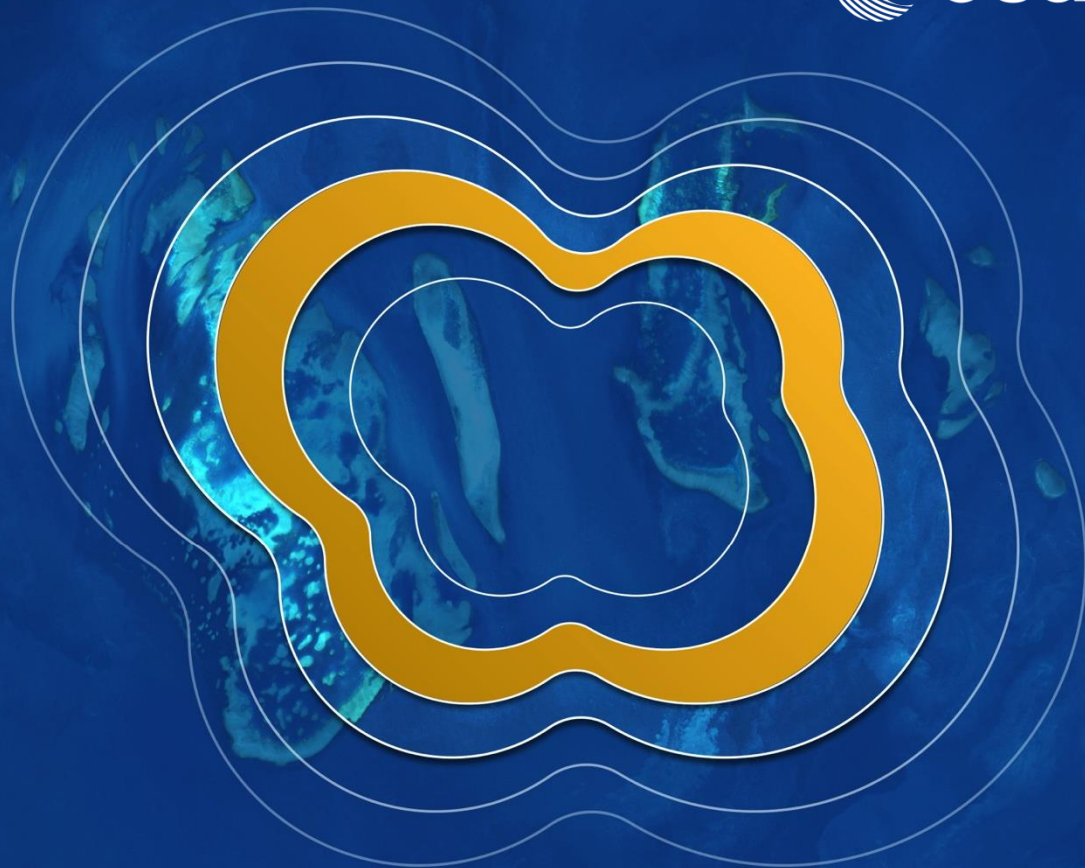


living planet symposium

MILAN
13-17 May
2019



On the use of high and very-high resolution optical remote sensing for the post-Matthew recovery phase in Haiti

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Background

The Recovery Observatory (RO) project aims at demonstrating the value of EO satellites to support the post-disaster recovery phase

Already two years of operationnal cooperation between European and Haitian partners

Several products based on optical EO data have been released ...

Outline

Several applications through the following thematics :

- Building damage assessment & reconstruction monitoring
- Population dynamics within protected areas
- Vegetation classification & damage assessment to forest stands
- Coastline delineation & evolution rate
- Impact assessment to agricultural areas & mangroves
- Large-scale Land-use/Land-cover mapping

Building damage assessment & reconstruction monitoring

RO applications – Damage assessment & Reconstruction monitoring

Context :

- Need of an up-to-date database of building footprints
→ Territory development and planification purposes
- To speed-up the damage assessment after a disaster
- VHR satellite data = a « low cost » synoptic vision
- Possibility of regular updates
- First study over the city of Jérémie



Approach :

- By mean of visual interpretation
- Situation as of 2014 (reference) from ortho-photo coverage
- Damage assessment (10/2016) from Pléiades data
- Reconstruction monitoring one year after (10/2017)
- *State_2014, State_2016, State_2017, Roof_Type, Function*

Fonction :

Résidentiel (1)

Commercial (2)

Industriel (3)

Agriculteur (4)

Education (5)

Institution (6)

Loisirs (7)

Religiously (8)

Militaire (9)

Médical (10)

Medical (10)

[illegible]

RO applications – Damage assessment & Reconstruction monitoring

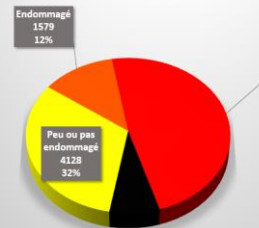
Results :

- Damage assessment (07/10/2016)

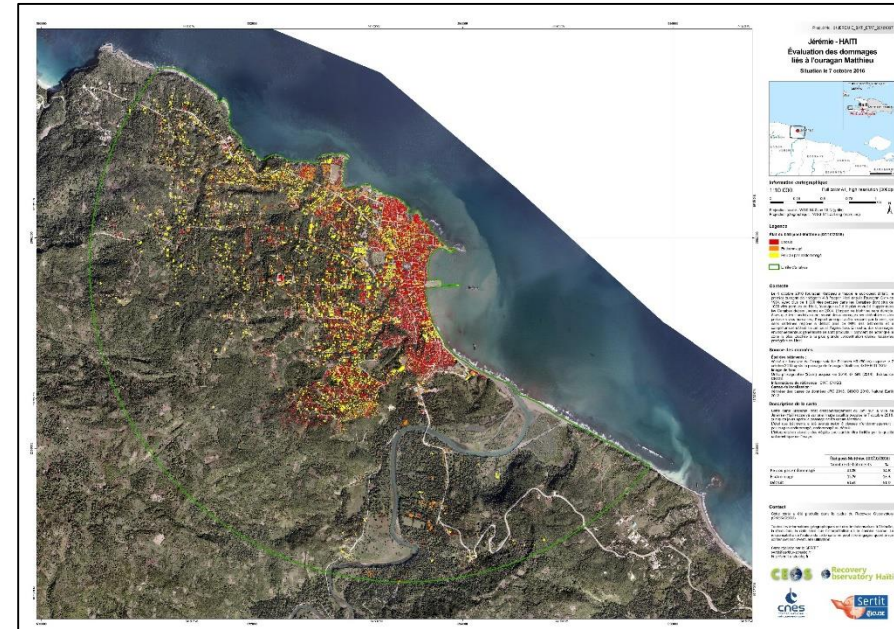
Légende
État du bâti post-Matthieu (07/10/2016)

- Détruit
- Endommagé
- Peu ou pas endommagé
- Limite d'analyse

État du bâti post-Matthieu (07/10/2016)



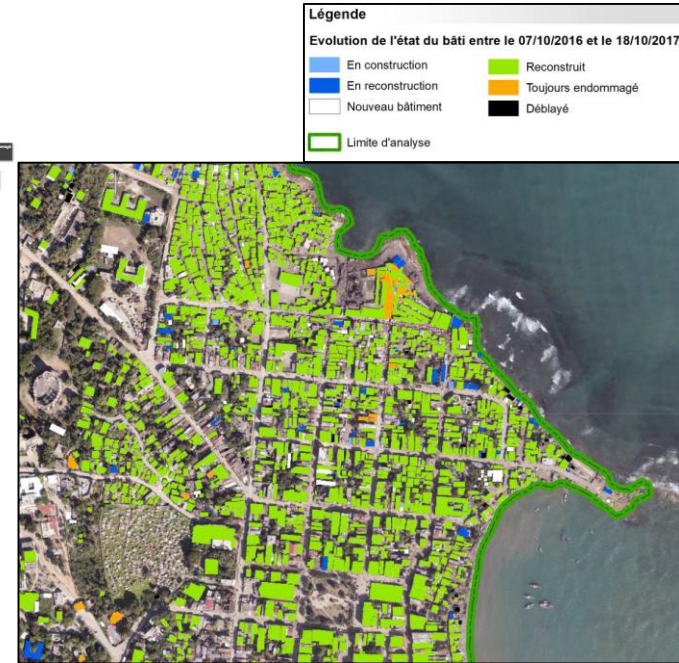
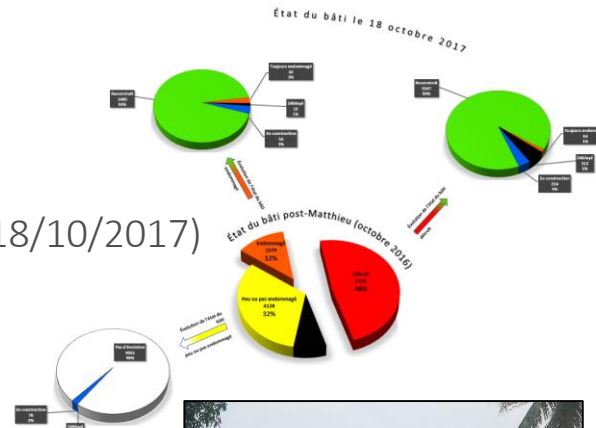
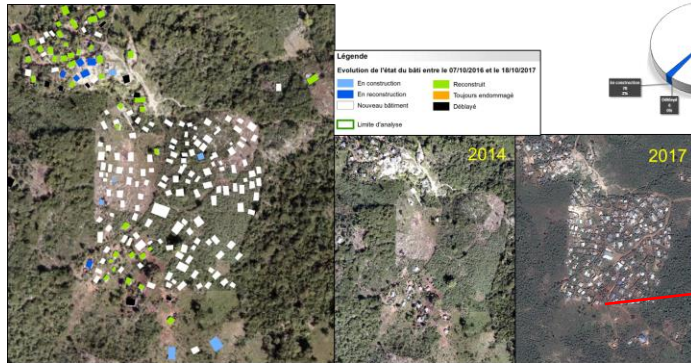
Nombre de bâtiments cartographiés : 12 823



RO applications – Damage assessment & Reconstruction monitoring

Results :

- Reconstruction monitoring (18/10/2017)



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RO applications – Damage assessment & Reconstruction monitoring

Context :

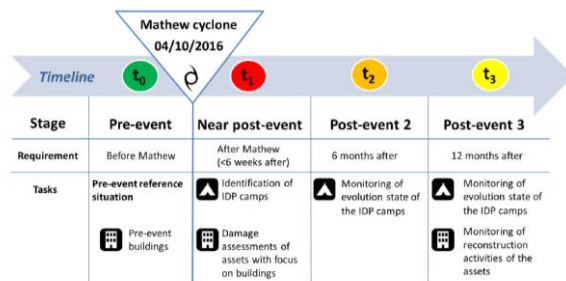
- Request for an extension of the study area (Jérémie, Les cayes)
- Damage assessment and reconstruction activities
- Identification and monitoring of IDP camps
- Products realised in the frame of Copernicus EMS RRM :

<https://emergency.copernicus.eu/mapping/list-of-components/EMSN050>



RO applications – Damage assessment & Reconstruction monitoring

Approach :



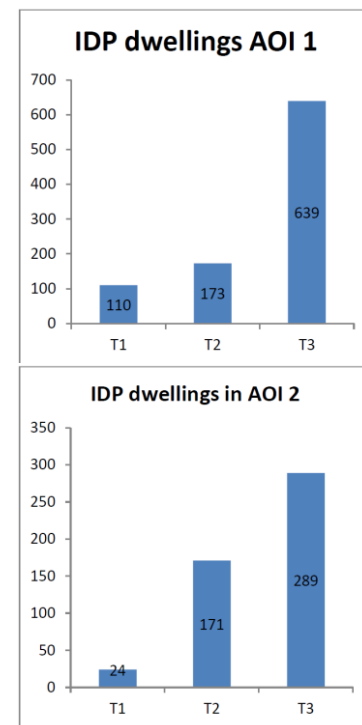
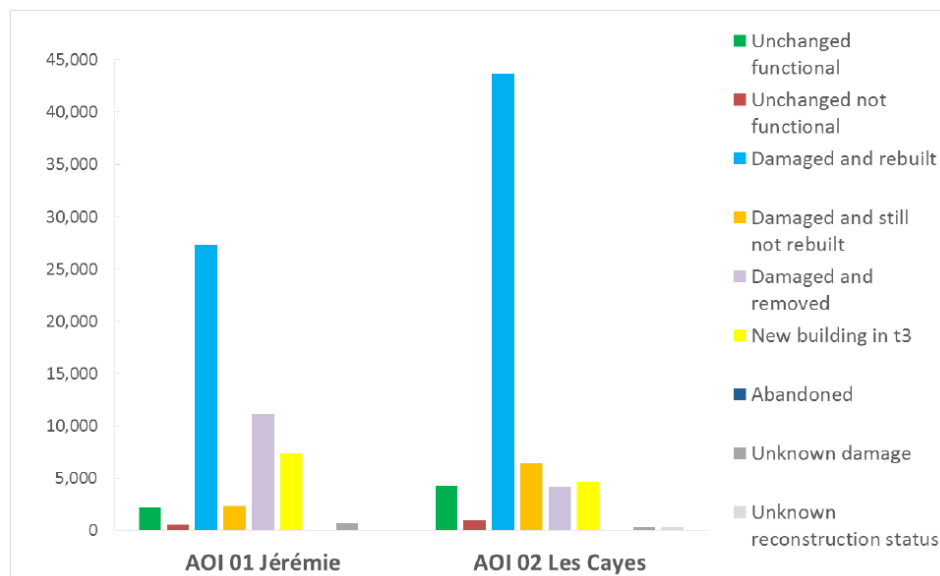
Codes used in every time stage.

Code	t_0	t_1	t_3
1	1-Fully Functional (pre-event)	1-Not visible damage	1-Not visible damage
2	2-Not functional (pre-event)	2-Damage	2-Damaged
3	N/A	N/A	3-Cleared
4	N/A	N/A	4-New building in t_3
5	5-Not present in t_0	5-Not present in t_1	N/A
9	9-Unknown	9-Unknown	9-Unknown

Code	Reconstruction Class	Comments	Additional comments
111	Unchanged functional	Unchanged functional, fully functional buildings in t_0 , t_1 , and t_3	N/A
211	Unchanged functional	Unchanged functional, fully functional buildings from t_1	N/A
511	Unchanged functional	Unchanged functional, not present in t_0	Building not present in t_0
222	Unchanged not functional	Unchanged not functional	N/A
522	Unchanged not functional	Unchanged not functional, not present in t_0	Building not present in t_0
121	Damaged and rebuilt	Damage and rebuilt, when the reconstruction work has been completed	N/A
221	Damaged and rebuilt	Damage and rebuilt, when the reconstruction work has been completed (damaged in t_0)	N/A
521	Damaged and rebuilt	Damage and rebuilt, when the reconstruction work has been completed, not present in t_0	Building not present in t_0
122	Damaged and still not rebuilt	Damaged and still not rebuilt, visible damage in t_1 but still not functional in t_3 (possible ongoing rebuild)	N/A
123	Damaged and removed	Removed, cleared at t_3 , but there existed a building at t_0 or t_1	N/A
523	Damaged and removed	Removed, cleared at t_3 , but there existed a building at t_1 , not present in t_0	Building not present in t_0
223	Removed	Not functional building in t_0 and t_1 and finally removed in t_3	N/A
554	New building in t_3	New structure visible in t_3 , not present in t_0 or t_1	Building not present in t_0
112	Abandoned	Building without maintenance and not functional in t_3	N/A

RO applications – Damage assessment & Reconstruction monitoring

Results :

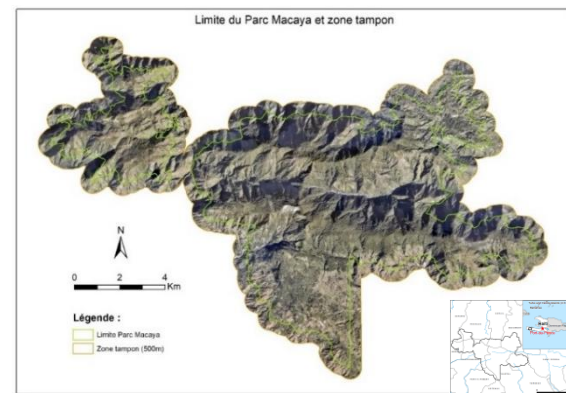


Population dynamics within protected areas

RO applications – Population dynamics

Context & approach :

- Request for an overview of human settlements over the Makaya Park
- Identification of buildings for 2014 (orthophoto)
- Monitoring for 2017 & 2018 (Pléiades data)
- Buffer area of 500 m (merge of protected areas)

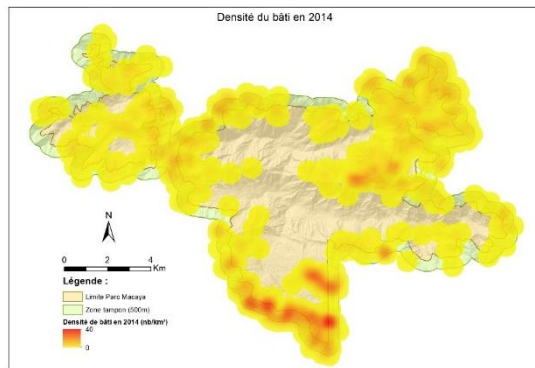


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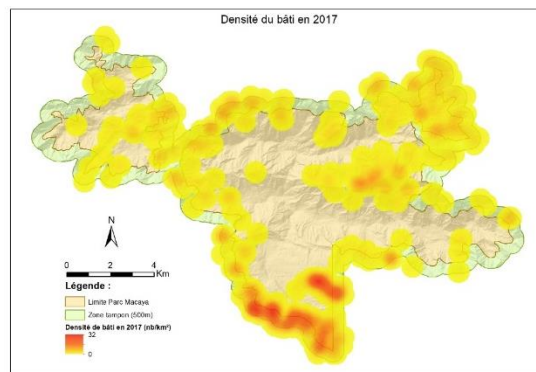
RO applications – Population dynamics

Results : Density over time

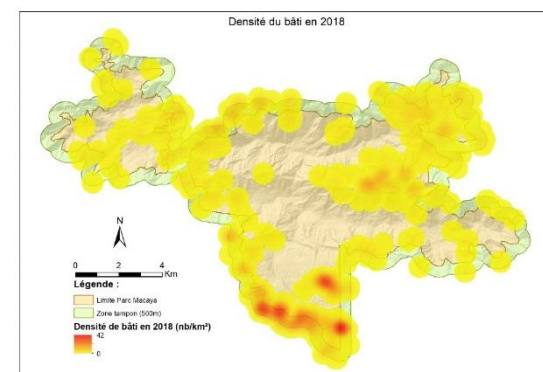
2014	
Nombre de bâtiments	1 299
Surface de la zone d'étude	15 105 ha
Densité	8,6 bâtiment/km ²



2014-2017	
Bâtiments toujours présents	637
Nouveaux bâtiments	153
Bâtiments disparus	546
Bâtiments non analysés (nuages)	116
Surface de la zone d'étude	15 105 ha
Densité	Non applicable



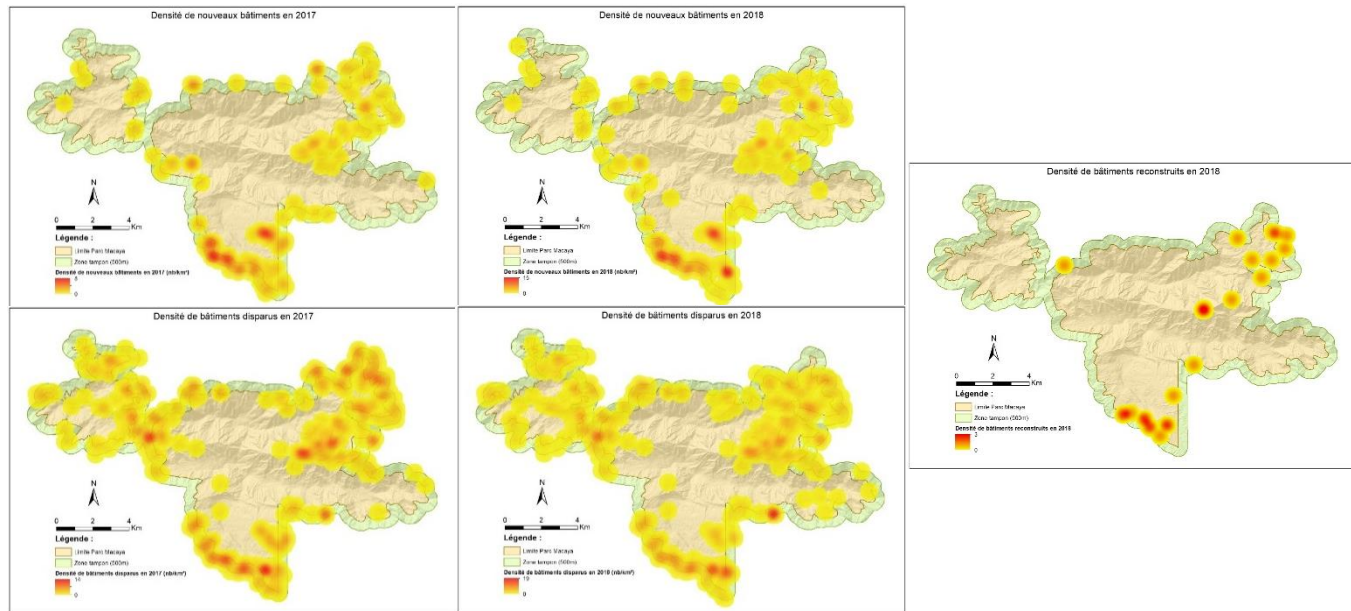
2014-2017-2018	
Bâtiments toujours présents	533
Nouveaux bâtiments	232
Bâtiments reconstruits	25
Bâtiments disparus	554
Bâtiments non analysés (nuages)	219
Surface de la zone d'étude	15 105 ha
Densité	Non applicable



RO applications – Population dynamics

Results :

- Dynamic of changes
- Density of reconstruction



Impact assessment to agricultural areas

Context :

- <https://emergency.copernicus.eu/mapping/list-of-components/EMSN051>

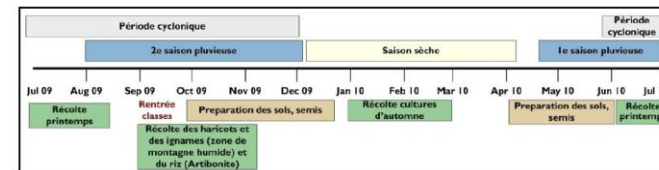


RO applications – Impact assessment to agricultural areas

Approach :

- Small-size crops, complex agricultural calendar, cloud cover ...
→ Impossibility to identify crop types
- Importance of woodland (i.e. agro-forestry)
→ Focus on this component within agricultural landscapes
- Tens of Pléiades & SPOT-6/7 data were required !

Territoires agricoles - L'ensemble des surfaces à terres arables, cultures ligneuses agraires, fourragères permanentes, jardins et vergers de famille annexes aux entreprises agricoles.		
2.1 Cultures agricoles sans couvert arboré	Zones utilisées pour les cultures ou en jachère, généralement selon un schéma de rotation : cultures vivrières ou alimentaire. Ces espaces peuvent contenir quelques arbres d'un pourcentage maximum de 5%.	<ul style="list-style-type: none"> Primarily Vegetated Areas Terrestrial Cultivated and Managed Terrestrial Areas Herbaceous Crops
2.2 Cultures agricoles avec couvert arboré	Zones contenant quelques arbres dispersés pouvant être estimés entre 5% et 30%, utilisées pour les cultures ou en jachère, généralement selon un schéma de rotation : cultures vivrières ou alimentaire. Cette surface se différencie des systèmes agro-forestiers par la fréquence des arbres.	<ul style="list-style-type: none"> Primarily Vegetated Areas Terrestrial Cultivated and Managed Terrestrial Areas Herbaceous Crops // Primarily Vegetated Areas Terrestrial Natural and Seminal Terrestrial Vegetation Trees Sparse (4 - 20%)
2.3 Systèmes agro-forestiers	Ensemble de systèmes et de techniques d'utilisation des terres où des plantes ligneuses sont délibérément associées aux cultures ou à la production animale sous forme d'un arrangement spatial ou d'une séquence temporelle prenant place sur une même unité de gestion de la terre.	<ul style="list-style-type: none"> Primarily Vegetated Areas Terrestrial Natural and Seminal Terrestrial Vegetation Trees Closed to Open (40 - 100%) > 30 - 3m (Trees Height) + Primarily Vegetated Areas Terrestrial Cultivated and Managed Terrestrial Areas Shrub Crops Multiple Crops One Additional Crop Herbaceous Terrestrial Crop With Simultaneous Period



RO applications – Impact assessment to agricultural areas

Approach :

- Extraction of woodland surfaces, & classification based on surface/density
→ Distinction between « forest », « copse » & « isolated trees »
- Extraction of « low-lying vegetation » & « crops »
→ Based on the persistence of vegetation over time
- Extraction of « shrubs » : residual after forest separation

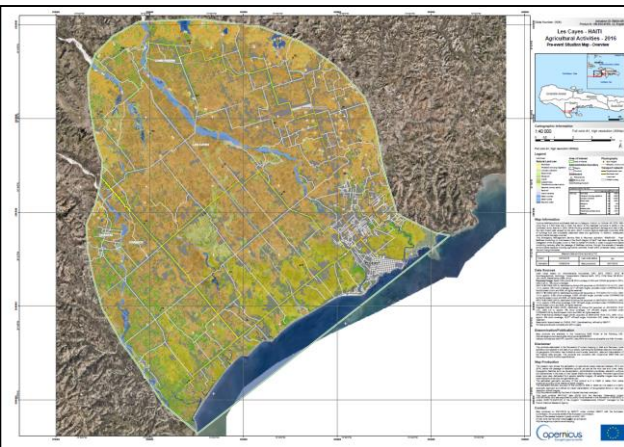
Class number	Tree cover class	Class criteria
313	Mixed forest	Density $\geq 10\%$ Size ≥ 0.5 hectares
314	Mangrove	Initial area photo-interpreted from tree-cover classification
315	Copse	Size ≥ 0.02 hectares and ≤ 0.5 hectares
316	Isolated trees	Trees outside the above classes

Class Number	Tree density class	Class criteria
1	Low density trees within agricultural area	Density $\geq 10\%$ and Density $< 30\%$
2	Trees within agri-forestry system	Density $\geq 30\%$ and Density $< 65\%$
3	Dense woodland	Density $\geq 65\%$

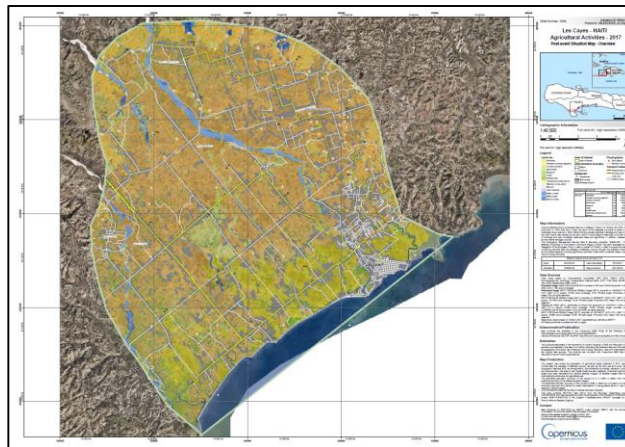
RO applications – Impact assessment to agricultural areas

Results :

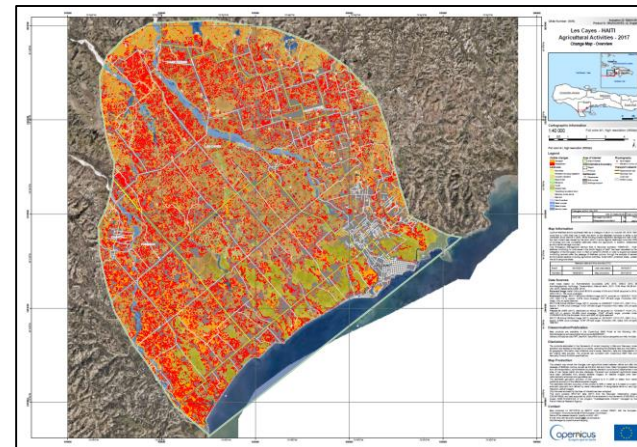
Pre



Post



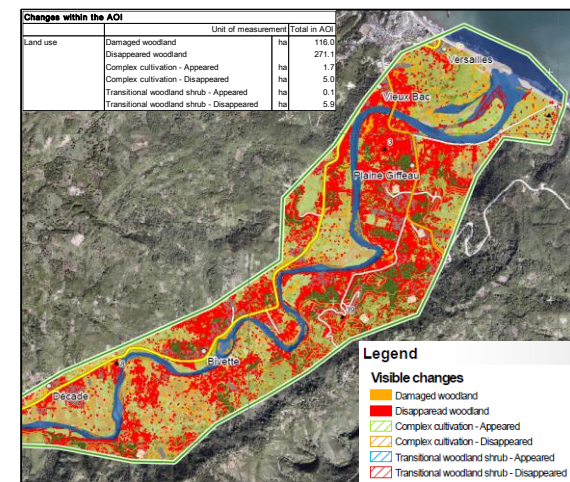
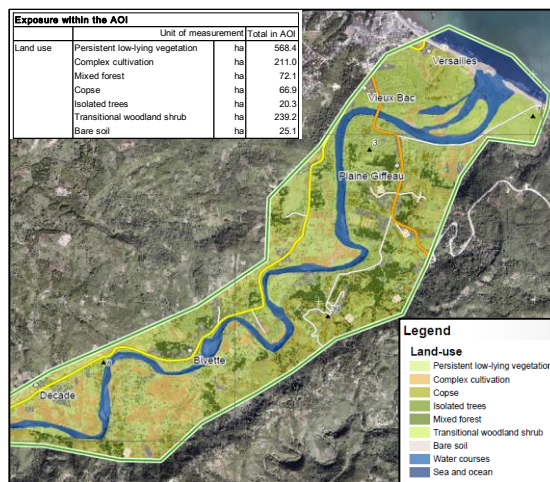
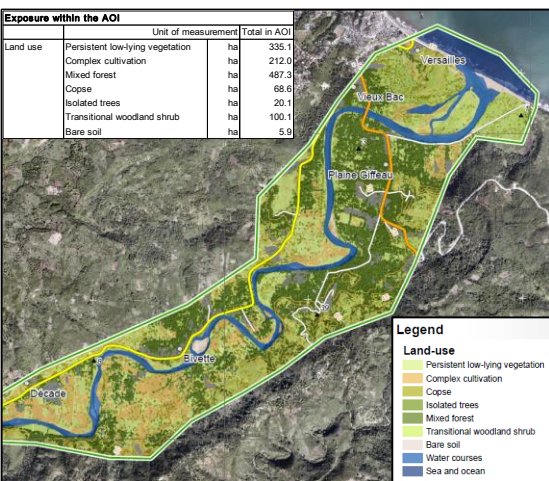
Change



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RO applications – Impact assessment to agricultural areas

Results :



Vegetation classification & Damage assessment to forest stands

RO applications – Vegetation classification & Damage assessment to forest stands

Context :

- Request for an impact assessment over the Makaya Park (2 protected areas)
- Need of a pre-disaster vegetation's classification map
- Post-disaster damage assessment within the « woodland » class
- Regeneration monitoring one year after
- Products realised in the frame of Copernicus EMS RRM :

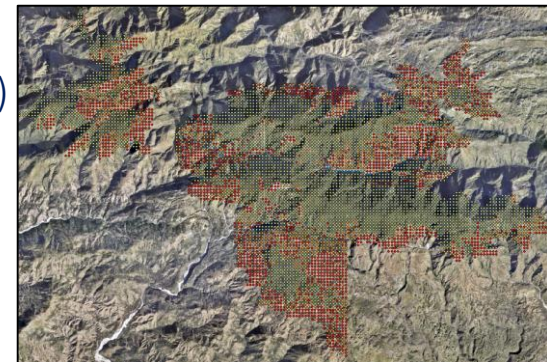
<https://emergency.copernicus.eu/mapping/list-of-components/EMSN051>



RO applications – Vegetation classification & Damage assessment to forest stands

Approach :

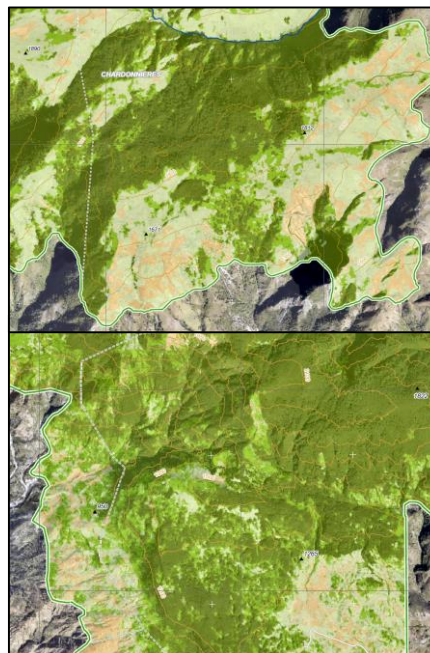
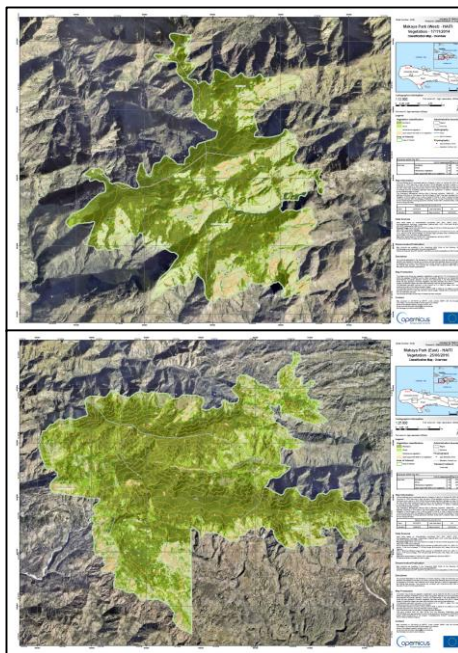
- 4 classes : « woodland », « shrub », « herbaceous » & « open spaces without vegetation »
- Supervised classification on SPOT-6/7 pansharpened data (June 2016)
- Samples provided by a national database of observations by point (2010)
- Agregation of the database classes
- Correction by photo-interpretation (orthophoto 2014)
- Sampling / training / classification (RF) / validation



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RO applications – Vegetation classification & Damage assessment to forest stands

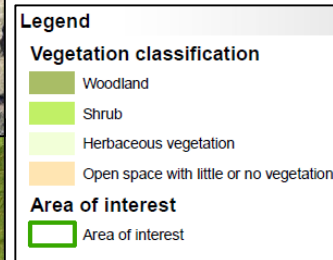
Results :



Woodland	ha	835.3
Shrub	ha	153.4
Herbaceous vegetation	ha	438.9
Open space with little or no vegetation	ha	82.8

Forest = 55%

Overall accuracy = 88%



Overall accuracy = 86%

Woodland	ha	4704.5
Shrub	ha	2258.6
Herbaceous vegetation	ha	1379.6
Open space with little or no vegetation	ha	376.5

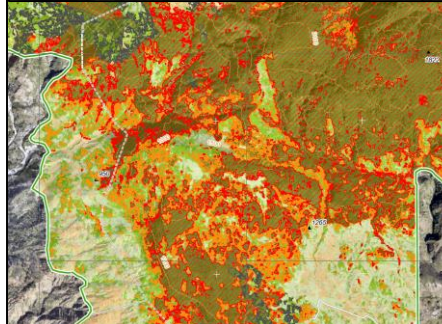
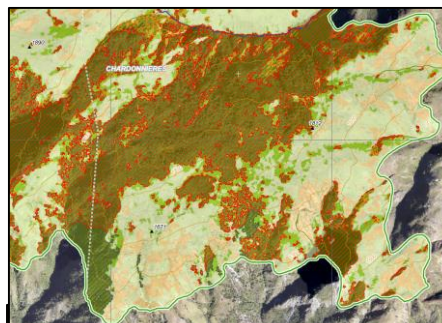
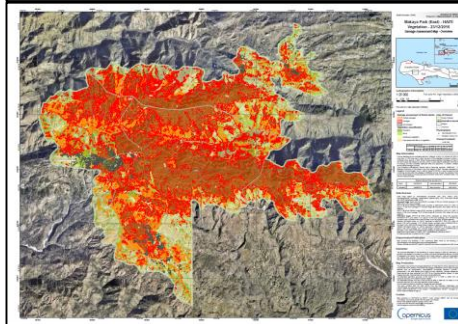
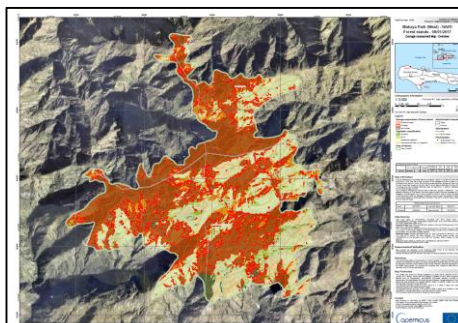
Forest = 54%

Approach :

- Identification of damaged forest stands from VHR images : 100% impacted !
- Grade assessment : « partially damaged », « damaged » & « Not analysed » (i.e. cloud cover)
- Simple method based on the vegetation activity (still active vs. no activity)
- To deal with shadows : use of an hillshade mask for a separate thresholding
- Monitoring of the regeneration one year after, based on the same principle (and constraints)

RO applications – Vegetation classification & Damage assessment to forest stands

Results :



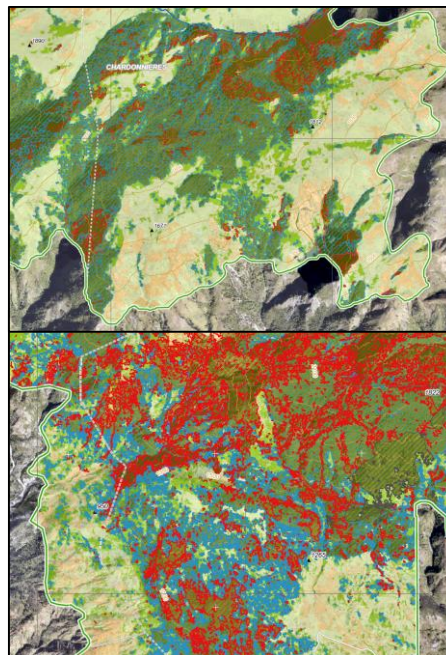
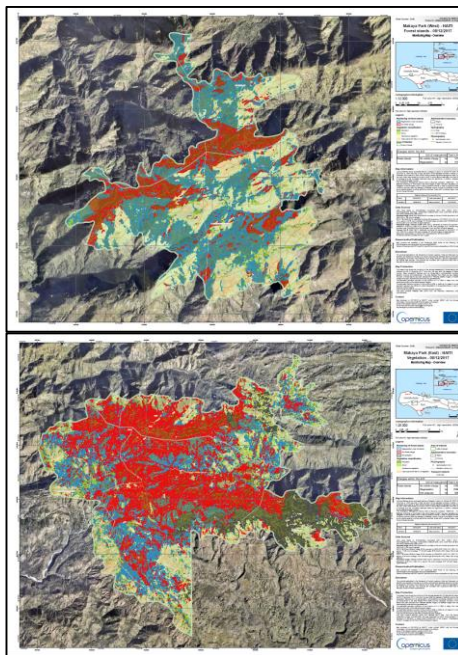
Unit of measurement		Damaged	Partially damaged	Not analyzed	Total affected	Total in AOI
Woodland	ha	722.9	92.6	19.8	815.5	835.3

Legend	
Damage assessment of forest stands	
	Partially damaged
	Damaged
	Not Analysed
Vegetation classification	
	Woodland
	Shrub
	Herbaceous vegetation
	Open space with little or no vegetation
Area of interest	
	Area of interest

Unit of measurement		Damaged	Partially damaged	Not analyzed	Total affected	Total in AOI
Woodland	ha	3925.8	684.3	94.5	4610.1	4704.6

RO applications – Vegetation classification & Damage assessment to forest stands

Results :



Changes within the AOI			
	Unit of measurement		Total in AOI
Forest stands	No visible change	ha	297.6
	Regeneration	ha	515.6
	Not analysed	ha	22.2

Regeneration = 60%

Legend	
Monitoring of forest stands	
	Regeneration under old stands
	No visible change
	Not analyzed
Vegetation classification	
	Woodland
	Shrub
	Herbaceous vegetation
	Open space with little or no vegetation

Regeneration = 50%

Changes within the AOI			
	Unit of measurement		Total in AOI
Forest stands	No visible change	ha	1759.2
	Regeneration	ha	2336.5
	Not analyzed	ha	608.8

Impact assessment to mangrove

RO applications – Impact assessment to mangrove

Context :

- Impact of the cyclone to mangrove ?
- Need of pre & post-disaster situation maps
- Cross-comparison for change map production
- Area of interest n°6
- Products realised in the frame of Copernicus EMS RRM :

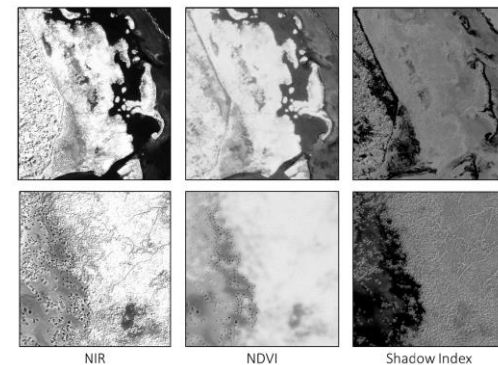
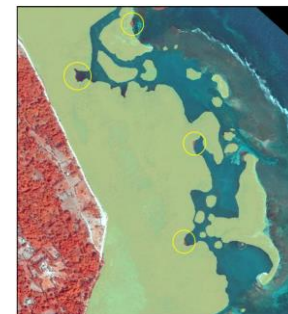
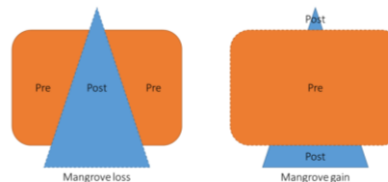
<https://emergency.copernicus.eu/mapping/list-of-components/EMSN051>



RO applications – Impact assessment to mangrove

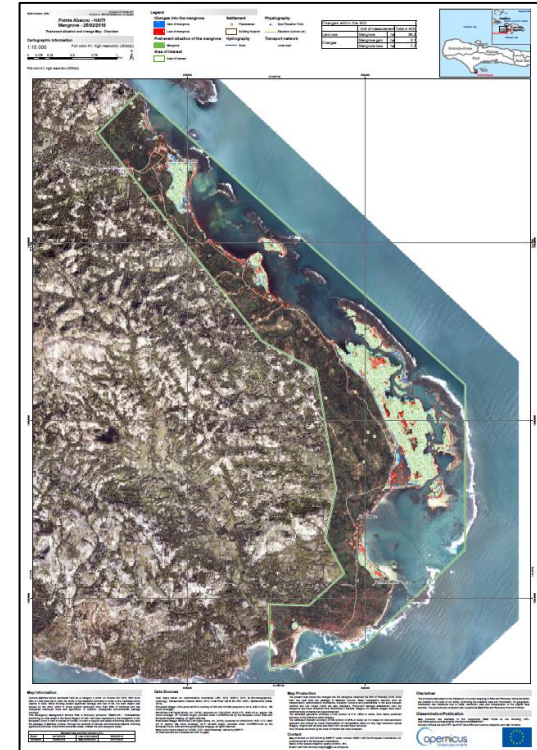
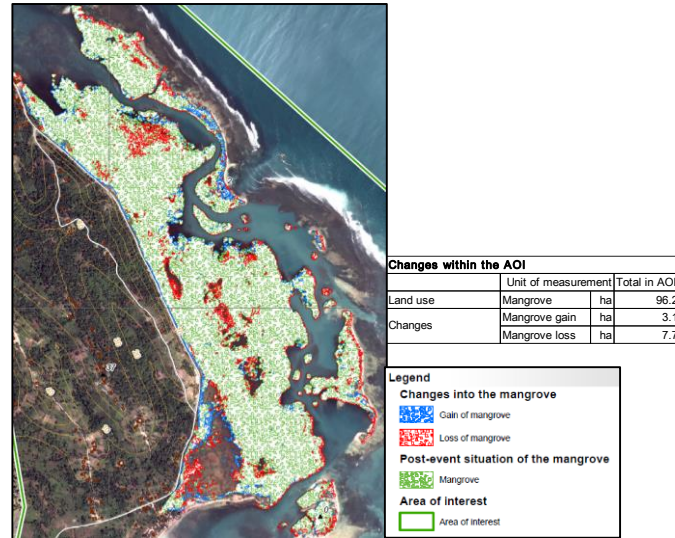
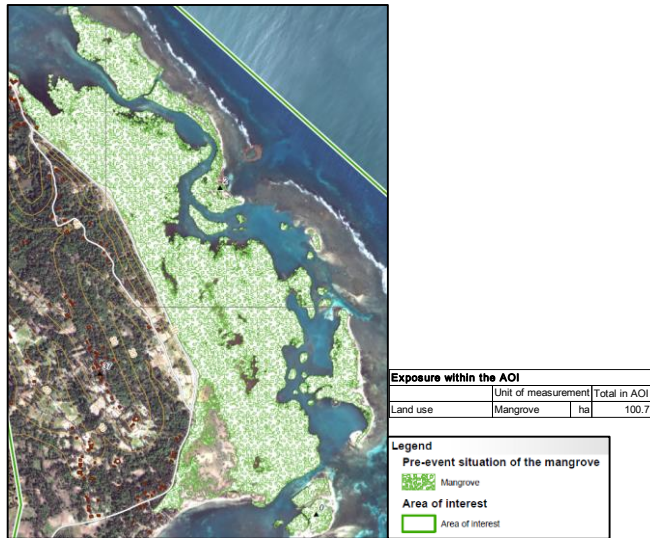
Approach :

- Visual identification of mangrove areas from VHR images (0.5 m)
- Rough delineation, binary mask
- Precise extraction of mangrove : $f(\text{Red, NIR, SI, BI, Mask})$
- Morphological operations and filtering
- Extent for 2016 & 2018
- Loss and gain over this period



RO applications – Impact assessment to mangrove

Results :



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Coastline delineation & evolution rate

RO applications – Coastline delineation & evolution rate

Context :

- Archives of coastline delineation for 1978, 2002 & 2010
- Post-Matthew coastline position
- From Jérémie to Les Cayes (≈250km)
- Computation of evolution rate
- Products realised in the frame of Copernicus EMS RRM :

<https://emergency.copernicus.eu/mapping/list-of-components/EMSN051>



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RO applications – Coastline delineation & evolution rate

Approach :

- Definition of the coastline (tricky !)
- SPOT-6/7 coverage (1.5 m) acquired the 14/02/2017
- Manual delineation, quality control
- Use of the Digital Shoreline Analysis System (USGS)
- Evolution rate computed along regularly spaced transects

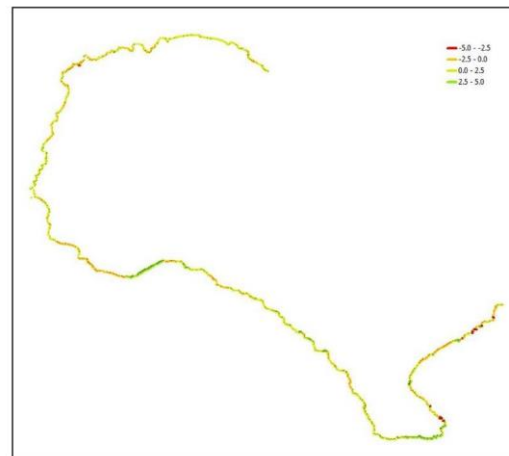
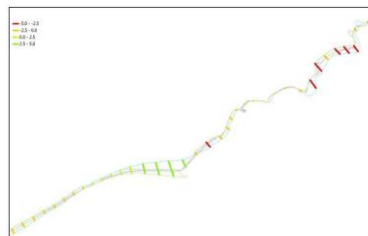


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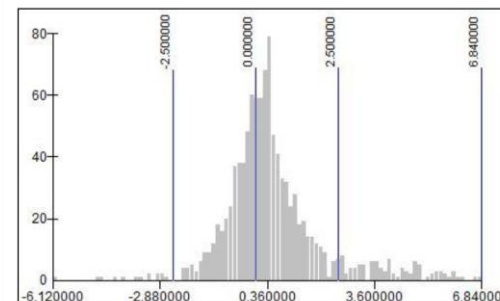
RO applications – Coastline delineation & evolution rate

Results :

- More progradation than erosion
- Geometrical accuracy of archives ?



Coastal line evolution rate (m/year)	Number of transects
-5.0 to -2.5	14
-2.5 to 0.0	368
0.0 to 2.5	565
2.5 to 5.0	95

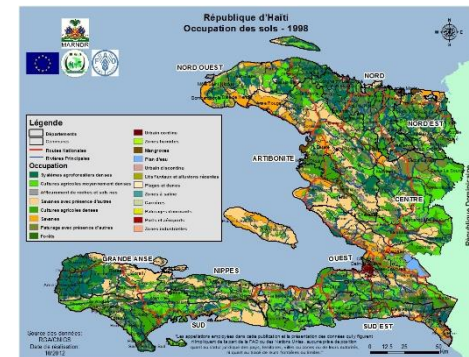


Large-scale Land-use/Land-cover mapping

RO applications – Land-use/Land-cover mapping

Context :

- Land-cover is a critical issue in terms of Development and Disaster Risk Reduction in Haiti
- Lack of recent LULC map over Haiti : the last one was produced in 1998 !
- Rapid evolution of landscapes
- Impact of the Matthew cyclone to tree cover



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Approach :

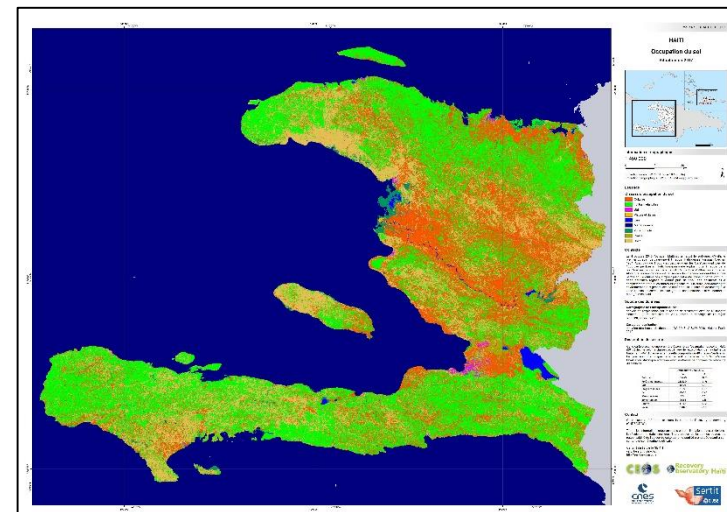
- To take benefits from the Copernicus Sentinel-2 mission
- Processing chain for operational LULC mapping based on S-2 L2A developed by CESBIO (*iota*²)
- Enhanced Sentinel-2 L2A datasets produced by Théia/CNES over Haiti
- First experiments on the adaptation of *iota*² processing chain
- Production of LULC map for 2017

RO applications – Land-use/Land-cover mapping

Results :

- To deal with clouds !
- Promising ... but well ...
- Come to see why at the next poster session :
« Towards an operational land-use mapping over Haiti from Sentinel-2 »
- More details about *iota*² over France at this session :

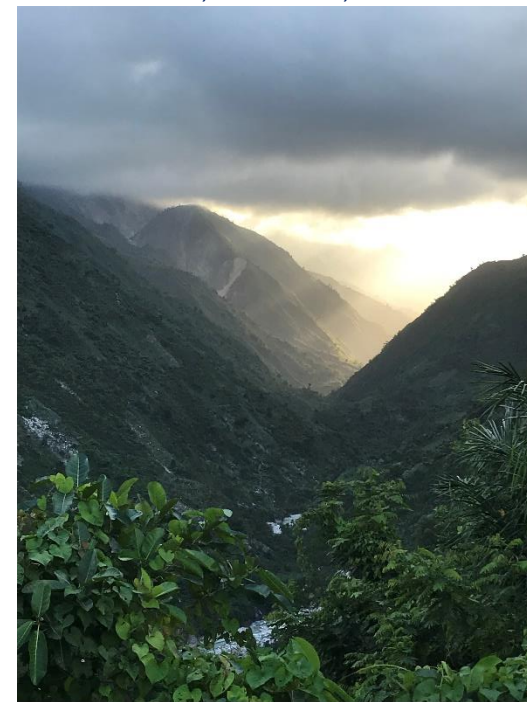
« Mapping France's Land-cover at 10 m Every Year. Lessons Learned and Future Improvement » (J. Inglada, 11h40, Space 2)



RO applications – Perspectives

- Monitoring of human activities within Makaya Park
- New monitoring of vegetation regeneration
- New vegetation classification (situation as of 2019)
- Production of LULC map for 2018 (ongoing improvements)
- Large-scale & long-term monitoring of mangroves
- Landslide inventory (EOST)
- Radar-based change detection & ground movement (ASI/CIMA)

Makaya Park – May 2019



Thank you for your attention !

