CEOS Recovery Observatory

MALAWI DEMONSTRATOR – October 2016

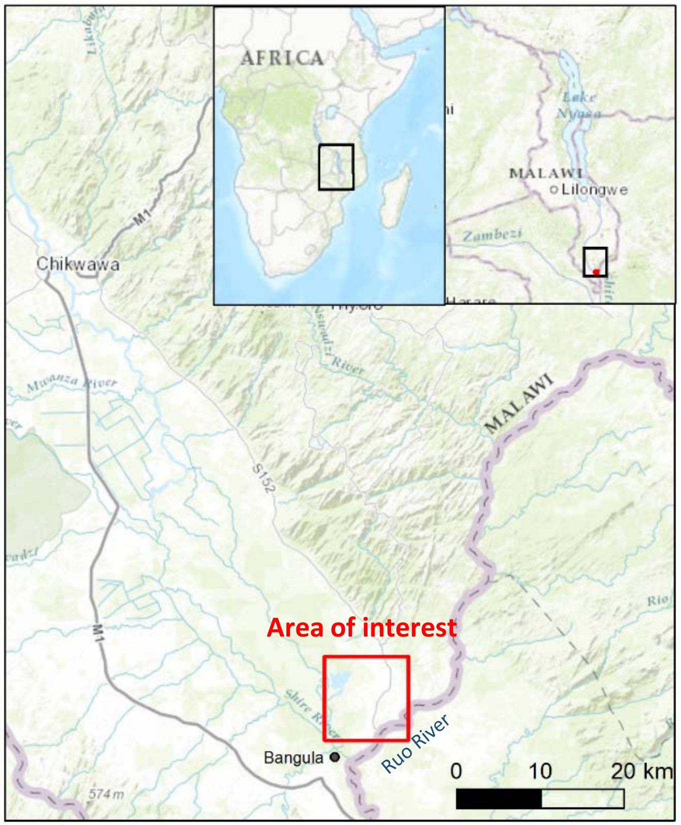
Agriculture monitoring in the Elephant Marsh area between 2013 and 2016

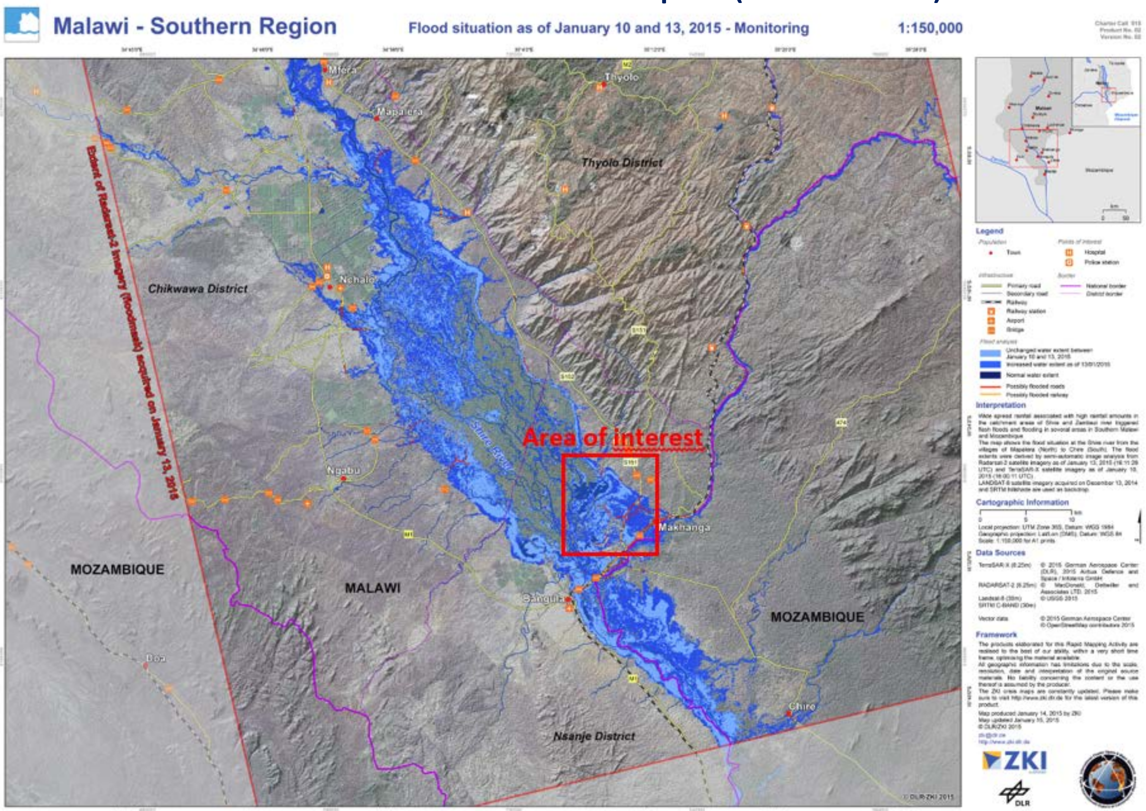
CEOS

sertit

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)



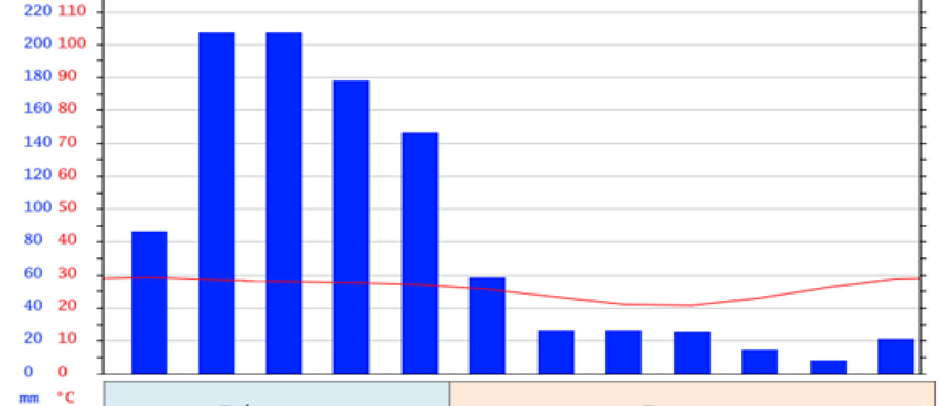


What the landscape in the abandoned agricultural area looks like.
Alluvial deposits and traces of crops in still humid areas are clearly visible (19th March 2015).

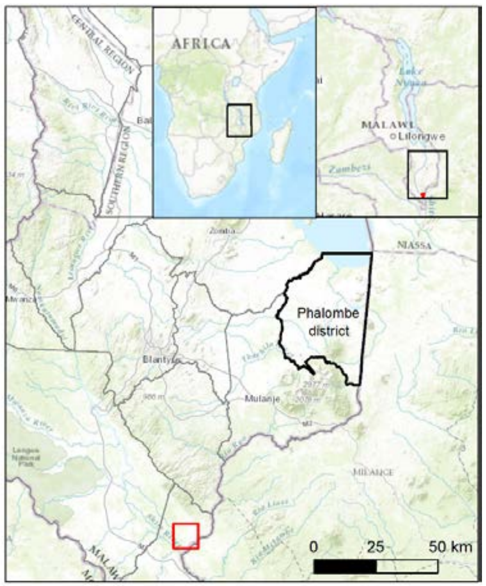
1. Context and overview of the study

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

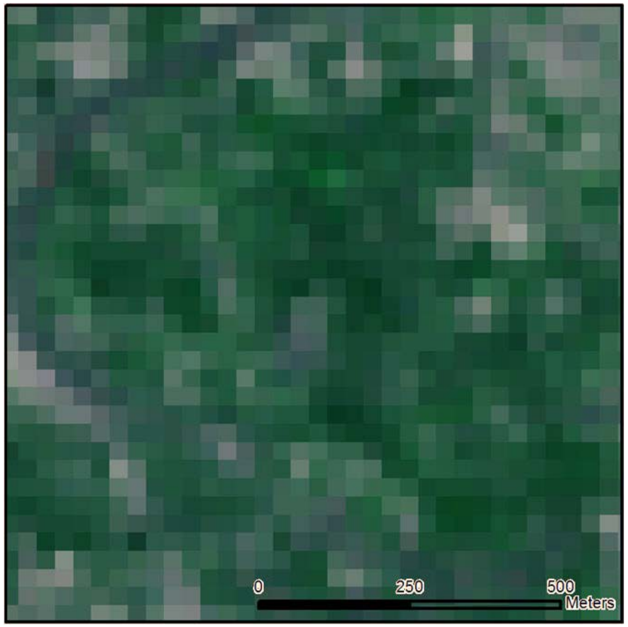
30/07/2016

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

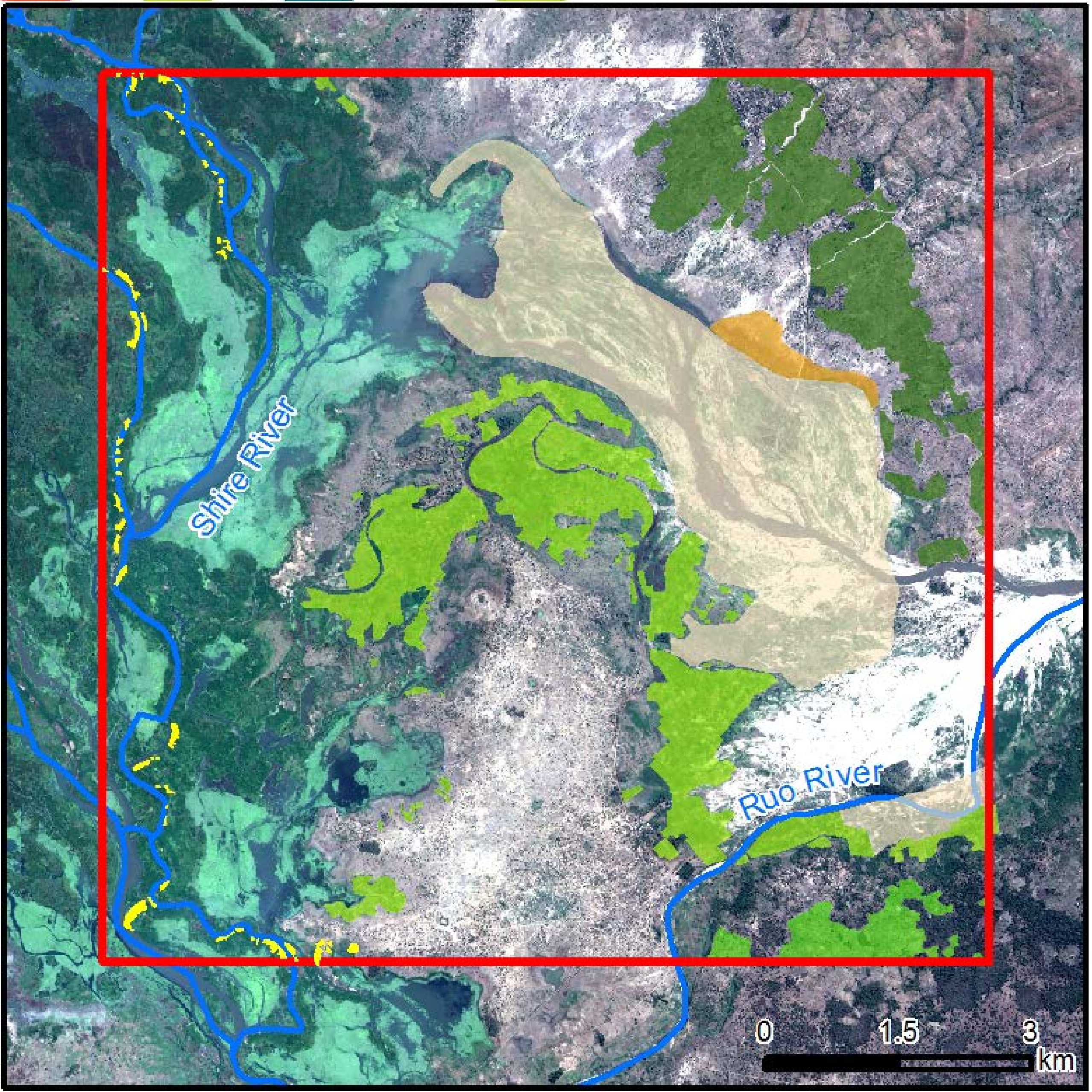
PAN 15 m

MS 30 m (4 VIS, 1 NIR, 2 SWIR)

MS 100 m (2 TIRS)

Systematic acquisition

2. Delineation of agricultural areas (SPOT-6)



Interpretation

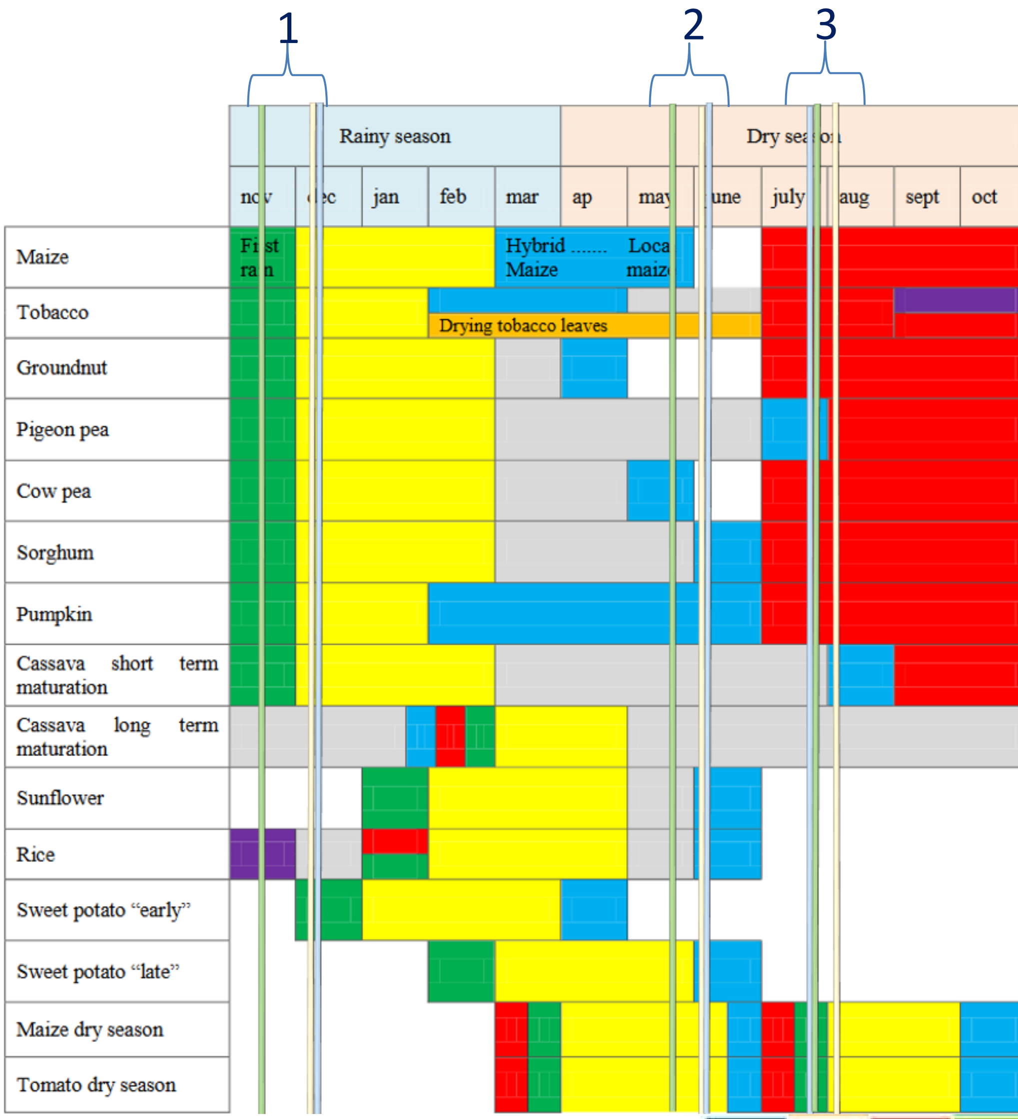
- Small isolated agricultural area
- Large agricultural areas. High density foliage and geometric patterns
- Large agricultural areas. No active vegetation but geometric patterns.
- Large agricultural areas in Mozambique. No active vegetation but geometric patterns. Isolated trees. Forest clearings
- 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

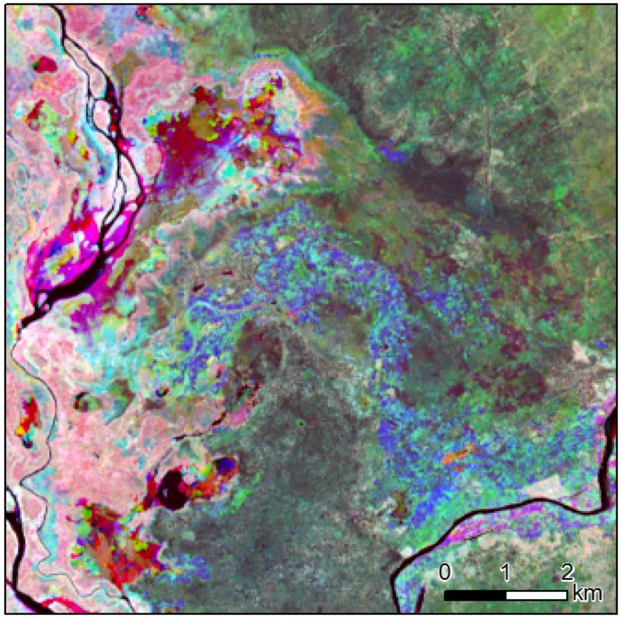
- Selection of consistent dates between agricultural seasons to facilitate the comparison between them

	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



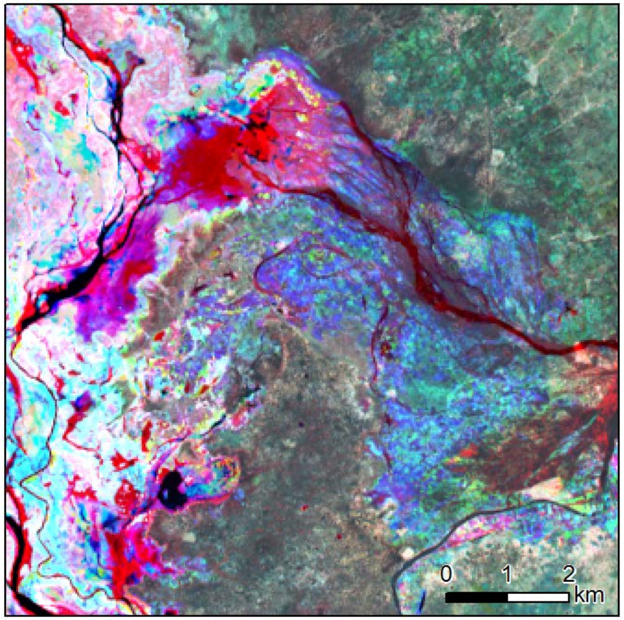
Season 2013 - 2014

Coloured composition

Blue band : 10/12/2013

Green band : 04/06/2014

Red band : 07/08/2014



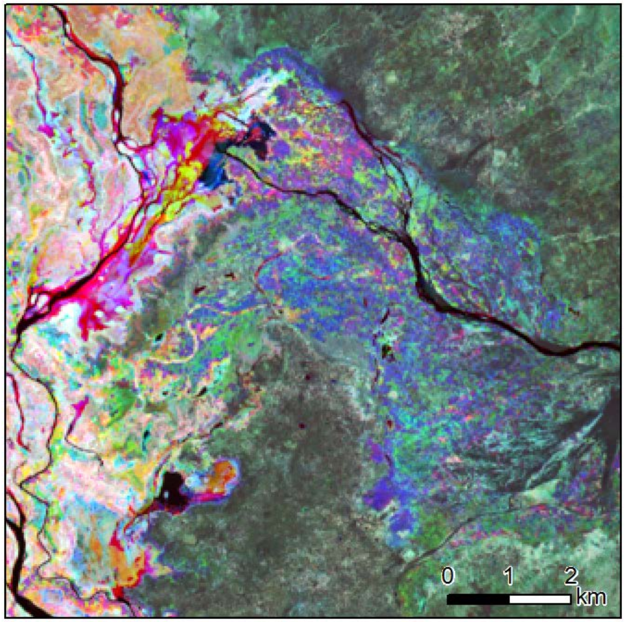
Season 2014 - 2015

Coloured composition

Blue band : 13/12/2014

Green band : 07/06/2015

Red band : 25/07/2015



Season 2015 - 2016

Coloured composition

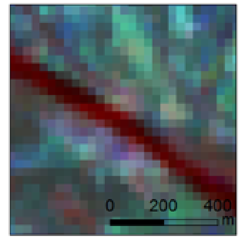
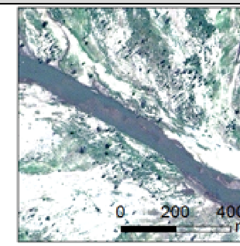
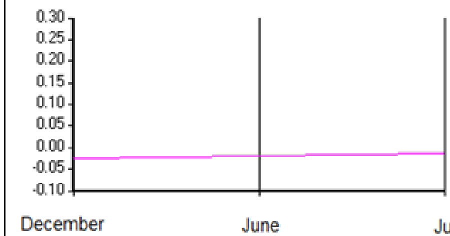
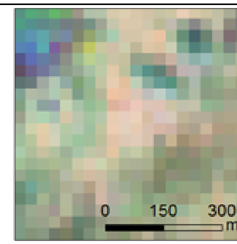
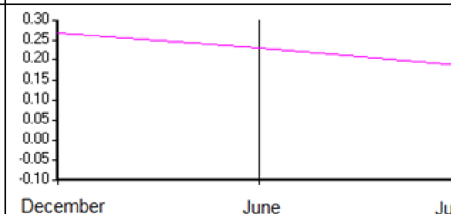
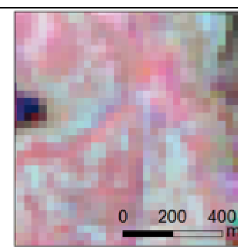
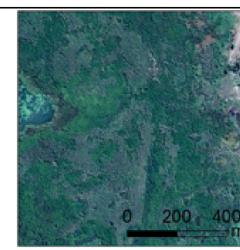
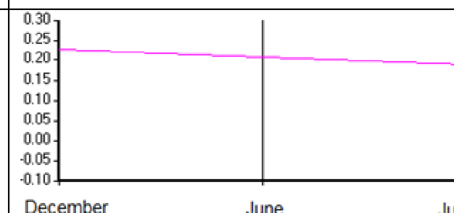
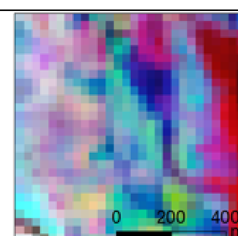
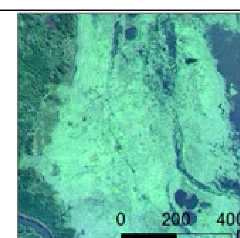
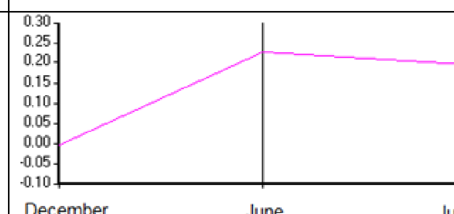
Blue band : 14/11/2015

Green band : 24/05/2016

Red band : 27/07/2016

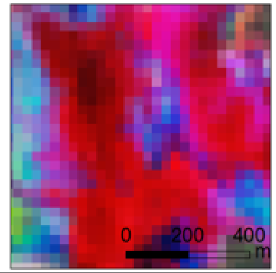
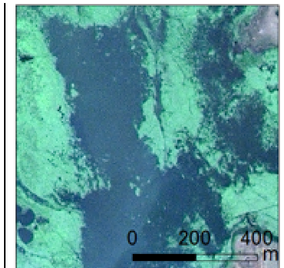
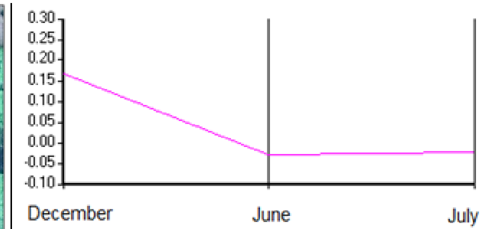
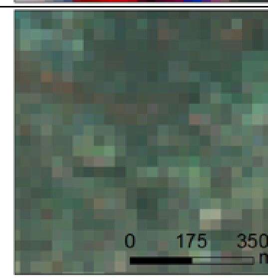
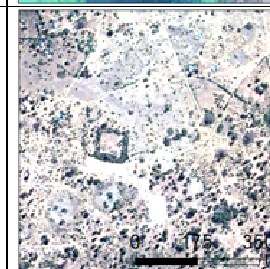
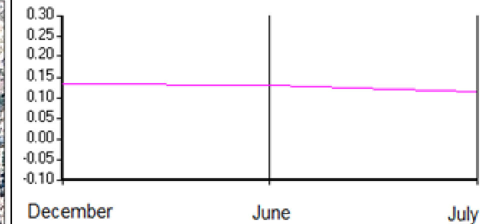
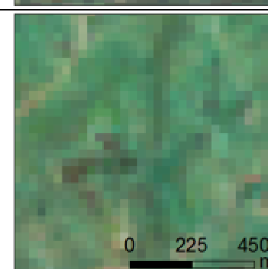
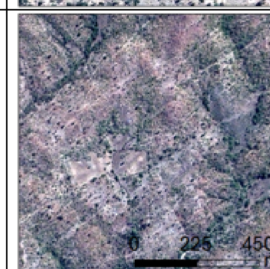
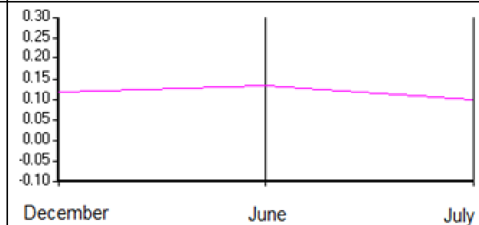
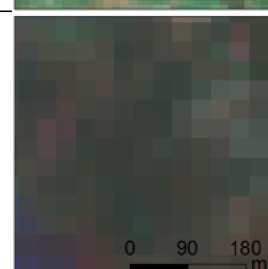
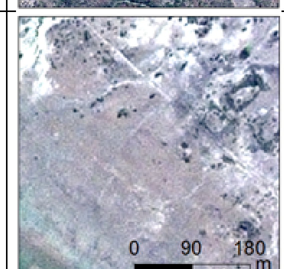
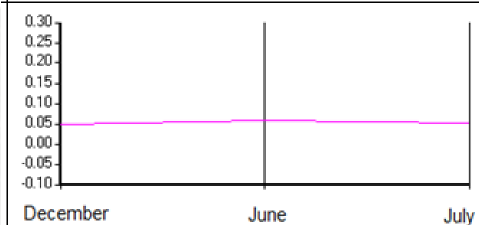
3. Studying flood impact on agricultural areas (L8)

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			

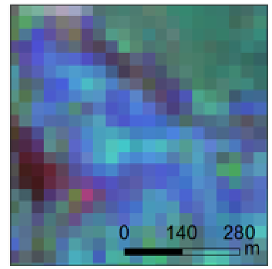
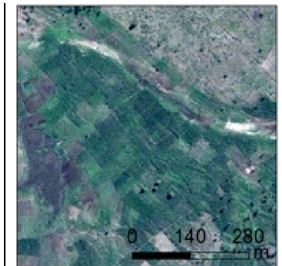
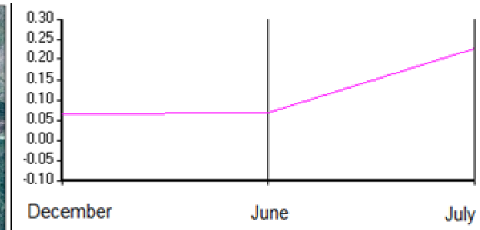
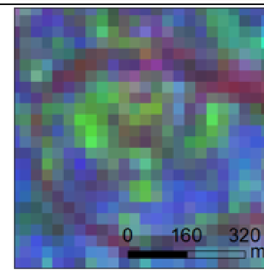
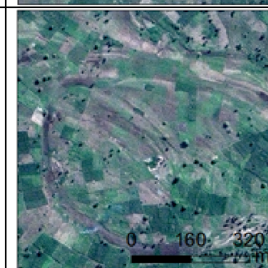
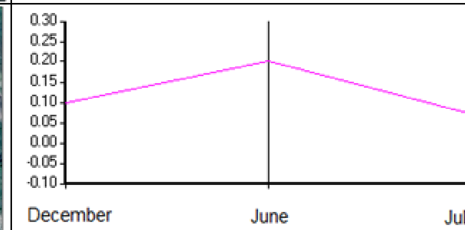
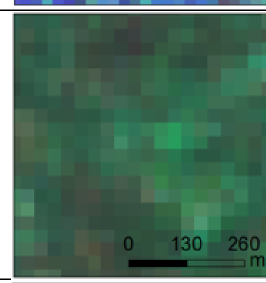
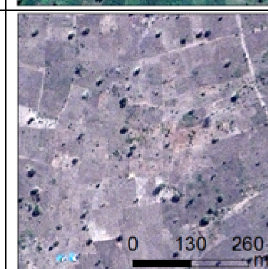
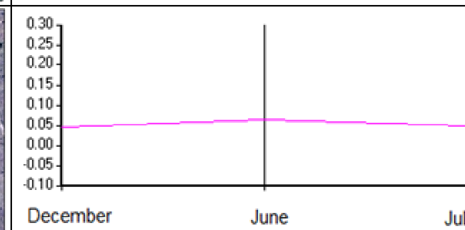
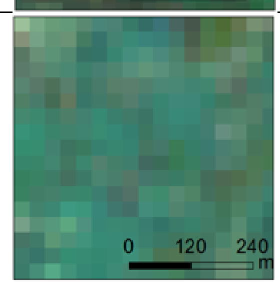
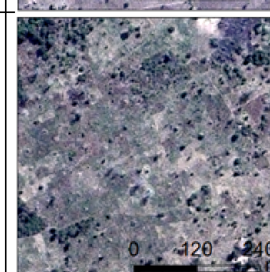
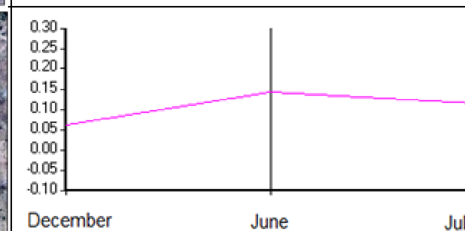
3. Studying flood impact on agricultural areas (L8)

Land-use description

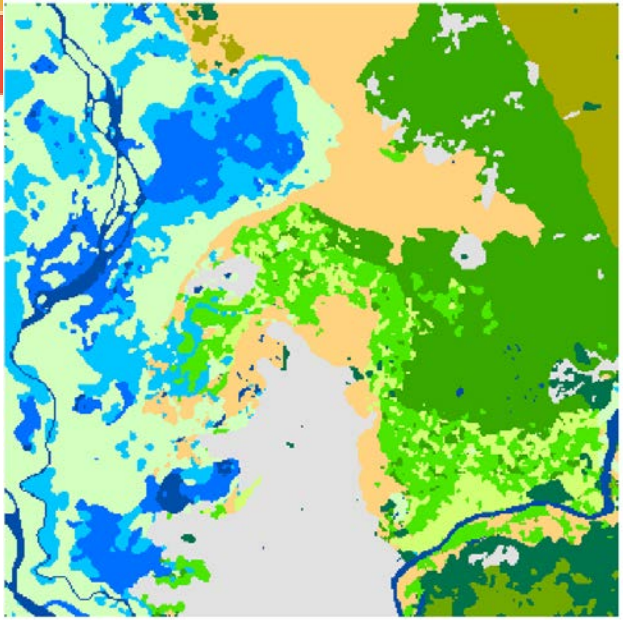
4	SUBMER2	Wetland observed submerged on 2 images per season			
5	POPULA	Sparsely populated area			
6	BUSH	Bush			
7	SOIL	Heterogeneous area, majority of bare soil and alluvial deposits			

3. Studying flood impact on agricultural areas (L8)

Land-use description

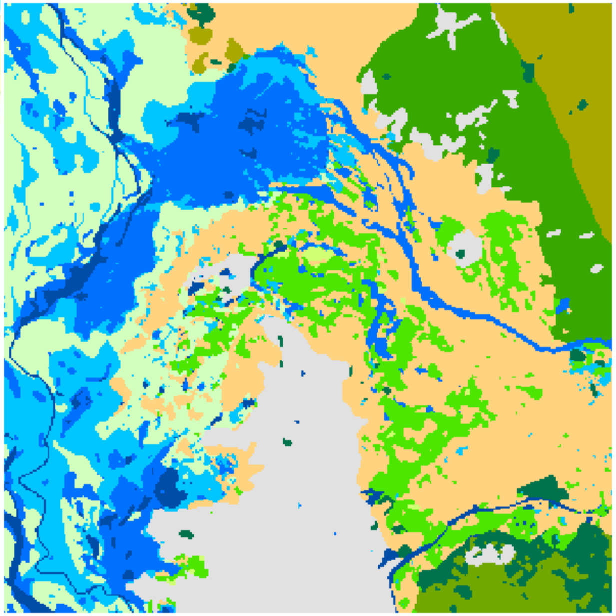
8	CROPS1	Crops type 1			
9	CROPS2	Crops type 2			
10	CROPS3	Crops type 3			
11	CROPS4	Crops type 4			

3. Studying flood impact on agricultural areas (L8)



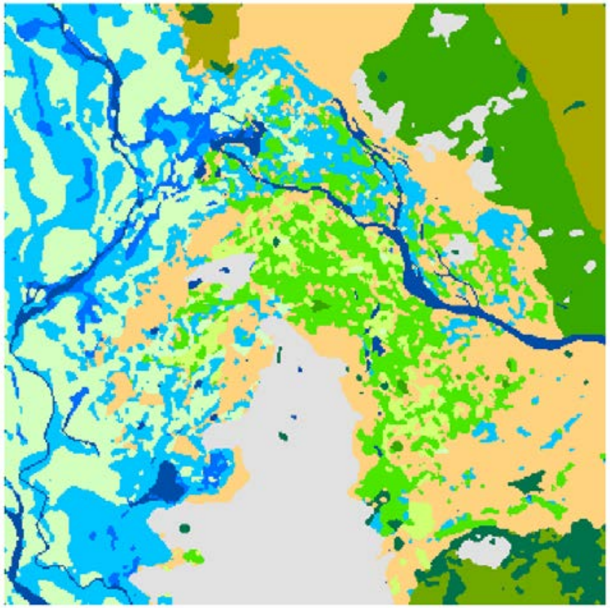
Season 2013 - 2014

Baseline



Season 2014 - 2015

Critical flooding early 2015



Season 2015 - 2016

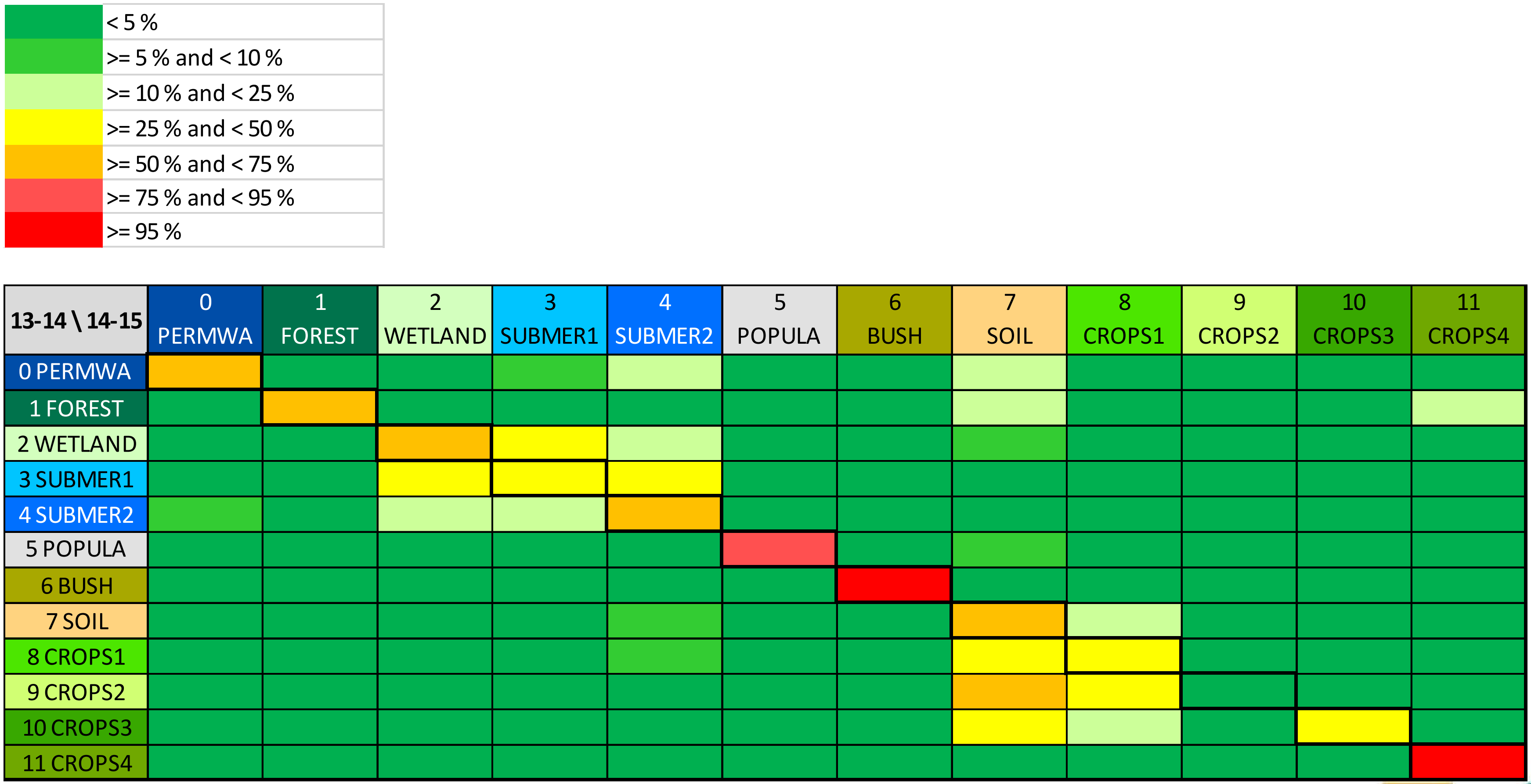
Severe drought

Large variations are the trends to focus on

ID	Short name	Description	Area (ha) 2013 - 2014	Area (ha) 2014 - 2015	Area (ha) 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**

Cross-tabulated land-use statistics

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



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												

These results should be taken with caution:

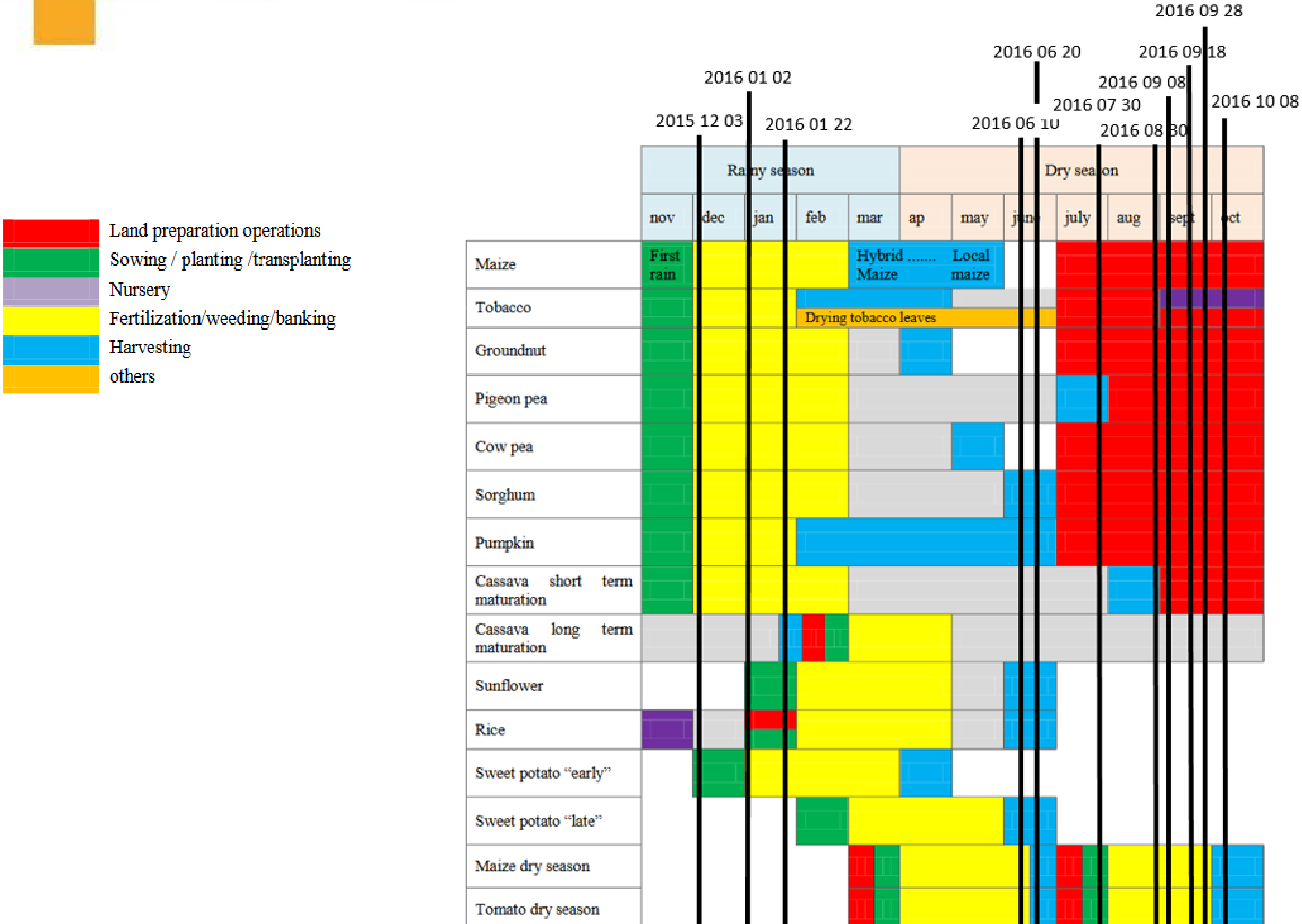
- Spatial resolution of Landsat-8 (30 m)
- Number of images used in the time series
- Absence of ground truth / validation

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

Large variations are the trends to focus on

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

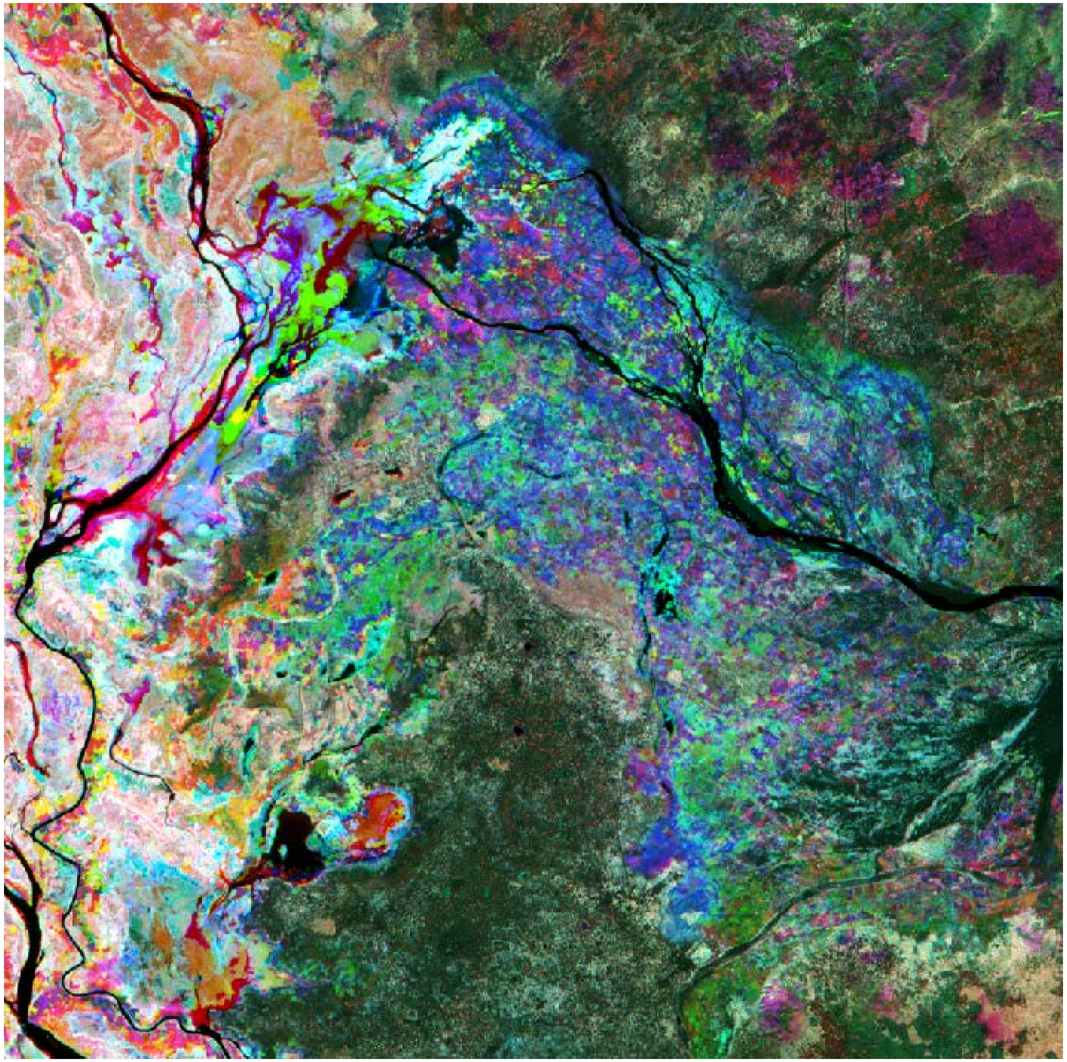
Data inventory and selection

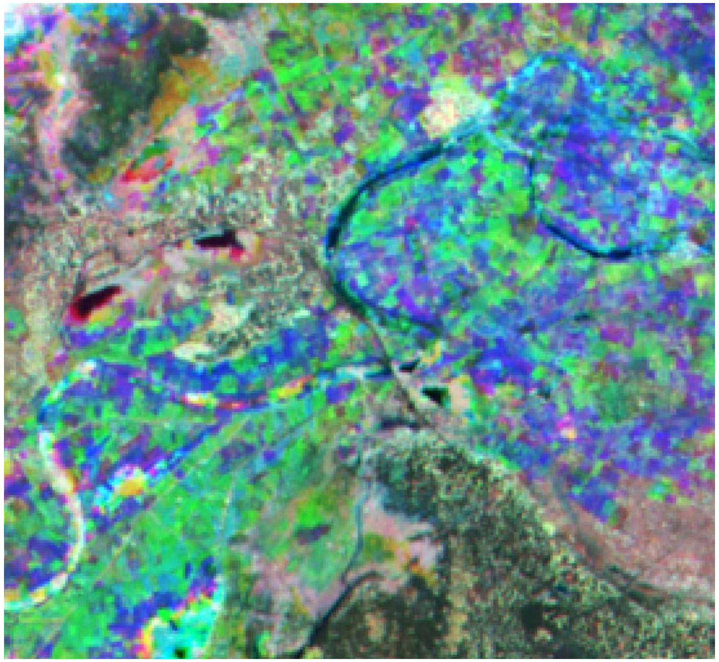


4. Crop-wise analysis for the 2015-2016 season (S2)

Processing

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





Season 2015 - 2016

Coloured composition

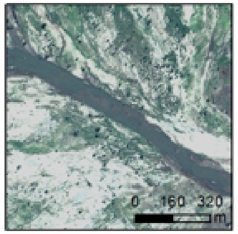
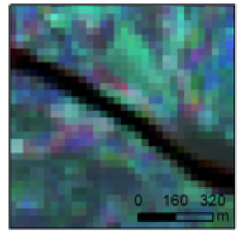
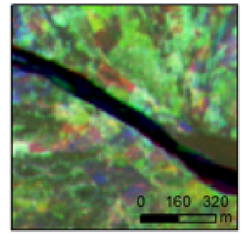
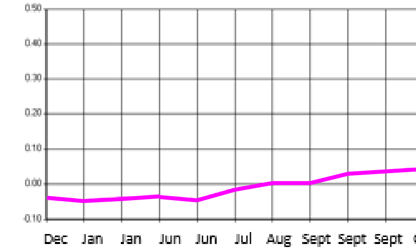
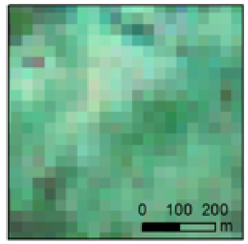
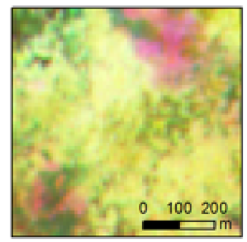
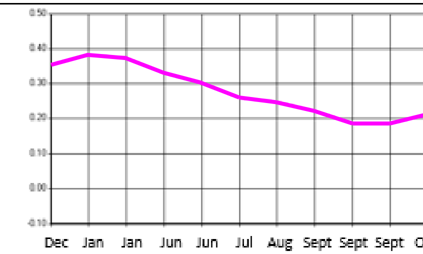
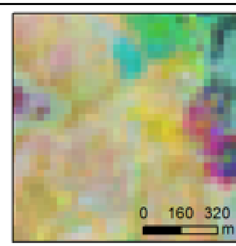
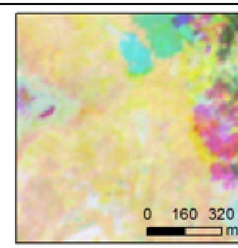
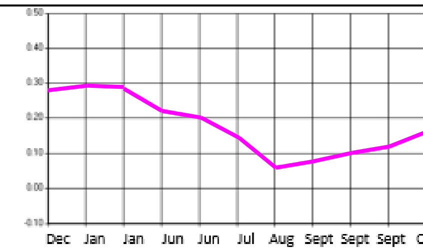
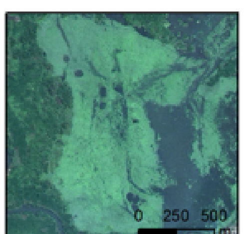
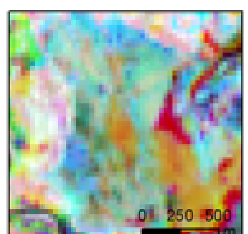
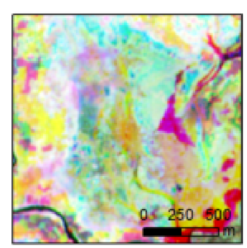
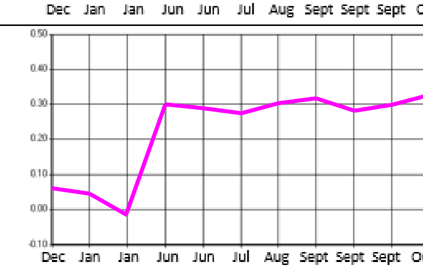
Blue band : 03/12/2015

Green band : 10/06/2016

Red band : 30/07/2016

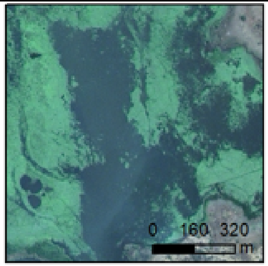
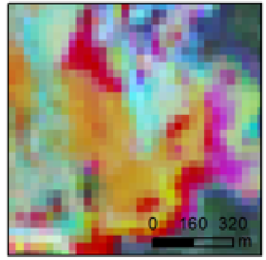
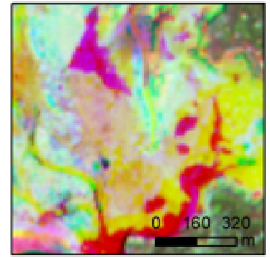
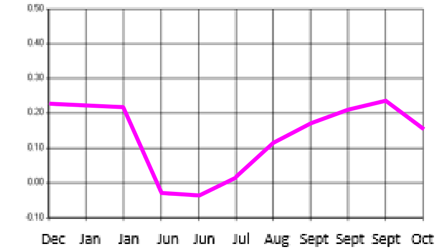
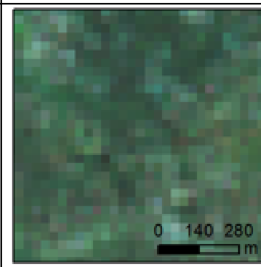
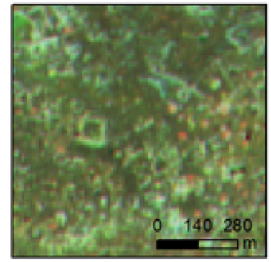
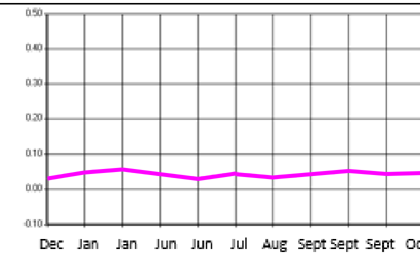
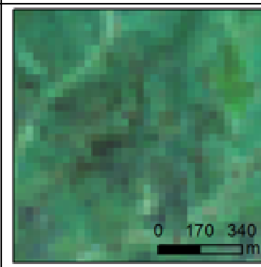
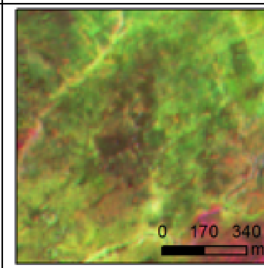
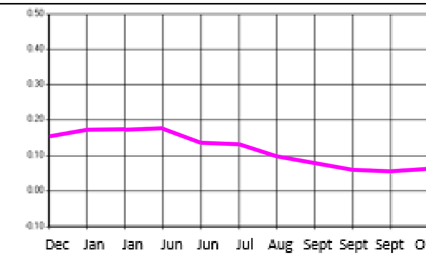
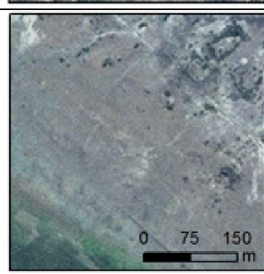
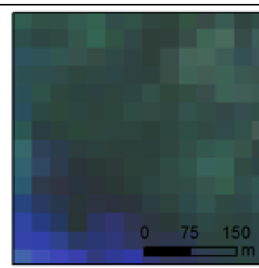
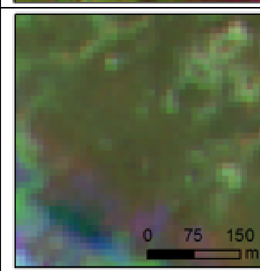
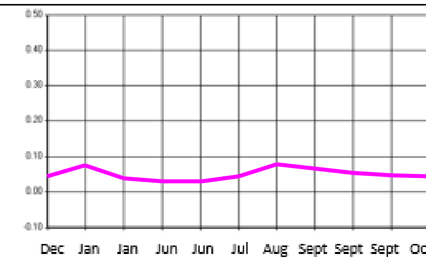
4. Crop-wise analysis for the 2015-2016 season (S2)

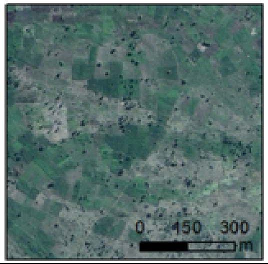
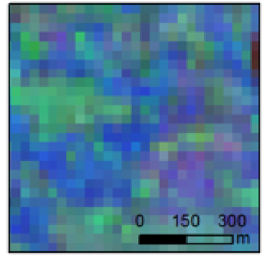
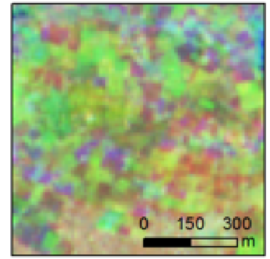
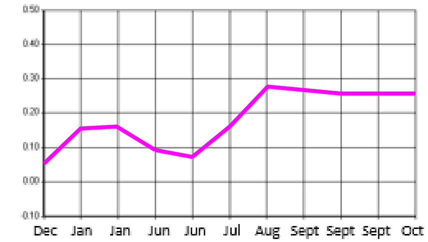
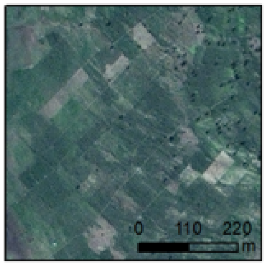
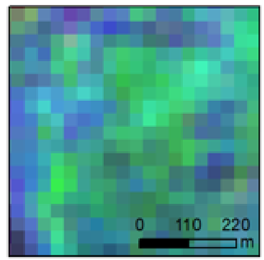
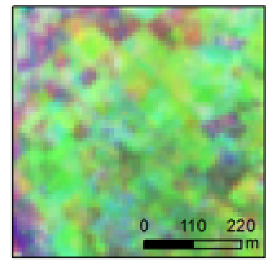
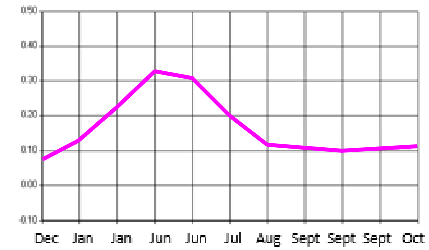
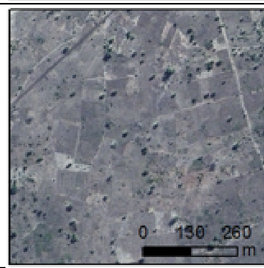
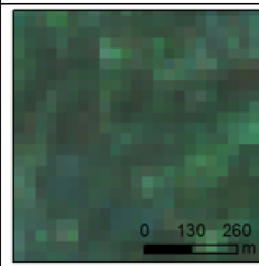
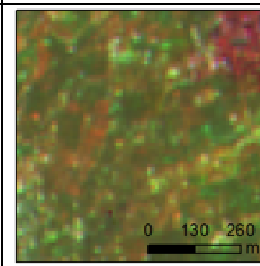
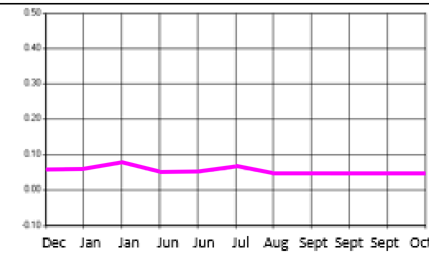
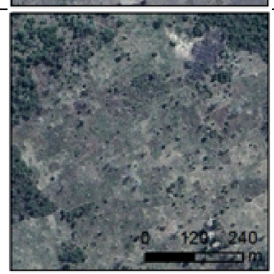
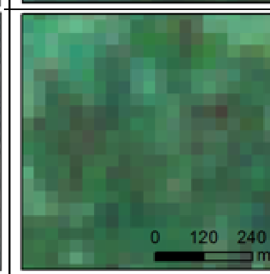
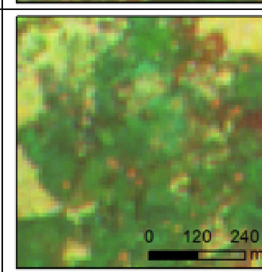
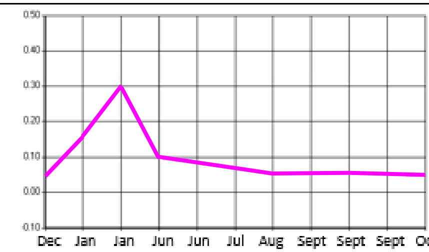
Land-use description

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				

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)

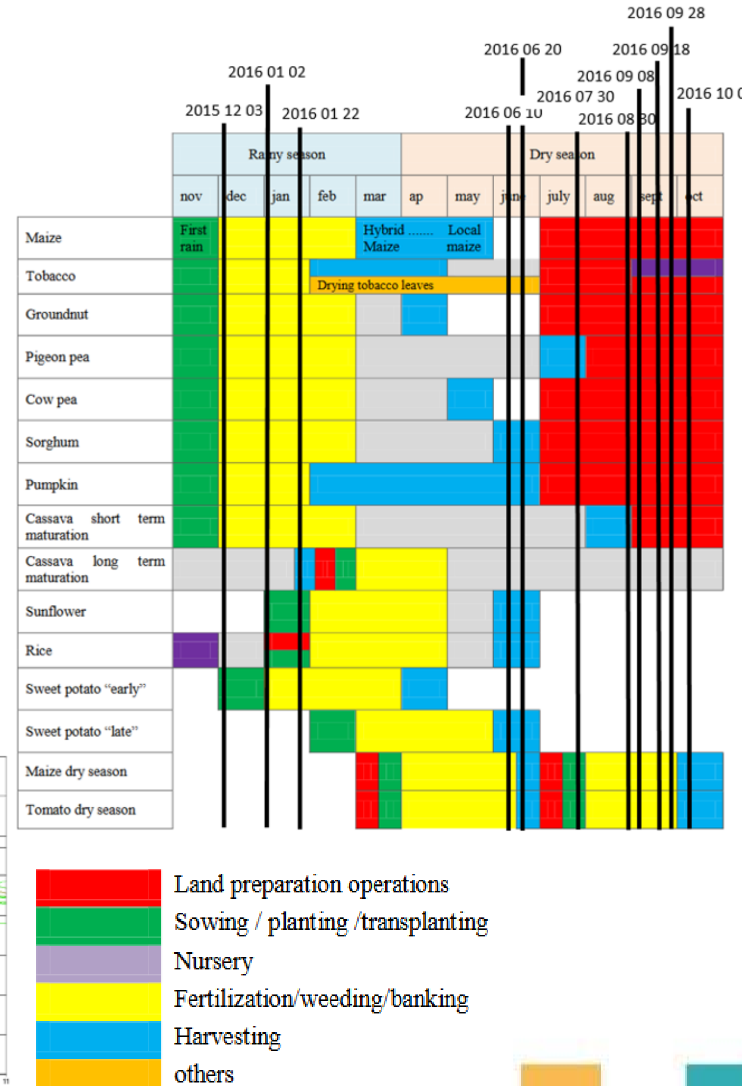
Assignation of crops types to crops classes

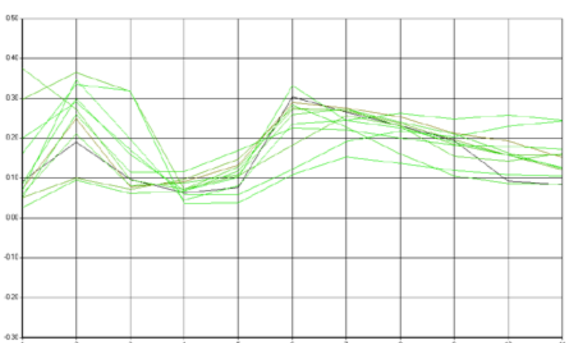
Matching should be taken with caution :

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

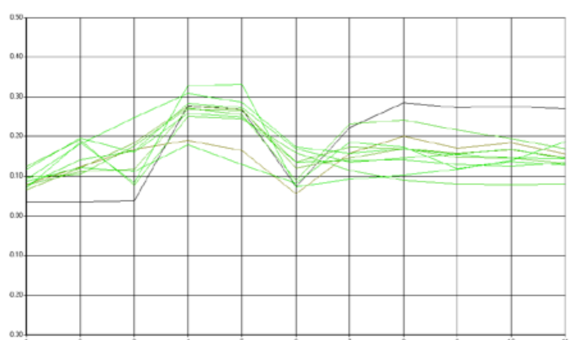
<u>Only ground expertise could consolidate this results</u>

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





CROPS1 temporal profiles



CROPS2 temporal profiles

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

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*

CEOS Recovery Observatory

MALAWI DEMONSTRATOR – October 2016

Example of state of the road S152 from the Thabwa Junction in the context of the recovery following the floods of January 2015

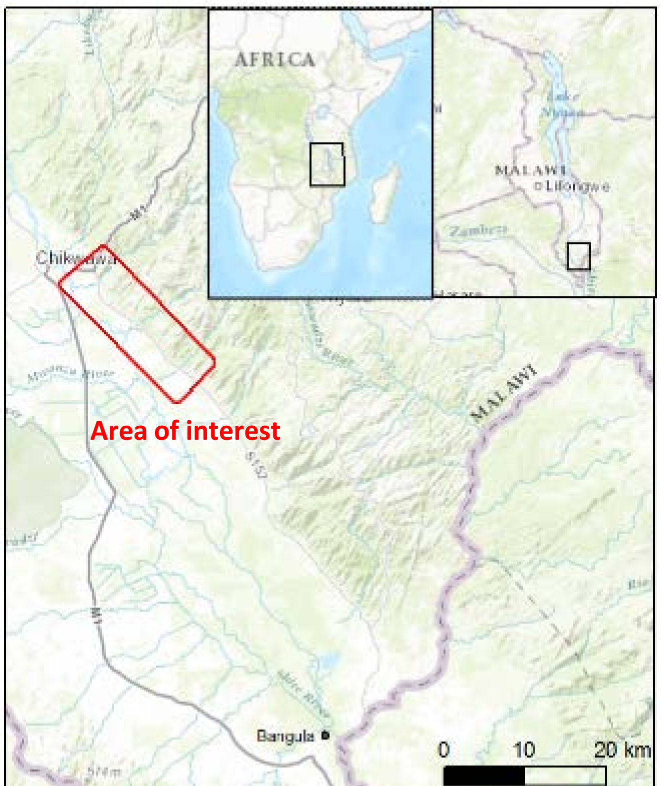
Non-exhaustive inventory. Refer to report for exhaustive assessment.

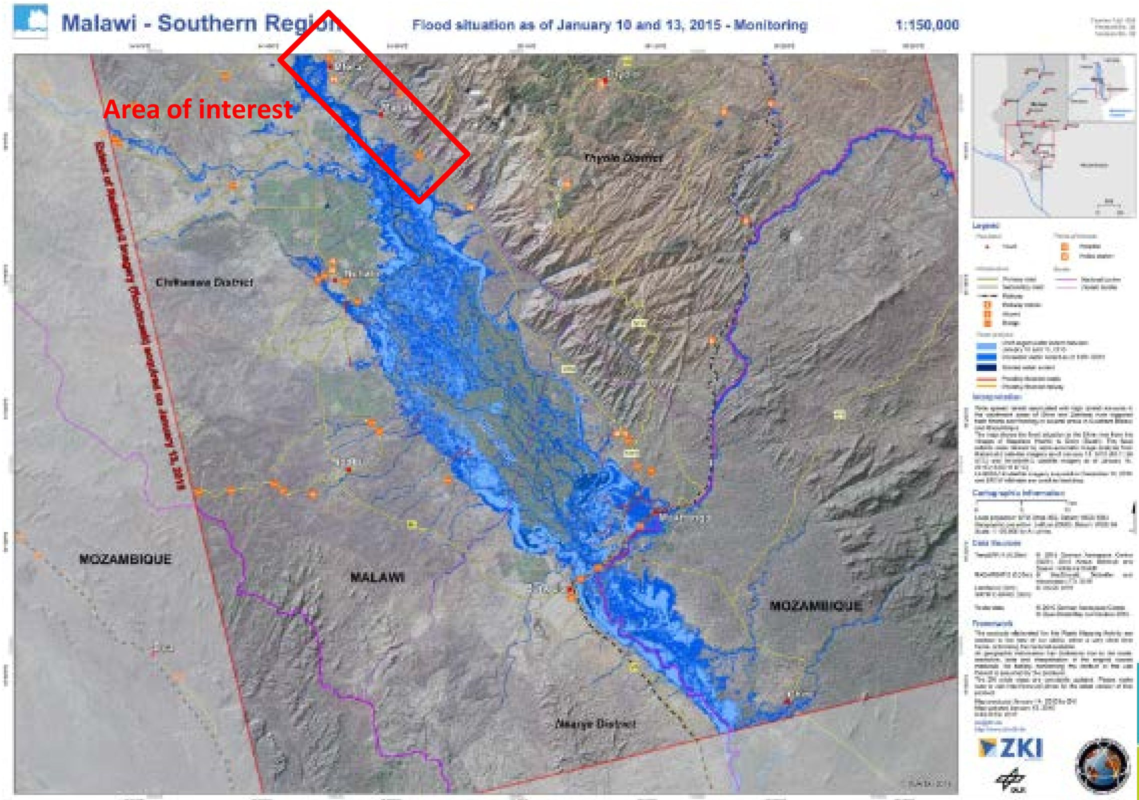
1. Context and overview of the study
2. Data
3. Situational analysis
   - Key information
   - General state of the road
   - Significant damages
   - State of the bridge
   - State of the culverts
   - State of the fording sites and aprons
   - Surrounding activities
4. Conclusion

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
- Road S152 (Thabwa-Masenjere-Fatima) has been particularly impacted by the rains.
- Emergency works have been carried out and completed in June 2015





- Post-event image:

Pleiades-HR 1B acquired on 11/08/2016, spatial resolution 50 cm

- Baseline (Google Earth):

26/10/2013 (pre-event). Source: Pleiades (CNES/Airbus DS), 50 cm
29/10/2014 (pre-event). Source: DigitalGlobe, 50 cm
20/01/2015 (post-event). Source: DigitalGlobe, 50 cm
27/01/2015 (post-event). Source: DigitalGlobe, 50 cm

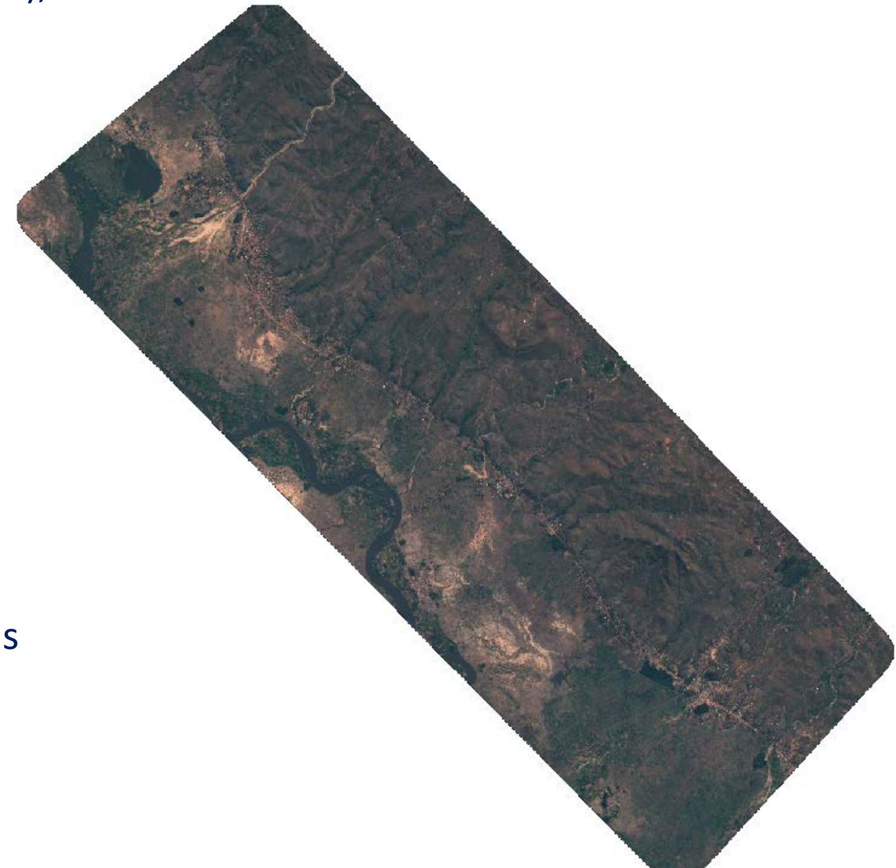
- What we are looking for:

Any changes that have taken place after the flood event:

- Construction works
- Significant damages
- Any new activities

But also:

- State of the bridges, culverts, fording sites and aprons

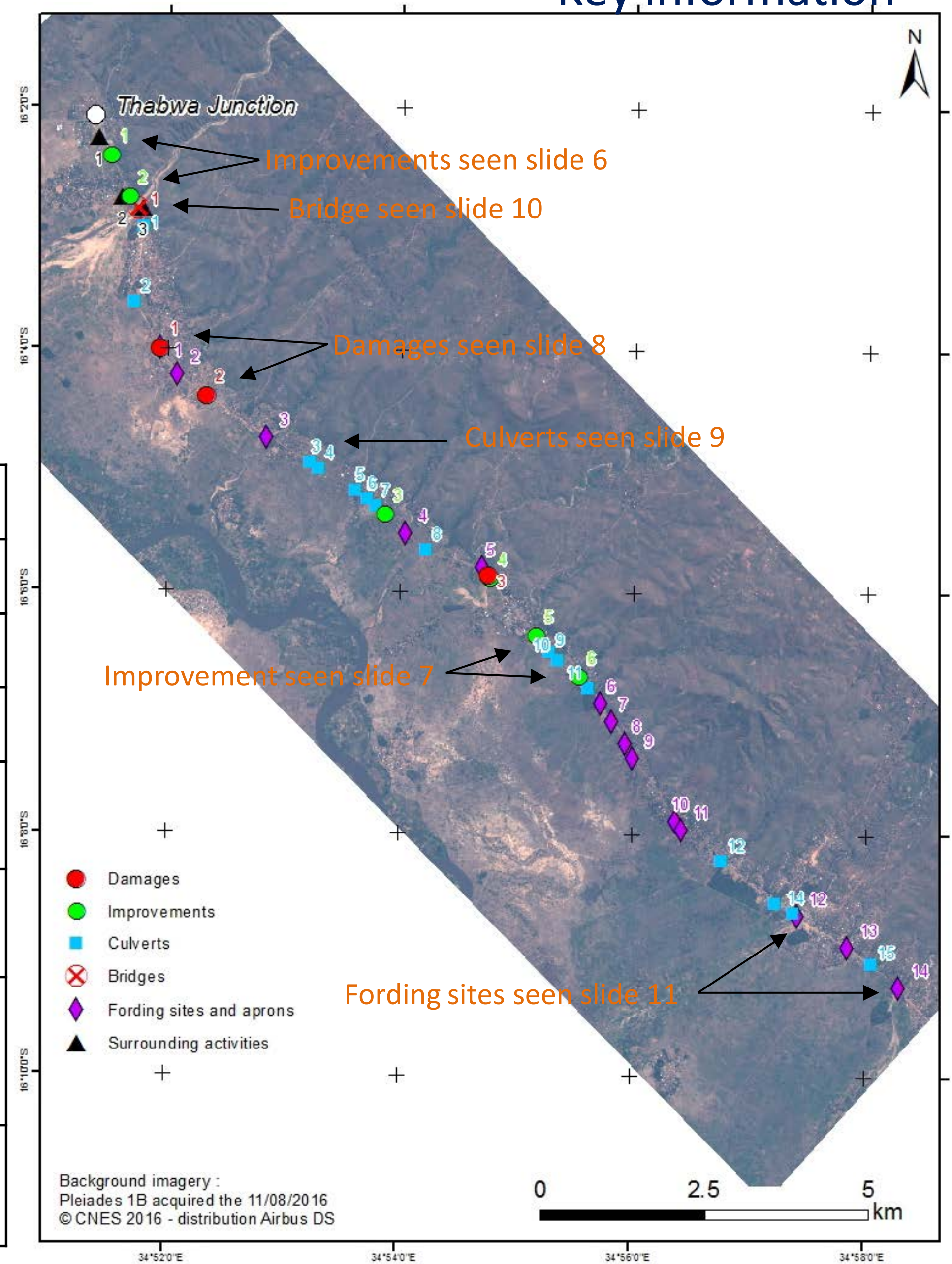


3. Situational analysis

Key information

Each symbol in the following map shows the location of the sites analyzed in the satellite images. Some sites are described in this document, with snapshots of full resolution satellite images (Pleiades image and the baseline). For an complete analysis of the sites, please refer to the report.

Length analyzed	19.8 km
Nature of the road surface	bare soil
Number of bridges	1
Number of culverts	15
Number of fording sites and aprons	14
Number of populated areas crossed	13
Altitude of the start point (Thabwa junction)	100 m (SRTM 1”)
Altitude of the end point (Chikadza)	97 m (SRTM 1”)



General state of the road

The general state of the road is good. Since the baseline, it appears that the road has been rehabilitated and widened, in some locations from a width of approximately 5-6 m to 8-9 m.

Improvement	Situation the 20/01/2015	Situation the 11/08/2016
Improvement #1 Road widened X = 698805.76 m Y = 8225735.04 m		
Improvement #2 Crossing widened X = 699086.93 m Y = 8225103.89 m		

Baseline imagery
DigitalGlobe 50 cm
(Google Earth)

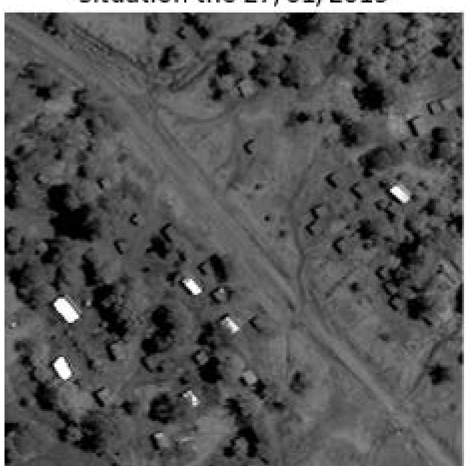
Post-event image
Pléiades, 50 cm

Non-exhaustive inventory

Refer to report for exhaustive assessment

3. Situational analysis

General state of the road

	Baseline (DigitalGlobe, 50 cm Google Earth)	Post-event image (Pléiades, 50 cm)
Improvement #5 Road rehabilitated X = 705280.72 m Y = 8218384.72 m	Situation the 27/01/2015 	Situation the 11/08/2016 
Improvement #6 Road rehabilitated X = 705938.28 m Y = 8217758.22 m	Situation the 27/01/2015 	Situation the 11/08/2016 

Non-exhaustive inventory

Refer to report for exhaustive assessment

3. Situational analysis
Significant damages

	Baseline (DigitalGlobe, 50 cm Google Earth)	Post-event image (Pléiades, 50 cm)
Damage #1 Damage in the road structure X = 699562. 65 m Y = 8222798.70 m	Situation the 20/01/2015 	Situation the 11/08/2016 
Damage #2 Damage in the road structure X = 700256.81 m Y = 8222071.60 m	Situation the 20/01/2015 	Situation the 11/08/2016 

Non-exhaustive inventory

Refer to report for exhaustive assessment

3. Situational analysis
State of the culverts

	Baseline (DigitalGlobe, 50 cm Google Earth)	Post-event image (Pléiades, 50 cm)
Culvert ID #3 No change visible on the infrastructure X = 701847.14 m Y = 8221034.23 m	Situation the 27/01/2015 	Situation the 11/08/2016 
Culvert ID #4 No change visible on the infrastructure X = 701972.40 m Y = 8220957.60 m	Situation the 27/01/2015 	Situation the 11/08/2016 

Source SHIdF (Togo)

Source ECHA (Burkina Faso)

Non-exhaustive inventory

Refer to report for exhaustive assessment

3. Situational analysis
State of the bridge

	Baseline (DigitalGlobe, 50 cm Google Earth)	Post-event image (Pléiades, 50 cm)
Bridge over the Mwamphanzi river No change visible on the infrastructure X = 699222.91 m Y = 8224921.76 m	Situation the 20/01/2015 	Situation the 11/08/2016 

Non-exhaustive inventory

Refer to report for exhaustive assessment

3. Situational analysis

State of the fording sites and aprons

	Baseline (DigitalGlobe, 50 cm Google Earth)	Post-event image (Pléiades, 50 cm)
Fording site ID #12 Apron rehabilitated X = 709263.57 m Y = 8214112.40 m	Situation the 20/01/2016 	Situation the 11/08/2016 
Fording site ID #14 Apron rehabilitated X = 710815.88 m Y = 8213003.08 m	Situation the 20/01/2016 	Situation the 11/08/2016 

Non-exhaustive inventory

Refer to report for exhaustive assessment

3. Situational analysis
Surrounding activities

	Baseline (DigitalGlobe, 50 cm Google Earth)	Post-event image (Pléiades, 50 cm)
Surrounding activity ID #1 Quarry X = 698631.18 m Y = 8226000.97 m	Situation the 20/01/2015 	Situation the 11/08/2016 
Surrounding activity ID #3 Water development project X = 699294.22 m Y = 8224930.62 m	Situation the 20/01/2015 	Situation the 11/08/2016 

Non-exhaustive inventory

Refer to report for exhaustive assessment


Source WesternAG (Delta Lake)

This study confirmed Very High Resolution Satellite capacities:

- significant enlargements of a road are visible
- significant rehabilitations of the road surface are visible
- above a certain size, damages in the road surface are visible
- water flows crossing a road are visible
- rehabilitations of aprons are visible, in case of deposits removal
- construction sites like water projects (irrigation for example) are visible

Without ground truth, it wasn’t possible to assess which changes were not visible.

Considering project monitoring and evaluation, the cost-benefit ratio of space-based observation needs to be compared with traditional methods (field mission).

CEOS Recovery Observatory

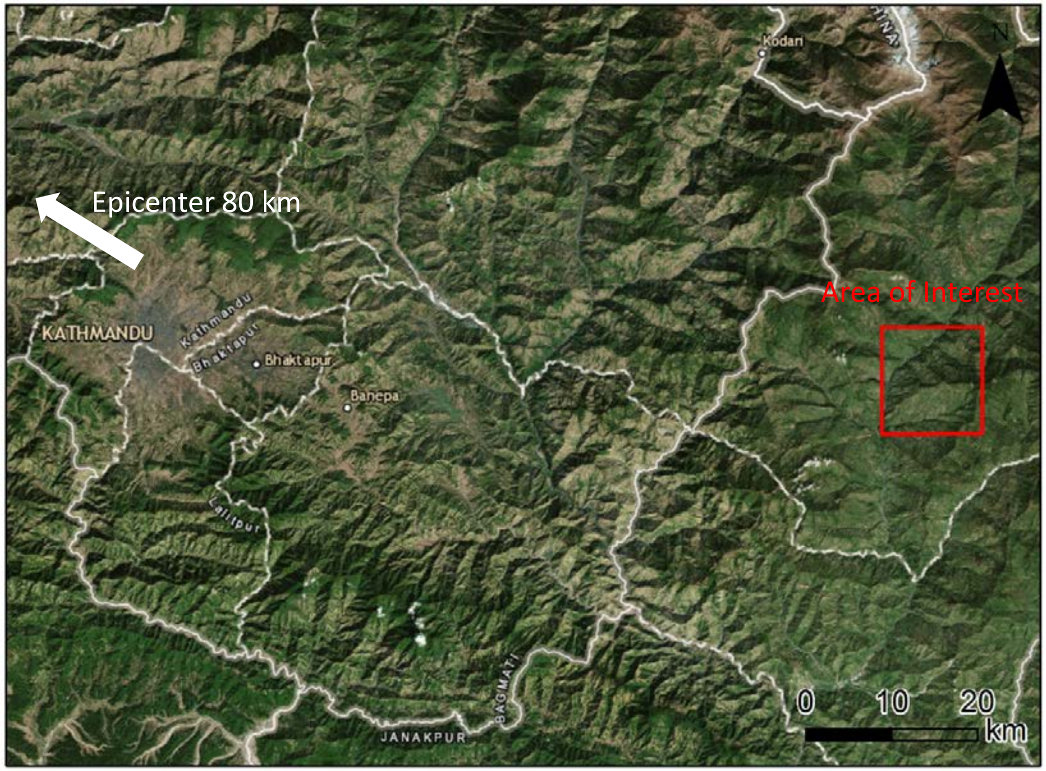
NEPAL DEMONSTRATOR – October 2016

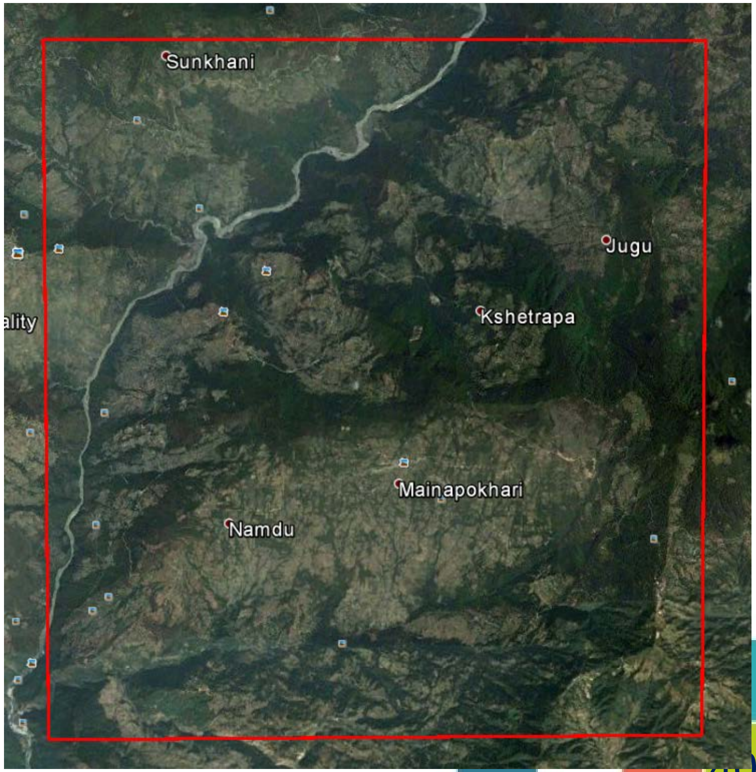
Progress on the monitoring of the reconstruction after the 2015 earthquake in the area of Mainapokhari

1. Context and overview of the study

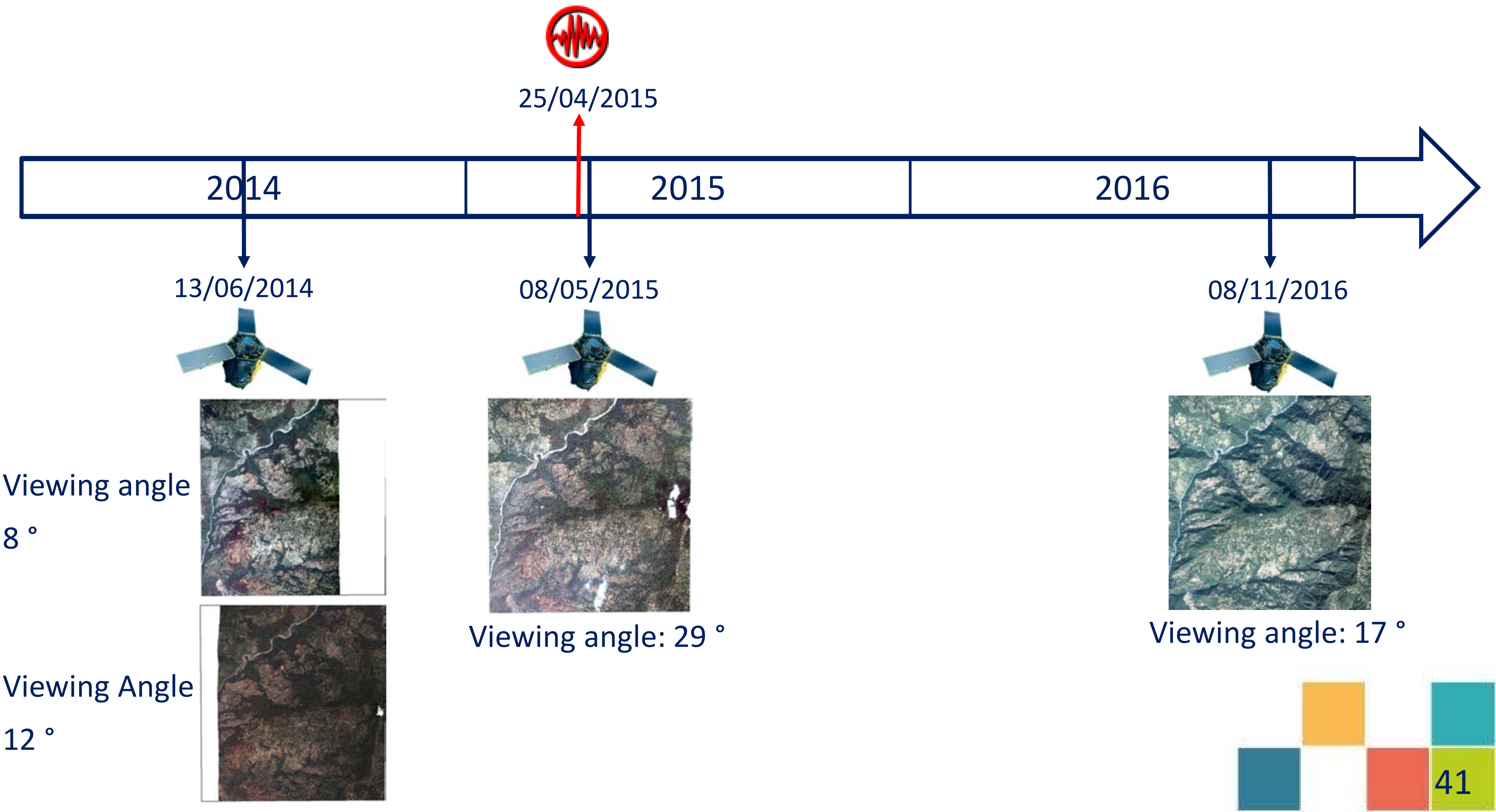
Area of interest

- 25th of April 2015, 11:56, Earthquake with a magnitude of 7.2
- Heavy casualties as well as extensive building damages
- The International Charter has been triggered the 25th of April 2015 the by the Disaster Management Support (DMS) Programme Office of the Indian Space Research Organisation (ISRO) and UNITAR/UNOSAT on behalf of UNICEF
- RO demonstrator : area 10 km x 10km, 80km east of Kathmandu





- 2 Pleiades images acquired the 13th of June 2014 (10 months before the earthquake)
- 1 Pleiades image acquired the 8th of May 2015 (13 days after the earthquake)
- 1 Pleiades image acquired the 7th of November 2016 (19 months after the earthquake)



3. Building grading
Examples

EMS98			RO grading
Grade 1		Negligeable to slight damage	1
Grade 2		Moderate damage	
Grade 3		Substential to heavy damage	2
Grade 4		Very heavy damage	
Grade 5		Destruction	3

13/06/2014

08/05/2015

3. Buildings grading
Examples

EMS98			RO grading
Grade 1		Negligeable to slight damage	1
Grade 2		Moderate damage	
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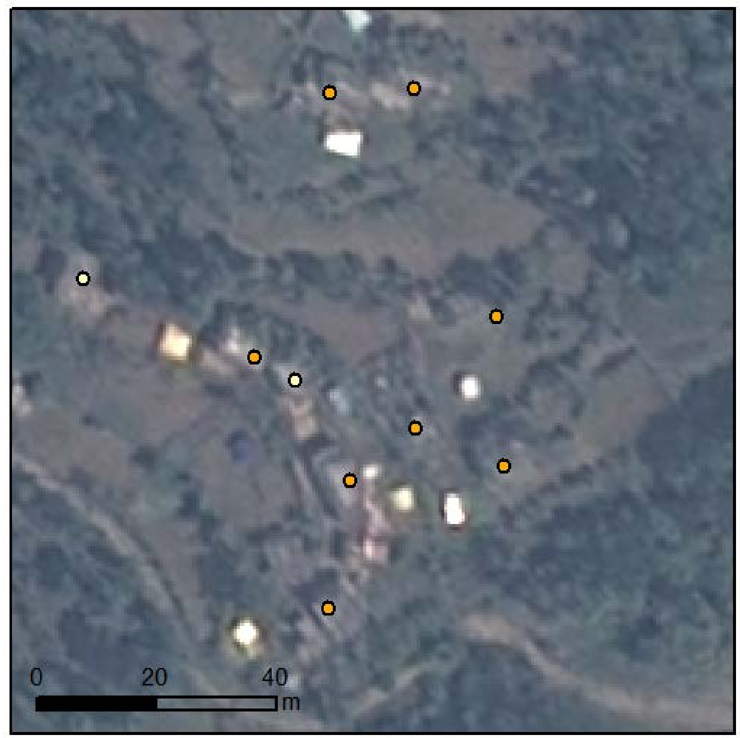
13/06/2014



08/05/2015

3. Buildings grading
Examples

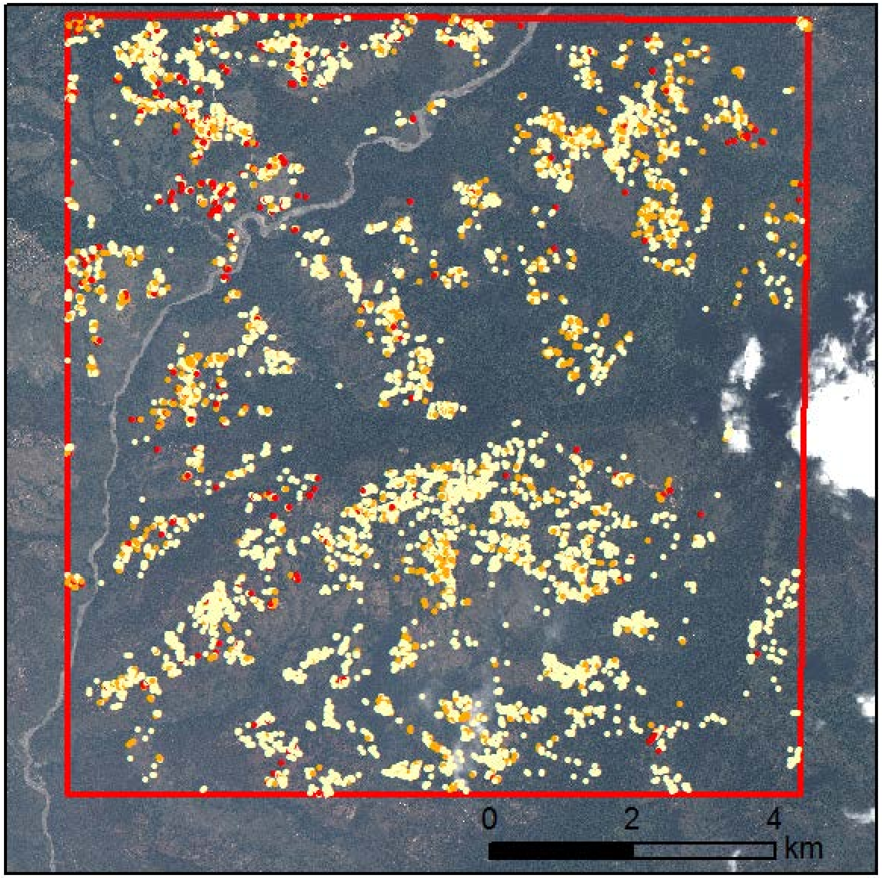
EMS98			RO grading
Grade 1		Negligeable to slight damage	1
Grade 2		Moderate damage	
Grade 3		Substantial to heavy damage	2
Grade 4		Very heavy damage	
Grade 5		Destruction	3

13/06/2014

08/05/2015

4. Damage assessment map

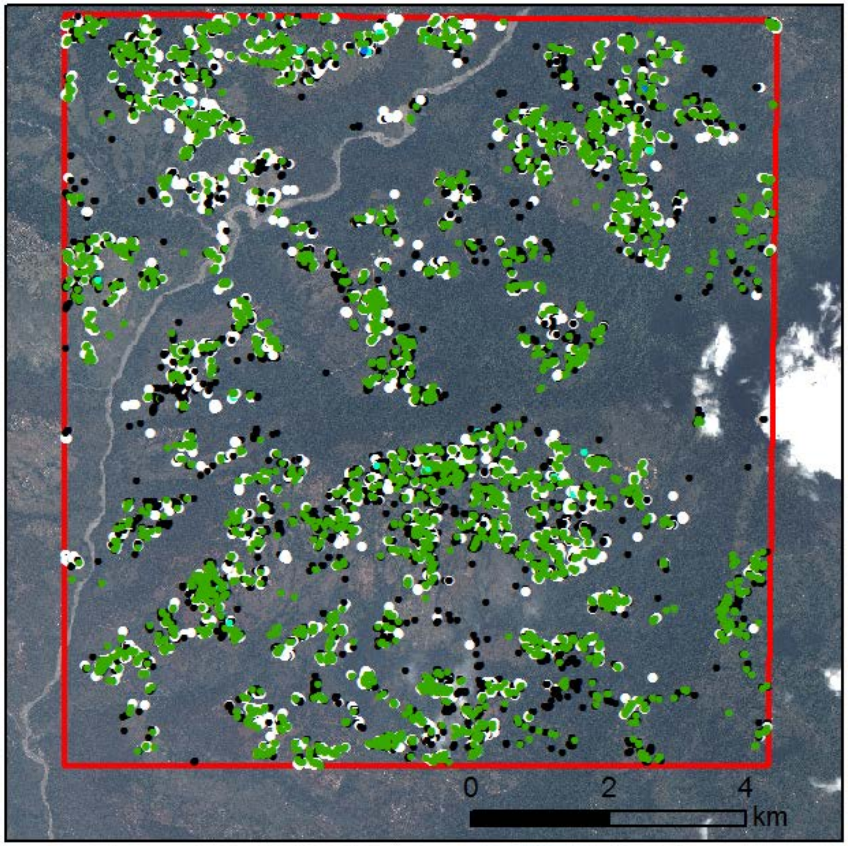
Number of buildings	9246
Buildings constructed between the 13/06/2014 and the 08/05/2015	287 (3 %)
Grade 1 (Negligeable to moderate damage)	6747 (73 %)
Grade 2 (Substential to very heavy damage)	1786 (19 %)
Grade 3 (destruction)	426 (5 %)



These figures should be taken with caution. the interpetation on the post-event image is delicate due to :

- the angle of the post-disaster image
- the size of the buildings

Total number of buildings the 07/11/2016 (19 months after the EQ)	**9655**	
- Number of buildings cleared up	2787	
- Number of buildings without visible changes	6338	
- **Buildings re-constructed identically between the 08/05/2015 and the 07/11/2016**	**134**	**100 %**
- stage "foundations excavated"	2	1.5 %
- stage "walls erected"	49	36.6 %
- stage "construction complete" (roof visible)	83	61.9 %
- **New buildings constructed between the 08/05/2015 and the 07/11/2016**	**3183**	**100 %**
- stage "foundations excavated"	2	0.1 %
- stage "walls erected"	13	0.4 %
- stage "construction complete" (roof visible)	3168	99.5 %

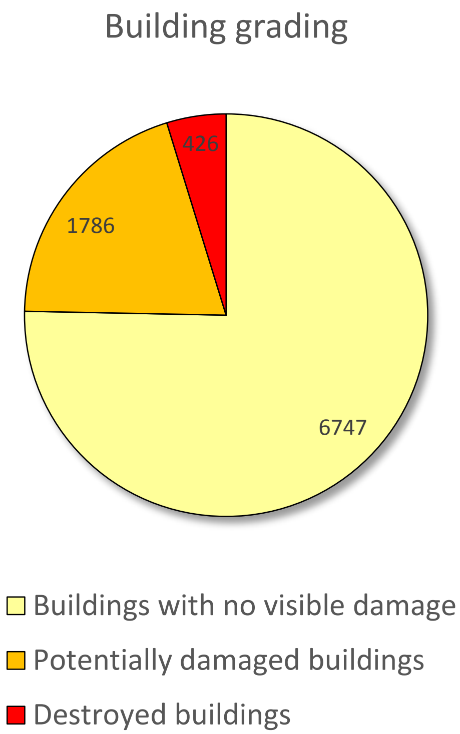


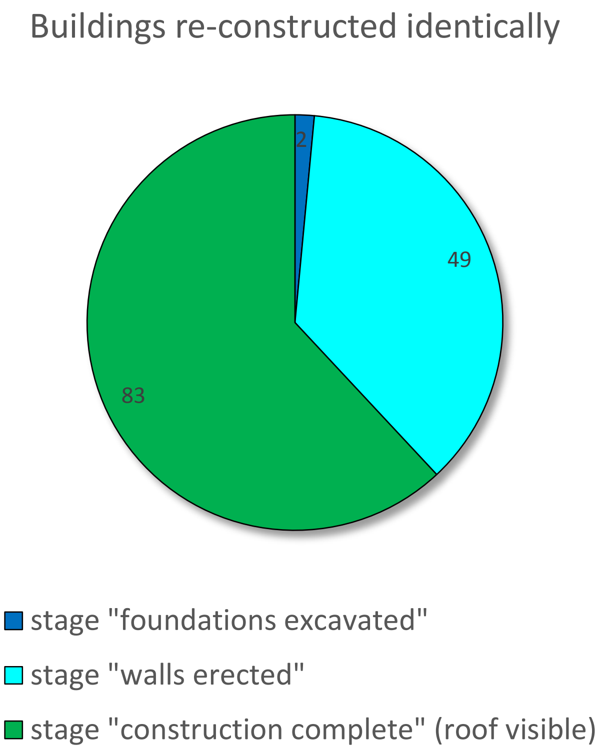
- Stage "foundations excavated"
- Stage "walls erected"
- Stage "construction complete (roof visible)"
- Unchanged building
- Cleared-up building

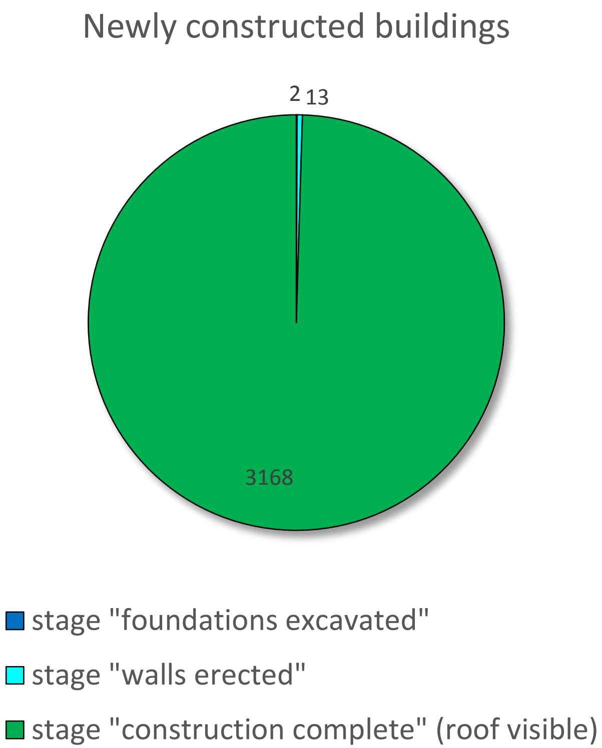
These figures should be taken with caution. the interpetation on the post-event image is delicate due to :

- the angle of the post-disaster image
- the size of the buildings

6. Recovery map







7. State of the reconstruction by grading level

	Number of buildings cleared up	Number of buildings without visible changes	Under re-construction Foundations visible	Under re-construction Walls erected	Re-construction complete	Total
Level 1 Negligeable to moderate damages	1756 (26.0 %)	4963 (73.6 %)	1 (0.0 %)	26 (0.4 %)	1 (0.0 %)	6747 (100 %)
Level 2 Substantial to very heavy damages	717 (40.1 %)	1043 (58.4 %)	1 (0.0 %)	19 (1.2 %)	6 (0.3 %)	1786 (100 %)
Level 3 Completely destroyed	284 (66.7 %)	63 (14.8 %)	0 (0.0 %)	3 (0.7 %)	76 (17.8 %)	426 (100 %)

7. State of the reconstruction by grading level