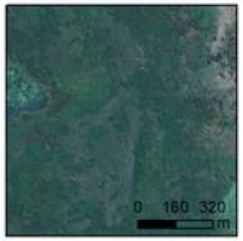
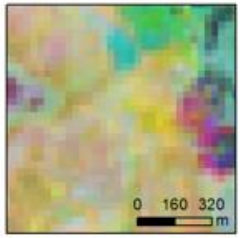
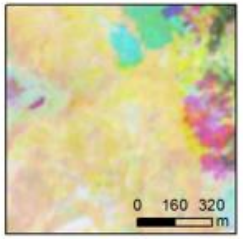
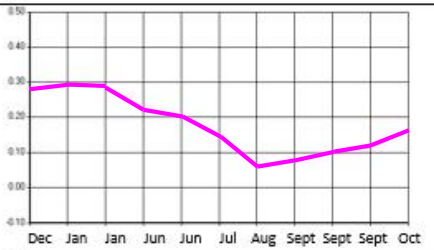
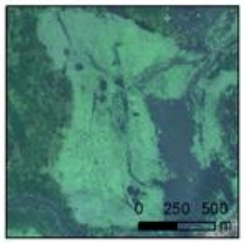
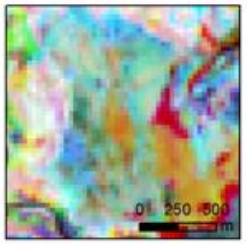
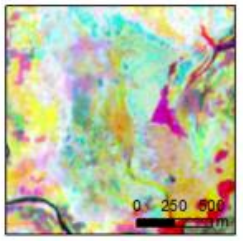
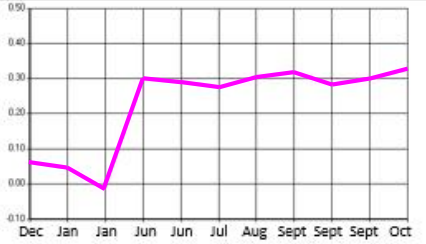
Blue band : 03/12/2015

Green band : 10/06/2016

Red band : 30/07/2016

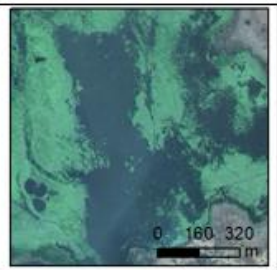
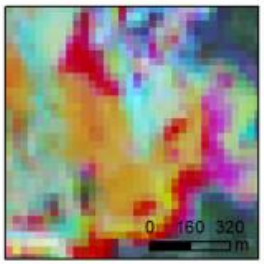
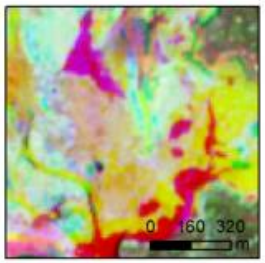
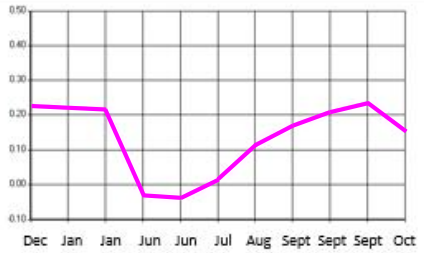
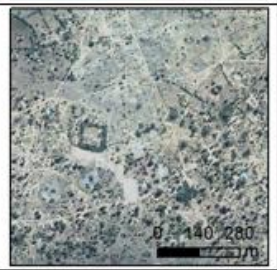
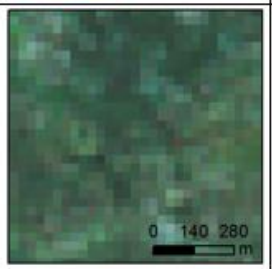
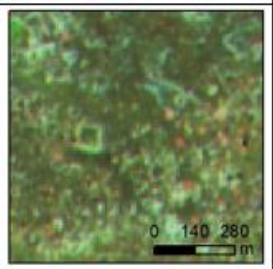
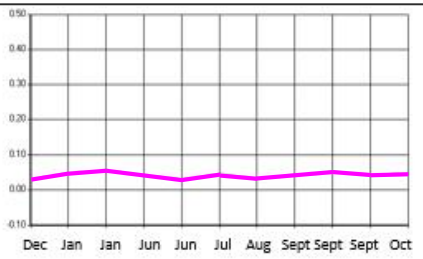
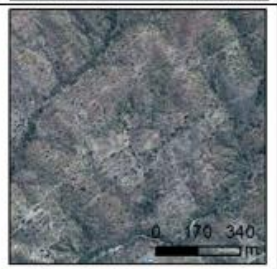
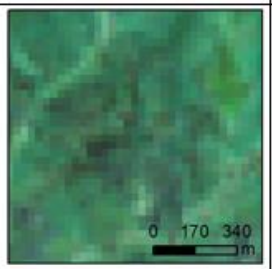
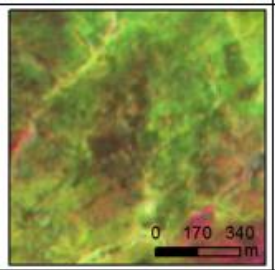
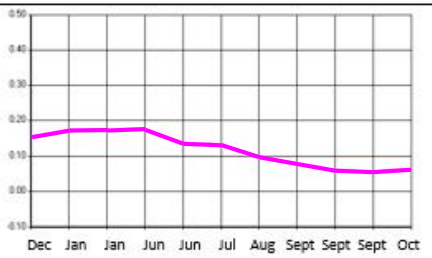
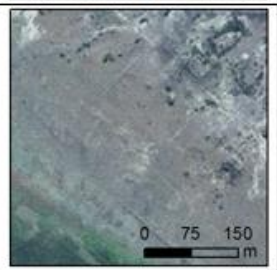
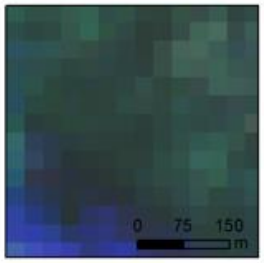
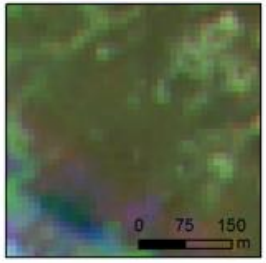
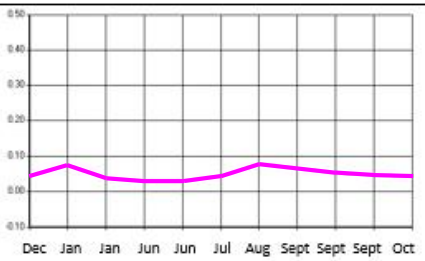
4. Crop-wise analysis for the 2015-2016 season (S2)

Land-use description

ID	Short name	Description	As seen on SPOT-6 imagery (natural colours)	As seen on Landsat time series 2015 - 2016	As seen on Sentinel-2 time series 2015 - 2016	Typical temporal profile of EVI Sentinel-2
0	PERMWA	Permanent water. Water seen on 3 images per season				
1	FOREST	Forest				
2	WETLAND	Wetland (not cultivated)				
3	SUBMER1	Wetland observed submerged on 1 image per season				

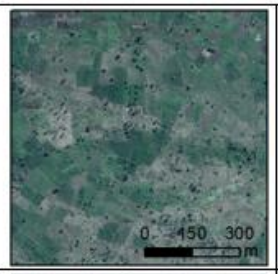
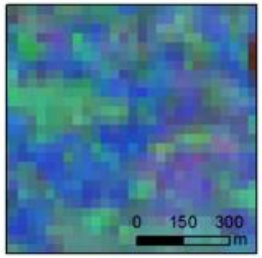
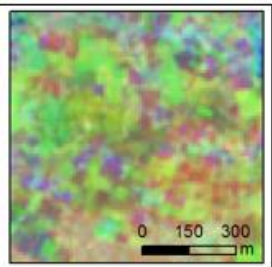
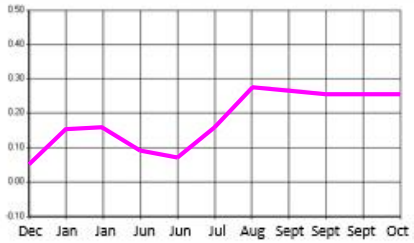
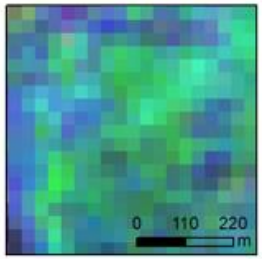
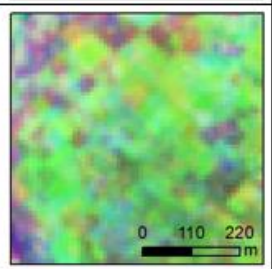
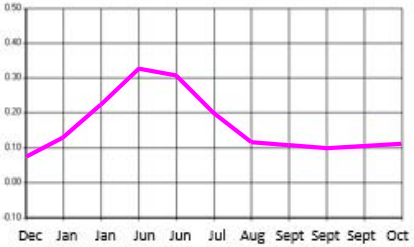
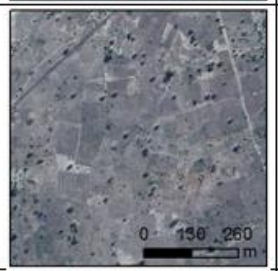
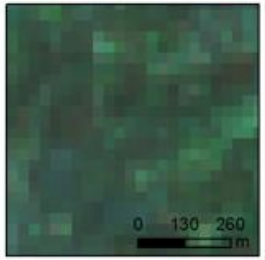
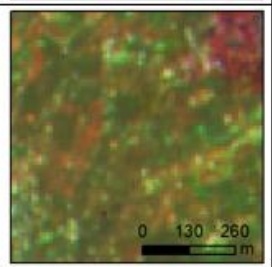
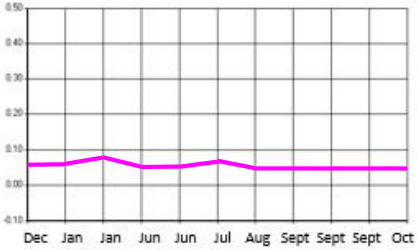
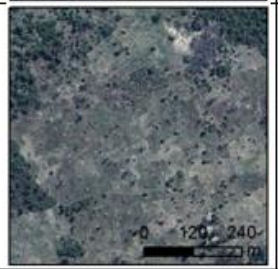
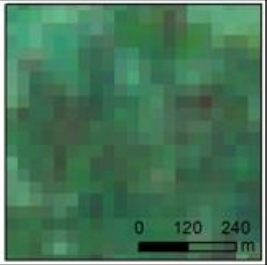
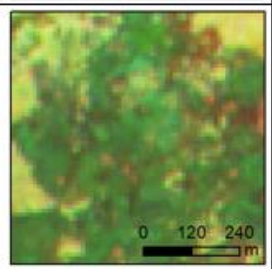
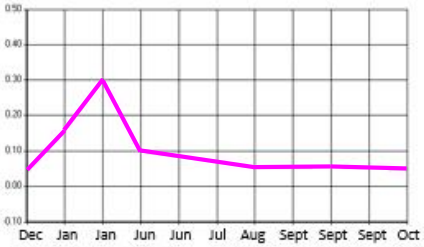
4. Crop-wise analysis for the 2015-2016 season (S2)

Land-use description

4	SUBMER2	Wetland observed submerged on 2 images per season				
5	POPULA	Sparsely populated area				
6	BUSH	Bush				
7	SOIL	Heterogeneous area, majority of bare soil and alluvial deposits				

4. Crop-wise analysis for the 2015-2016 season (S2)

Land-use description

8	CROPS1	Crops type 1				
9	CROPS2	Crops type 2				
10	CROPS3	Crops type 3				
11	CROPS4	Crops type 4				

4. Crop-wise analysis for the 2015-2016 season (S2)

Assignation of crops types to crops classes

ID	Short name	Description	Potential crops type
8	CROPS1	Crops type 1	Several vegetation cycles are observed during a year, which could correspond to a main crop in rotation with another intra-calendar crop, or with a fallow period. Based on the crop calendar used for this analysis, it is not possible to take a decision on the crop type without more specific expertise.
9	CROPS2	Crops type 2	• Maize (late harvesting) • Tobacco • Sorghum • Sunflower • Rice • Pigeon pea
10	CROPS3	Crops type 3	• Tobacco • Groundnut • Cow pea • Sorghum • Pumpkin • Sunflower • Sweet potatoes • Various vegetables
11	CROPS4	Crops type 4	• Tobacco • Groundnut • Cow pea • Sorghum • Pumpkin • Sunflower • Sweet potatoes • Various vegetables

4. Crop-wise analysis for the 2015-2016 season (S2)

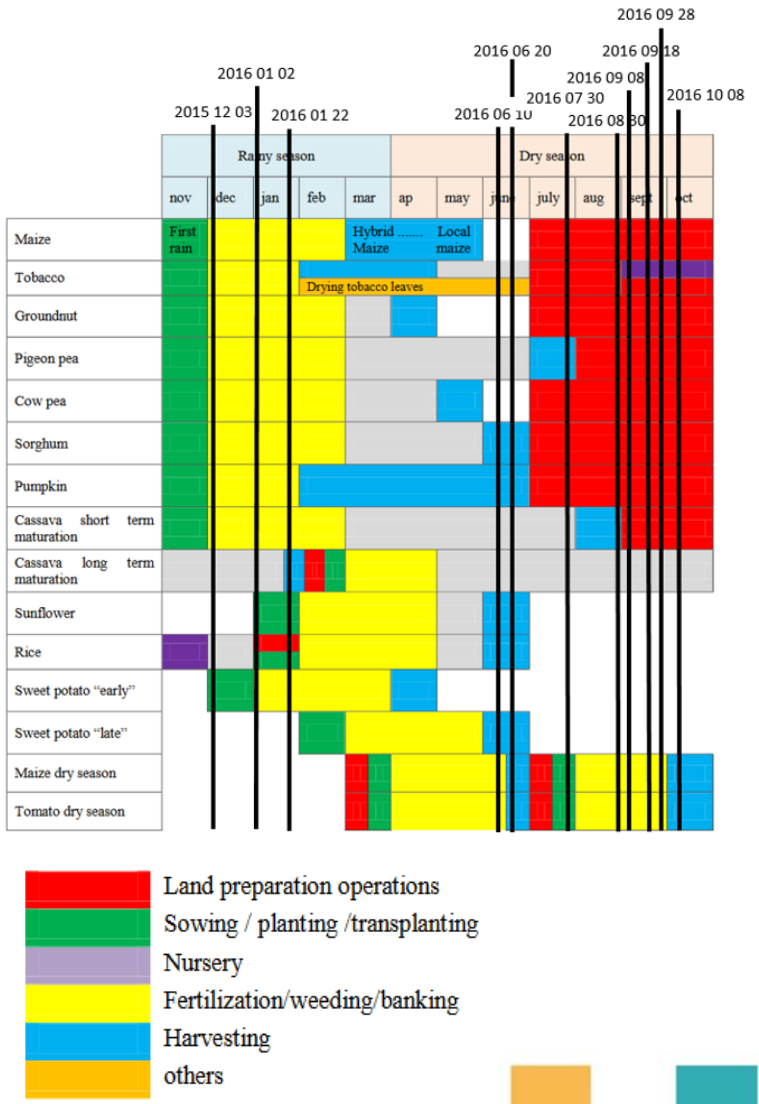
Assignation of crops types to crops classes

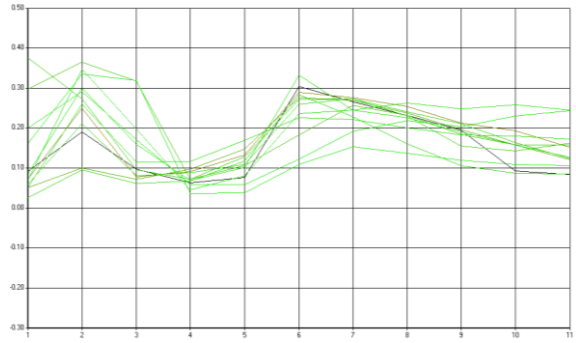
Matching should be taken with caution :

- Crop calendar of Phalombe district
- Absence of images between February and May
- Significant variations of temporal profiles

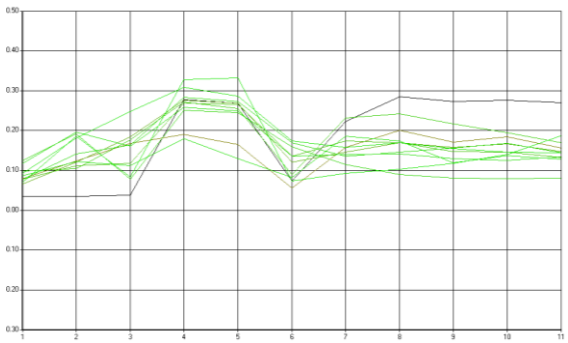
<u>Only ground expertise could consolidate this results</u>

- focus the analysis to more relevant classes grouping fewer crop per class
- increasing thematic classes





CROPS1 temporal profiles



CROPS2 temporal profiles

5. Conclusion

Goals achieved:

- Development of a methodology based on the exploitation of time series
- Quantification of the impact of the 2015 flood event
- Detection and characterization of several agricultural classes

Lessons learnt from the study:

- Paramount importance of ground expertise
- Data sampling / exhaustiveness of the time series
- Importance of high resolution data

6. Technical recommendations

1. Integrate ground observation and agricultural expertise
   - *To base the analysis on a specific crop calendar and focus the assumptions on crops type*

2. Study a combined use of both Landsat-8 and Sentinel-2 images within time series
   - *To improve the sampling of the time series*

3. Study an integration of SAR polarimetry into the time series
   - *To detect harvesting during the wet season*

4. Integrate 1 or 2 VHR imagery per season
   - *To provide a spatialization of the ground observations supporting assumptions on agricultural crops*