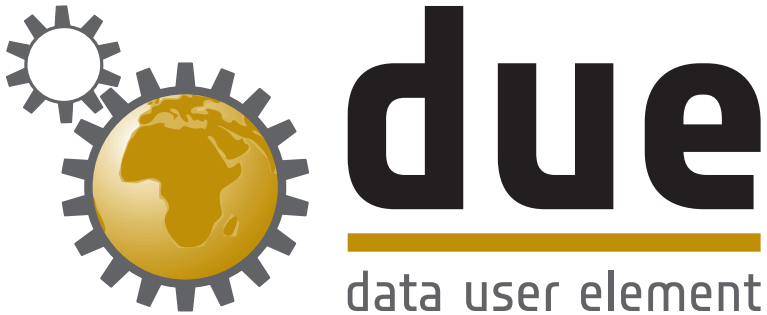
DUE preparatory activities for Sentinel 2 exploitation:

Agriculture, Land Cover Change, Costal Monitoring, Forest Mapping



Fostering the development and validation of EO applications with and for user communities

Benjamin Koetz, Olivier Arino, Marc Paganini, Simon Pinnock, Frank-Martin Seifert, Fabrizio Ramoino,

European Space Agency

+ ESA projects (GlobWetland, GSE GMFS, CoastColour, GSE Forest, TIGER)

COPERNICUS: Sentinel-2

Multispectral High Resolution Optical Imager

- Launch: 2014, 2016, ...
- 13 bands (VIS, NIR & SWIR)
- 290 km swath at 10, 20 and 60 m
- Systematic acq. of all land and coasts
- 5 days repeat cycle with 2 satellites
- 7 years design lifetime (max. 12 yrs)

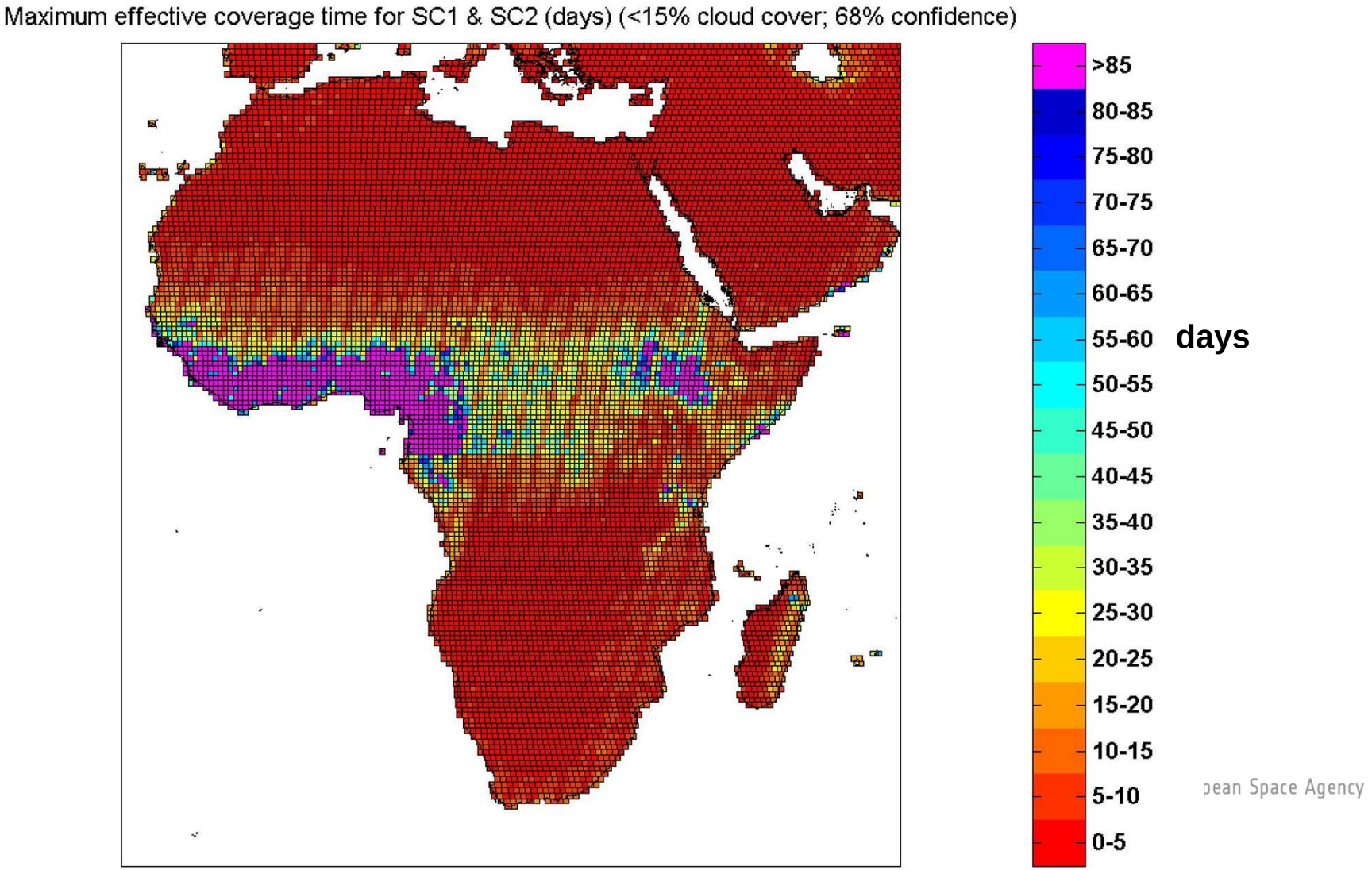
https://sentinel.esa.int/web/sentinel/home

http://spaceinvideos.esa.int/Videos/2013/09/Living_Planet_2013_-_Sentinel-2_mission

Sentinel-2 Revisit Time Capability

Revisit time over Africa in summer with 2 satellites

Based on a repeat cycle of 5 days and considering cloud coverage



The DUE programme, working with user communities

"The DUE - like its forerunner DUP - is an instrument to support the development of operational EO applications. It is in particular working to support the users of such applications along with the EO service industry, and is instrumental also to encourage the cooperation between parties in the various participating states."

Dr. Nico Bunnik - Former National Delegate to the Earth Observation (EO) Programme Board

User Groups: National & sub-national public authorities, European institutions, International organizations, NGOs

User requirements consolidation

Ground truthing In-situ data access

Products validation

Service assestment

EO data

Service Development

Products

Service Demonstration

Sentinel-2 User requirements

S2 preparatory symposium – April 2012, ESRIN

- Objective: requirements for S2 R&D preparatory activities
- Global scientific community (300+ participants)
- Wide range of EO applications
- recommendations for temporal S2 capabilities (3/28)
  - [5] Time series of simulated Sentinel 2 L1C products
  - [8] Time Series Analysis Methods (tools for different applications)
  - [18] Sentinel-2 – Landsat interoperability

Extension to running projects

FOREST

Addressing the policy related demands for securing the ecological functions in the forestry sector.

Prime: **GAF** (DE)

http://www.gmes-forest.info

COASTAL ZONES

Improving the uptake of MERIS for coastal water monitoring

Prime: BROCKMANN CONSULT(DE)

http://www.coastcolour.org

WETLANDS

Regional pilot project of the Ramsar Convention on Wetlands for wetlands inventory, assessment and monitoring.

Prime: **Jena Optronik** (DE)

http://www.globwetland.org

AGRICULTURE

Providing crop monitoring services for food security.

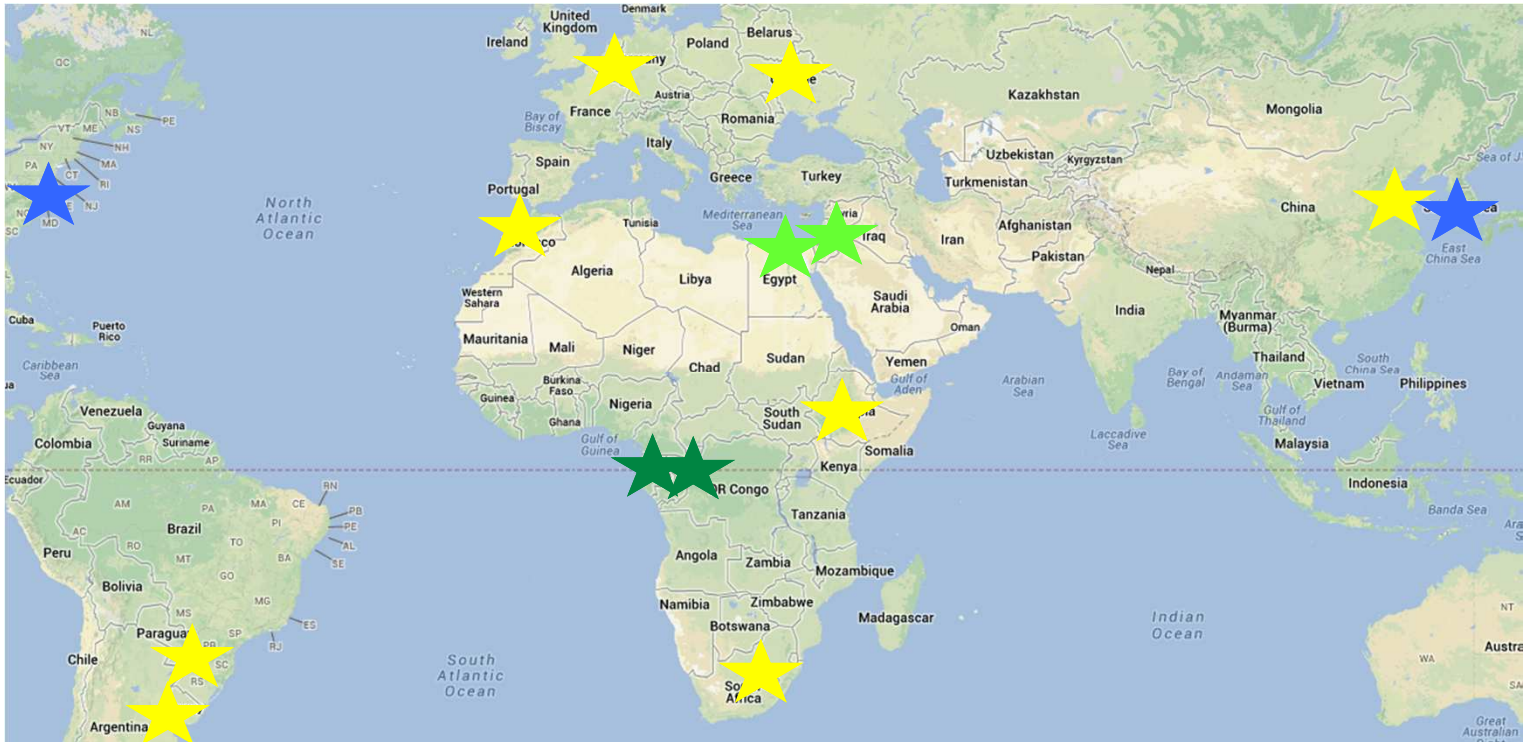
Prime: **VITO** (BE)

http://www.gmfs.info

Preparing for S-2 exploitation in agricultural monitoring (food security, national reporting, crop management, rural development)

Simulated Sentinel-2 Time Series
(part of Take5 initiative of CESBIO/CNES)

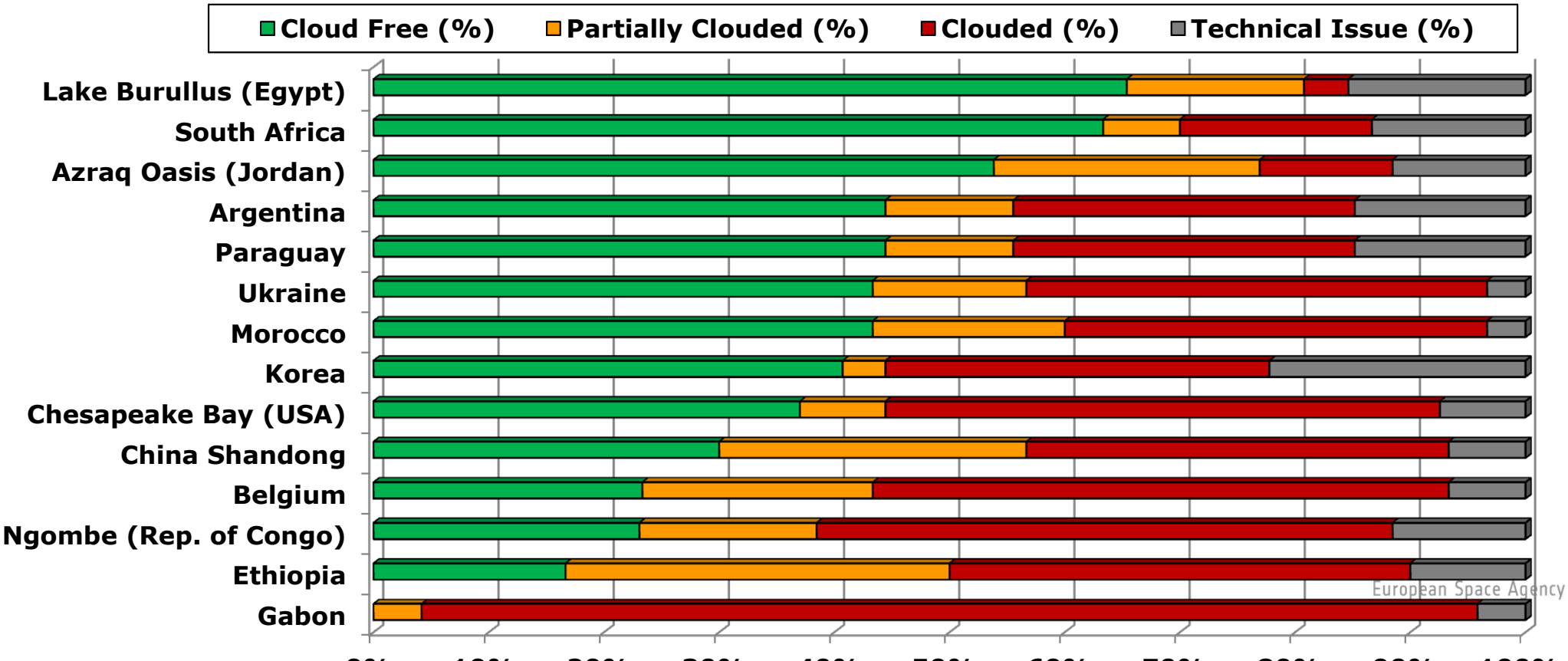
- 14 test sites, globally distributed
- Four major EO applications: Forest, Marine, Agriculture, Wetlands
- **Multi-sensor & multi-temporal data set** (February-June 2013)
  - SPOT4: 5 days repeat, 20 m, 60x60 km2, L1c & L2a
  - RapidEye: 5 days repeat, 5 m, 25x25 km2, L3a
  - Landsat-8: 16 days repeat*, 30 m, 180x180 km2, L1T



*since 15th of April (preferential acquisition)

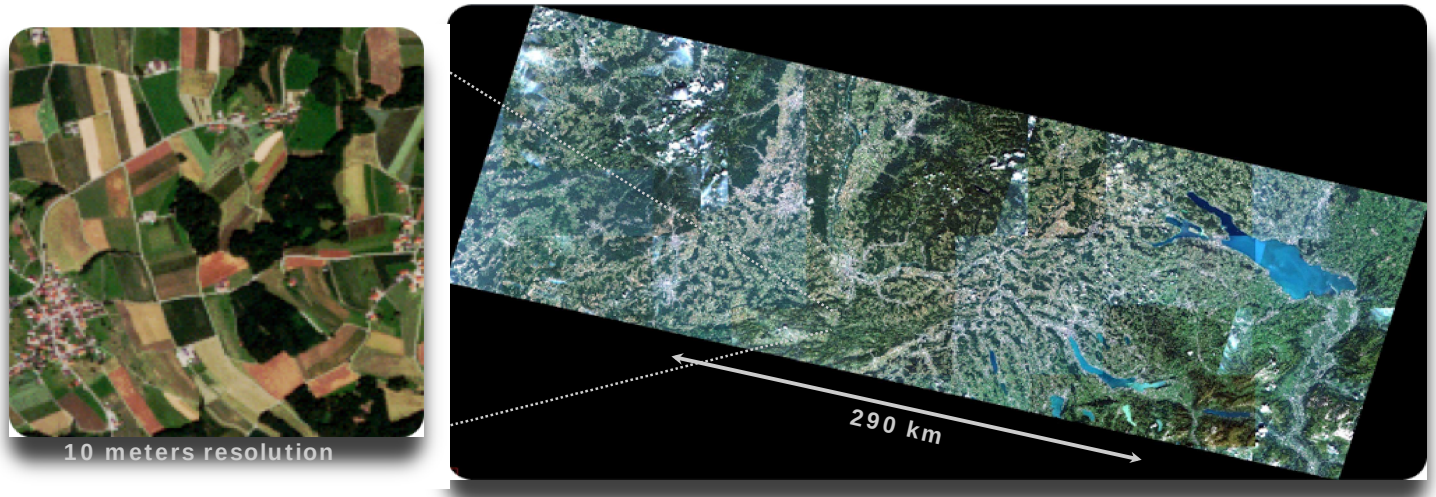
Overview of S2 Time Series: RapidEye

- Total of 390 acquisitions, 24-30 per site
- 38% cloud free of total acquisitions (0-65% at site level)
- Even with 5 days repeat, low coverage over Europe during growing season



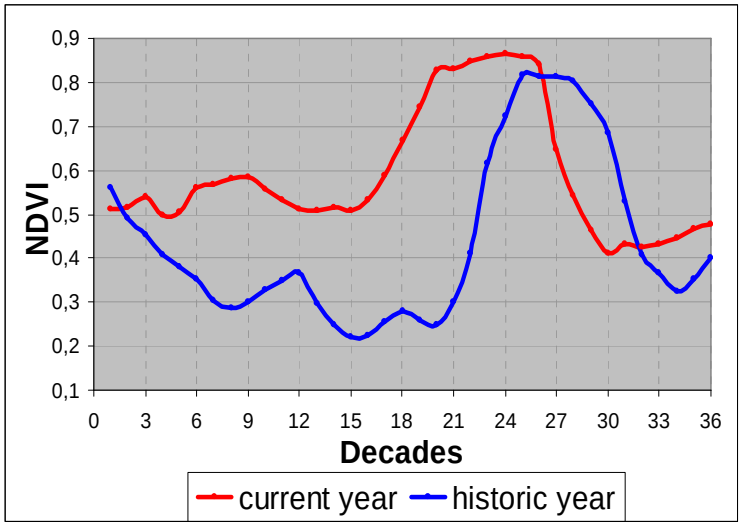
Agriculture: Requirements for S2

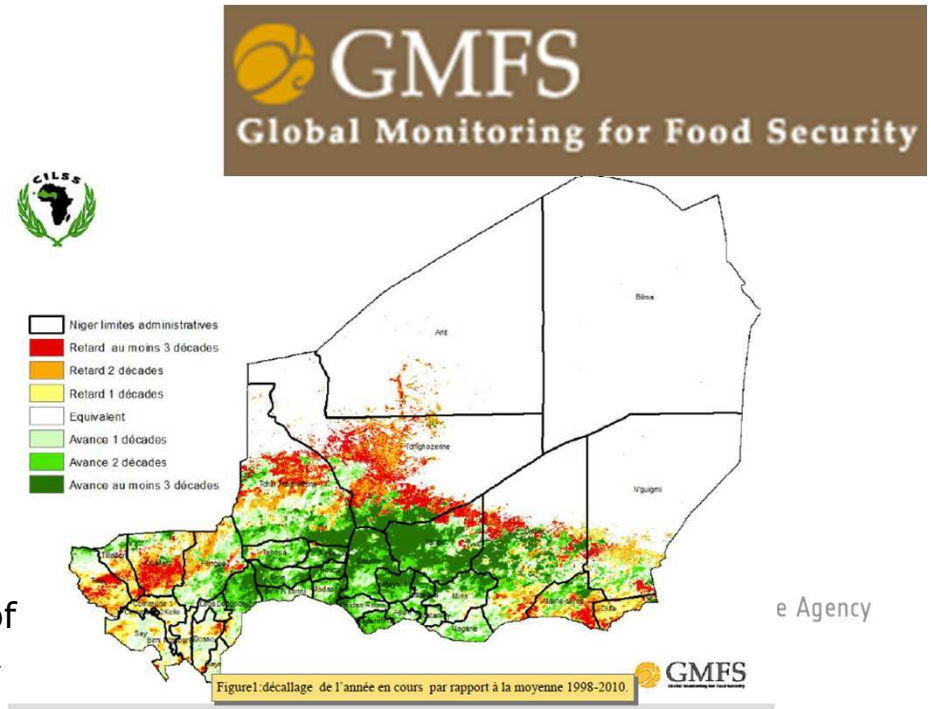
- "Sentinel-2 is exceptionally well defined spectrally, spatially and temporally for agricultural applications" (S2 symposium)
- The crop mapping at a spatial resolution of 10 m is a necessity for small fields (fragmented landscape in Europe but also in Africa)
- Improvement of **crop masks** (crop area separation from natural vegetation) and **crop type mapping** by temporal profiles
- High revisit of 5 days well suited to follow **crop dynamics** in sensitive crop growth periods
- Dedicated red-edge bands for crop state monitoring



Agriculture: Multi-temporal Methods

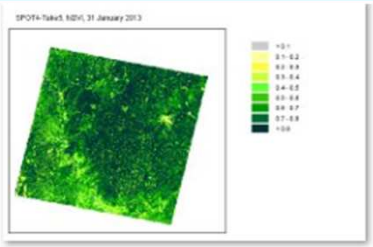
- Crop monitoring based on temporal anomalies
- Anomaly detection: comparison “actual” vs “reference” values
  1. “reference” derived from MODIS-250m long term average (equation)
  2. Absolute difference with long term average (ADVI)





See also LP2013 poster:
3-P-94 Global Monitoring for Food Security (GMFS): Ten Years of Operational Monitoring of Africa's Agriculture, S. Gilliams *et al.*,
Wed-P-06 Research and Applications with Optical RS: Land

First Results: Morocco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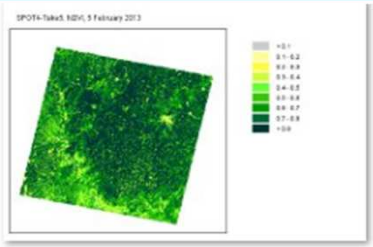
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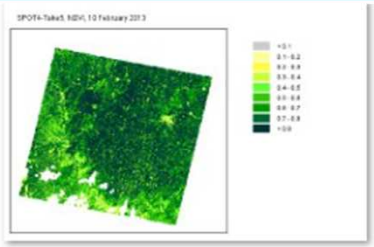
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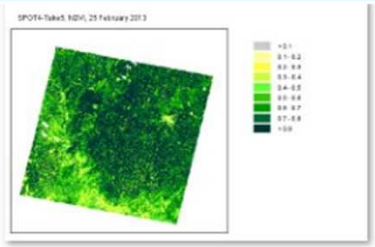
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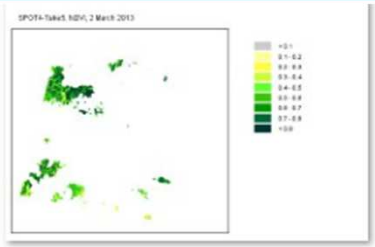
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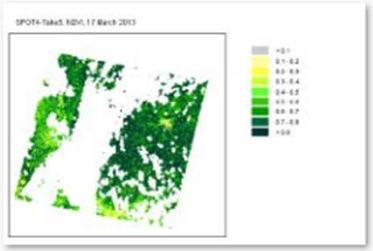
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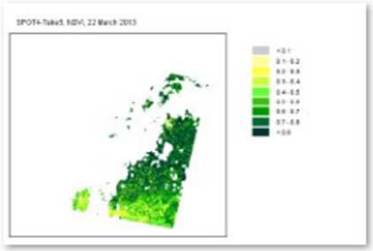
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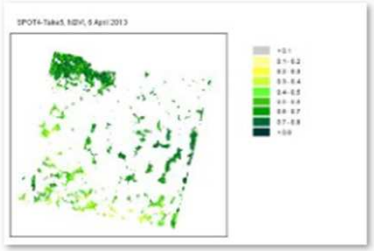
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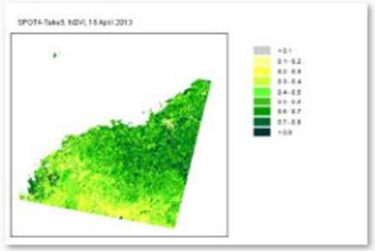
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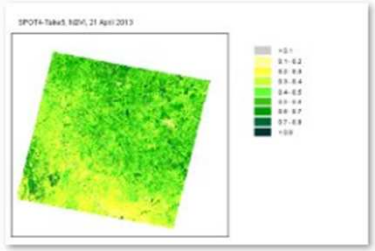
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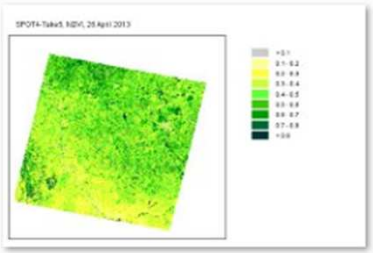
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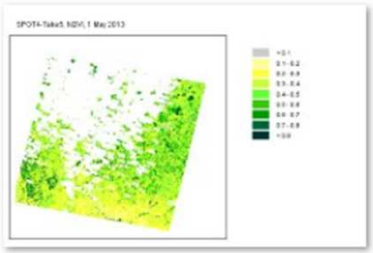
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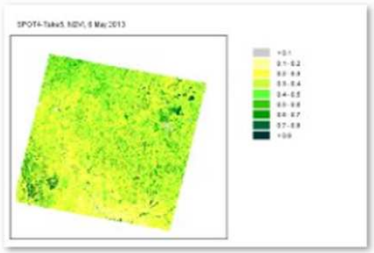
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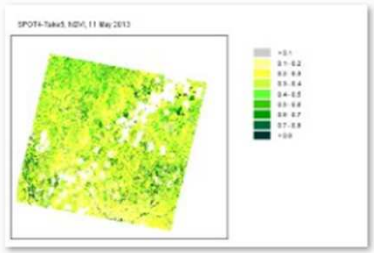
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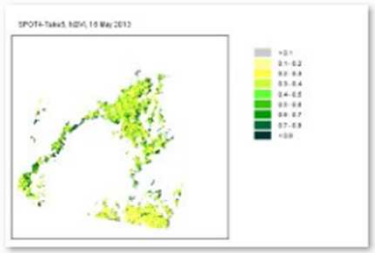
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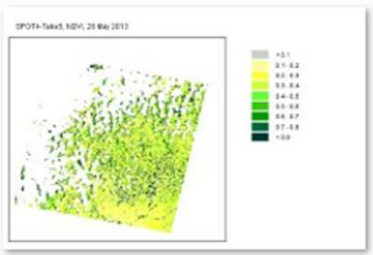
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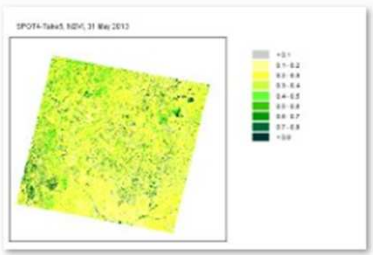
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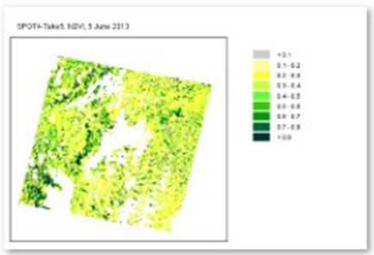
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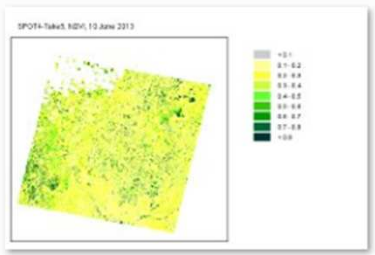
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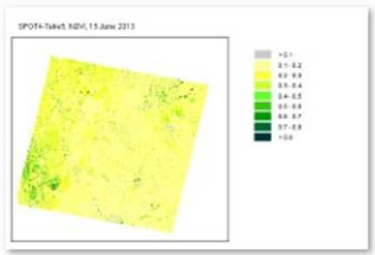
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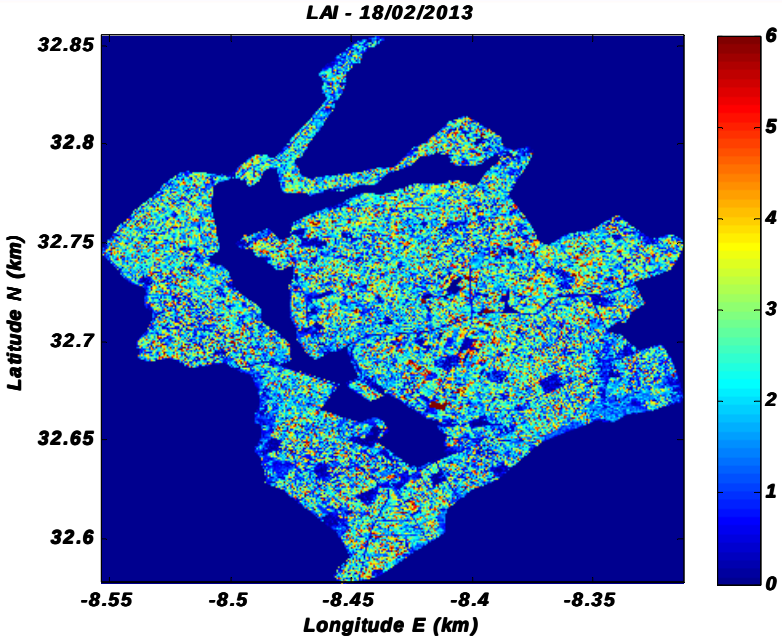
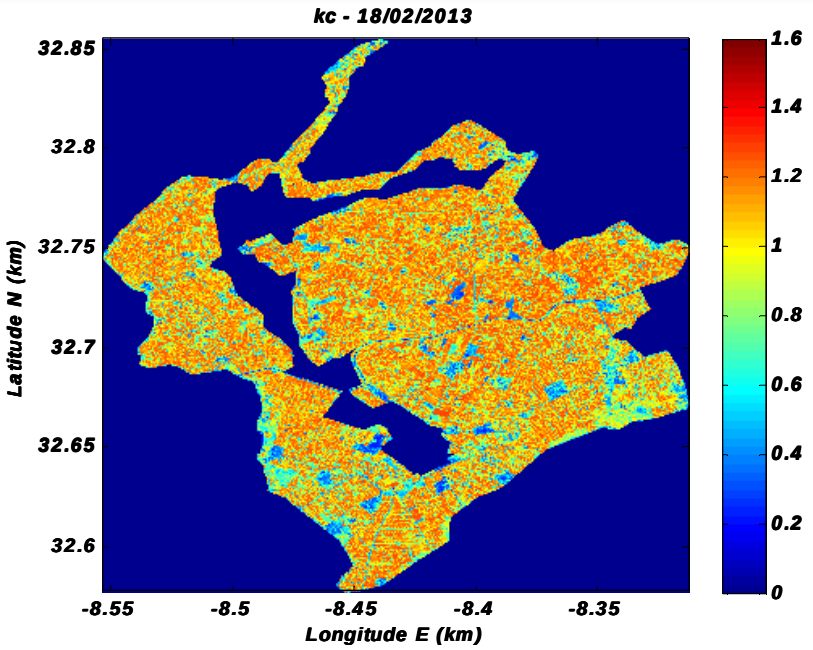
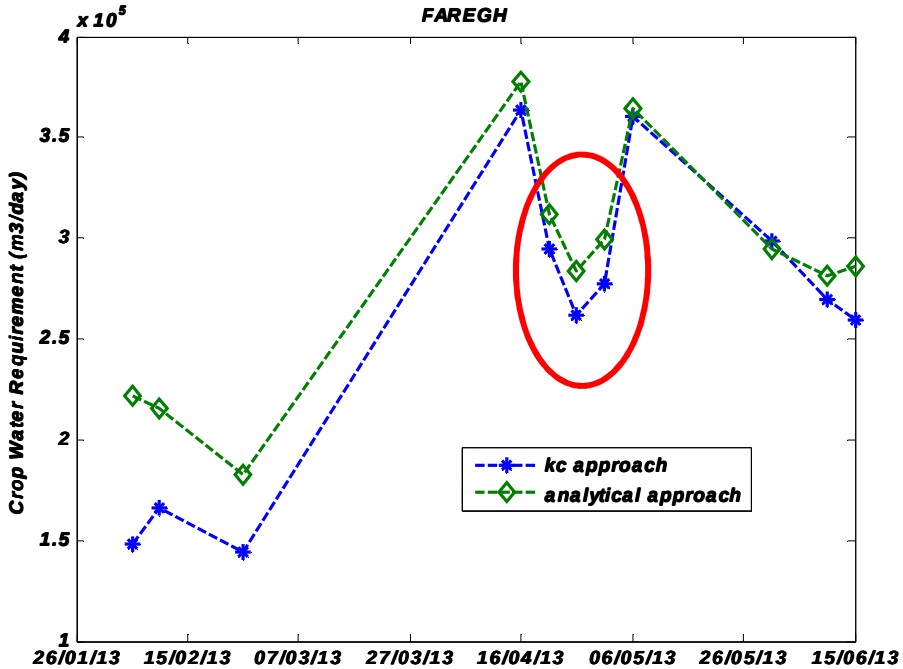
European Space Agency

GMFS
Global Monitoring for Food Security

First Results: LAI & Kc for Crop Water requirements







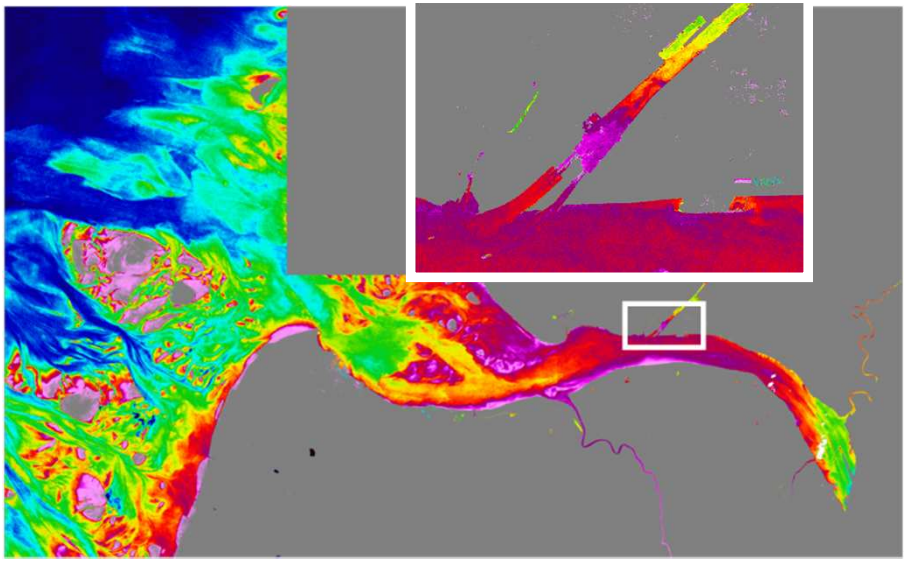
- Total crop water requirements for irrigated crops
- Kc- NDVI and analytical method
- Dip in June: transition from winter (sugarbeet) to summer (maize) crops

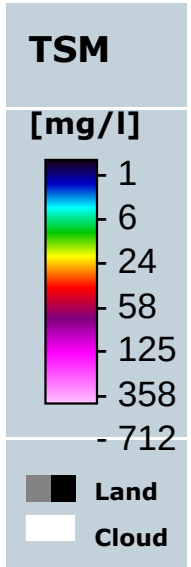
TIGER AFRICA

1: CHOUAIB DOUKKALI UNIVERSITY, MOROCCO
2: DELFT UNIVERSITY OF TECHNOLOGY, NETHERLANDS

Coastal Zones: Requirements for S2

- Understanding the spatial variability of water quality at S-2 resolution for inland and costal waters (Sentinel-2 symposium)
- Sentinel-2 will allow the mapping of small lakes & complex costal and inland waters (Sentinel-2 symposium)
- Sentinel-2 is felt as one of the most suitable system for a systematic monitoring of coral reef for the next decades
- Water quality monitoring, algal blooms and red tides, Fisheries management, Ecosystem change





RapidEye 5/10m River Elbe, Germany 2010-06-23 11:09 UTC

Marine: Preliminary Results

The Yellow Sea is often highly turbid. The test site is affected by sediments resuspended by tides.

RapidEye data
Feb-July 2013

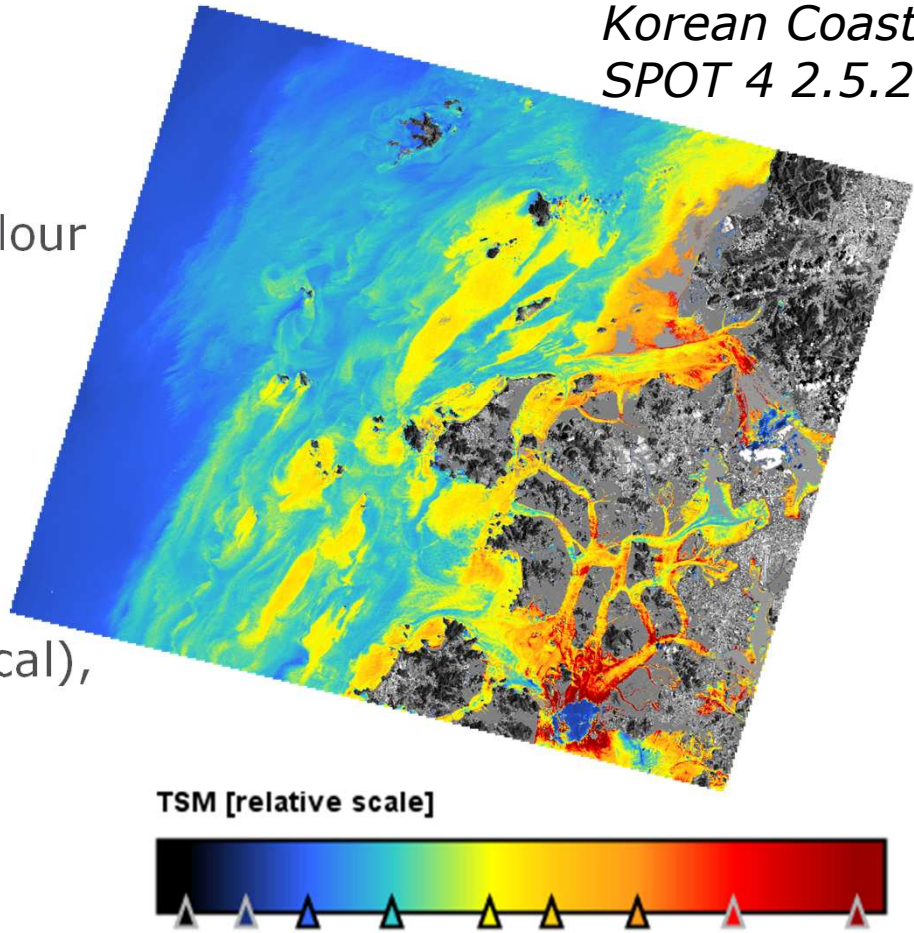
Test Site: Korean Peninsula Coastal Water

Marine: Multi-temporal Methods

Demonstrating the potential of spatial high resolution EO data for coastal ocean colour applications

- neural network technique of the CoastColour processing algorithm can be potentially applied to SPOT/RE data.
- The processing may require spatial averaging in order to increase the signal to noise ratio.
- **Approach**: Atmospheric correction (critical), Single band TSM algorithm, Intercalibration with MODIS & GOCI

Korean Coast
SPOT 4 2.5.2013



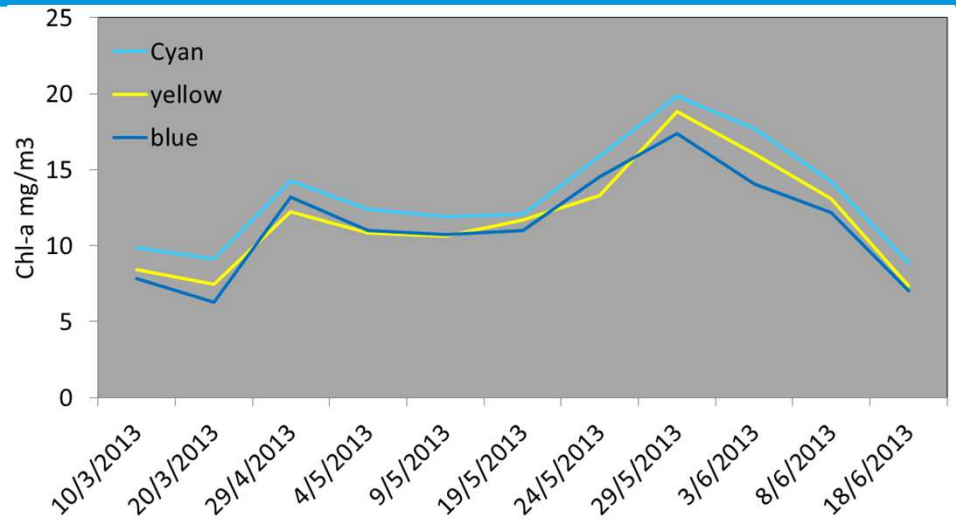
coastcolour

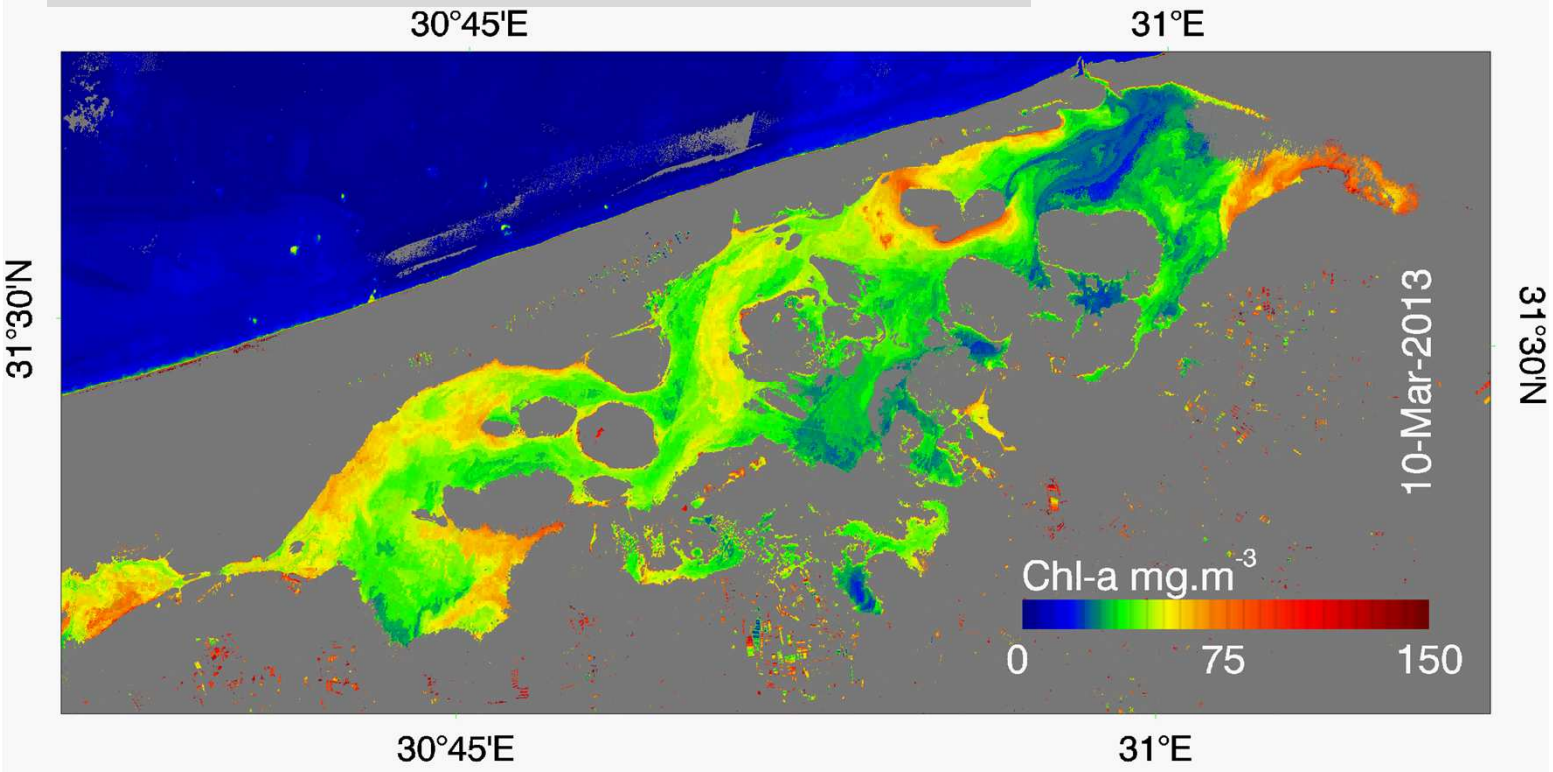
See also LP2013 poster:
2-P-108 CoastColour Global Full Mission Dataset and Spatial high Resolution Case Study
C. Brockmann *et al.* (Tue-P-07 Methods and Products OPT/IR)

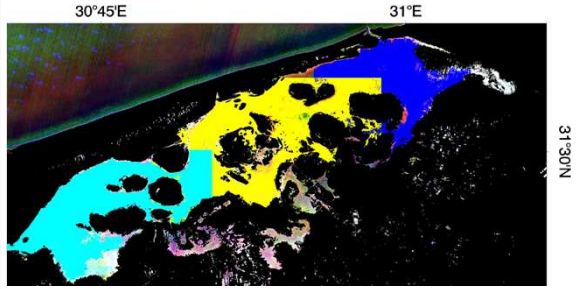
Marine: Spot products of Chl-a (preliminary results)

Spring and summer blooms are shown for three spatially averaged regions

The regions seem to have the same temporal behavior
The start of the summer bloom is delayed in the middle region







M. S. Salama, H. Farag and V. Vekerdy
University of Twente, The Netherlands

TIGER AFRICA

Wetland: Requirements for S2

Detailed land cover classification of satellite imagery to map & monitor precisely the wetlands habitats inside and outside the wetland area.

- **Low cost solution:** most wetland mapping are currently based on the use of the freely available global Landsat archive.
- **High resolution (well below 30m)** for small wetlands and for highly fragmented landscapes
- **High repetitively (3+ cloud free observations / month)** to capture the high water dynamics of wetlands
- **Large swath** to cover full catchment in few consecutive passes
- The **SWIR bands** are a necessity because sensitive to water contents

Sentinel-2 fulfills the wetland mapping needs (SWIR bands; high-resolution; low-cost; large swath)

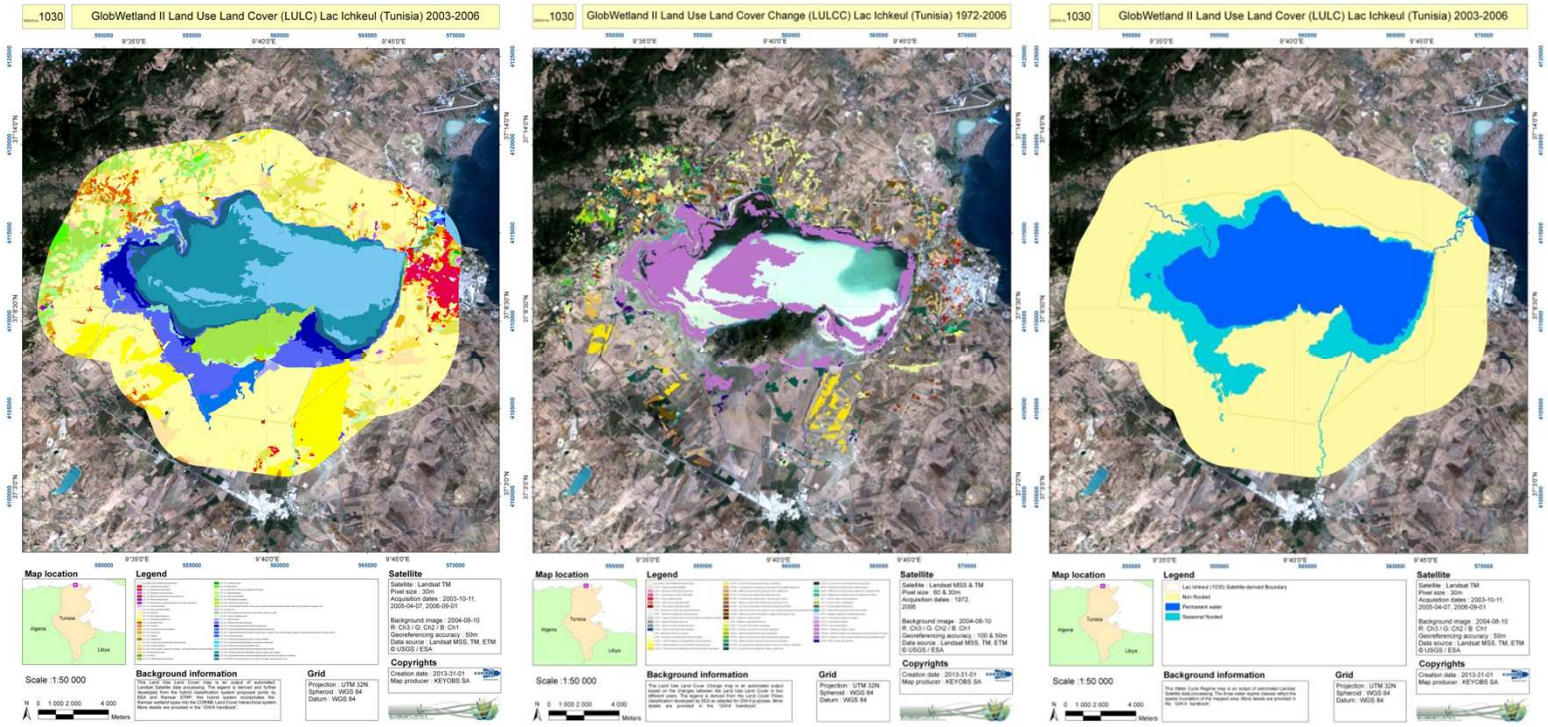
Wetland: Multi-temporal Methods

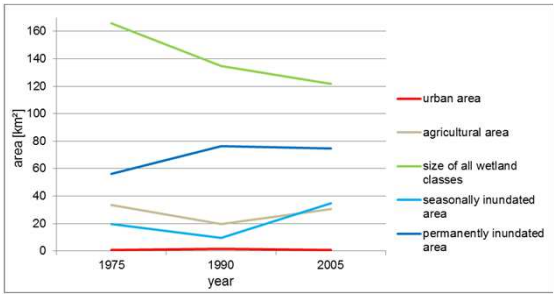
Wetland Information maps

1. Land Use / Land Cover map (including wetland typologies)
2. Change Detection maps (on Land Use / Land Cover)
3. Water Cycle Regime (seasonal and annual variations)

Indicators on the status and trends of wetland ecological functioning

1. Change in wetland area
2. Inundation of the ecosystem
3. Change in wetland area due to threats (urbanization and agriculture)
4. Status and trends of wetland threats





GLOBWETLAND

European Space Agency

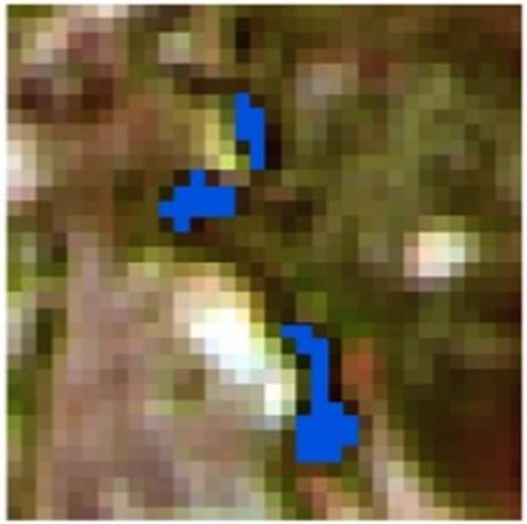
Wetland: Preliminary Results
Small water body mapping

R:nir/G:red/B:green
spatial resolution: 30 m

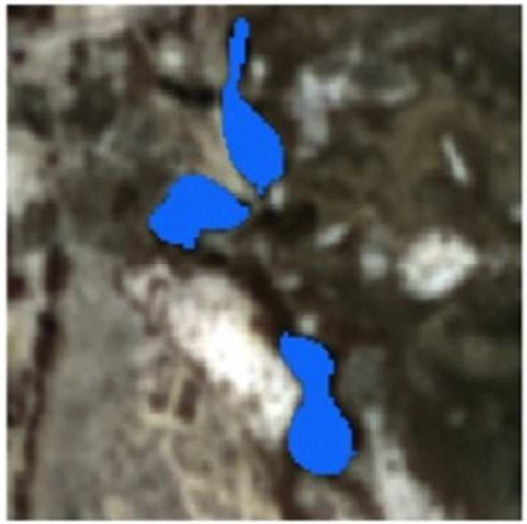
R:nir/G:red/B:green
spatial resolution: 20 m

R:nir/G:red/B:green
spatial resolution: 5 m

interpretation
2005-01-28 Landsat TM

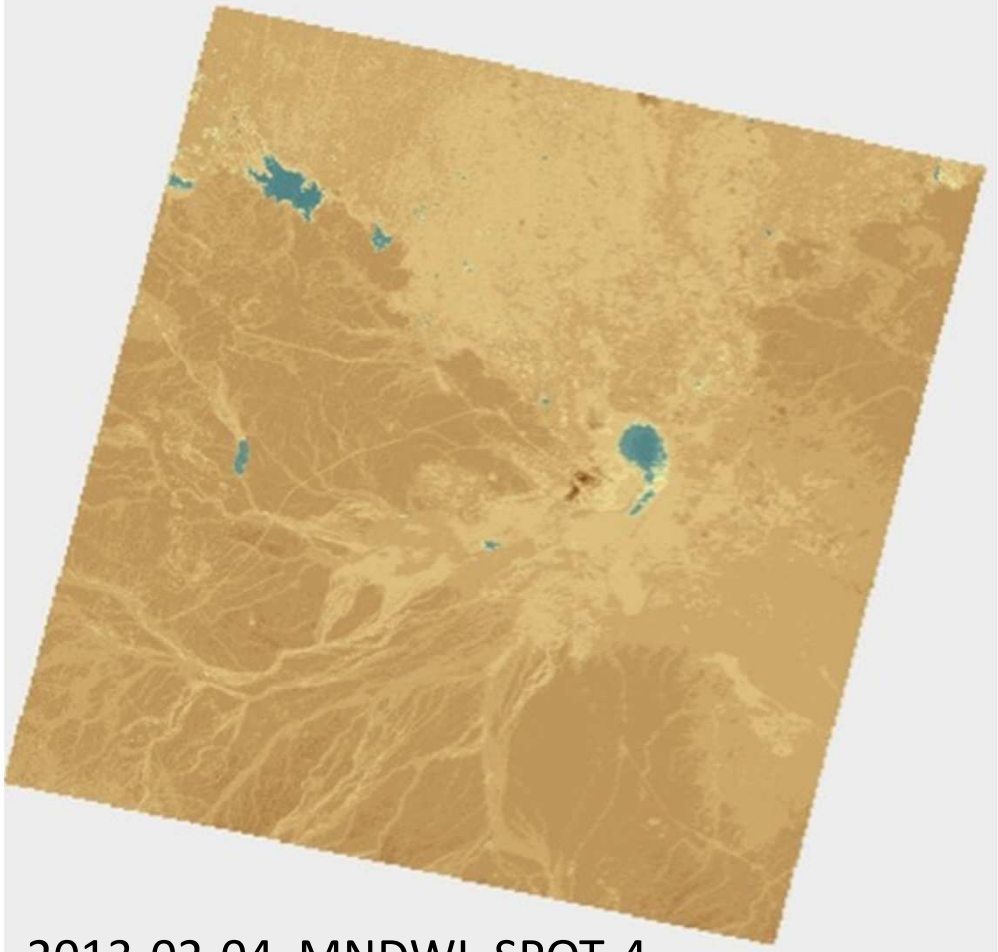


interpretation
2013-02-24 SPOT-4

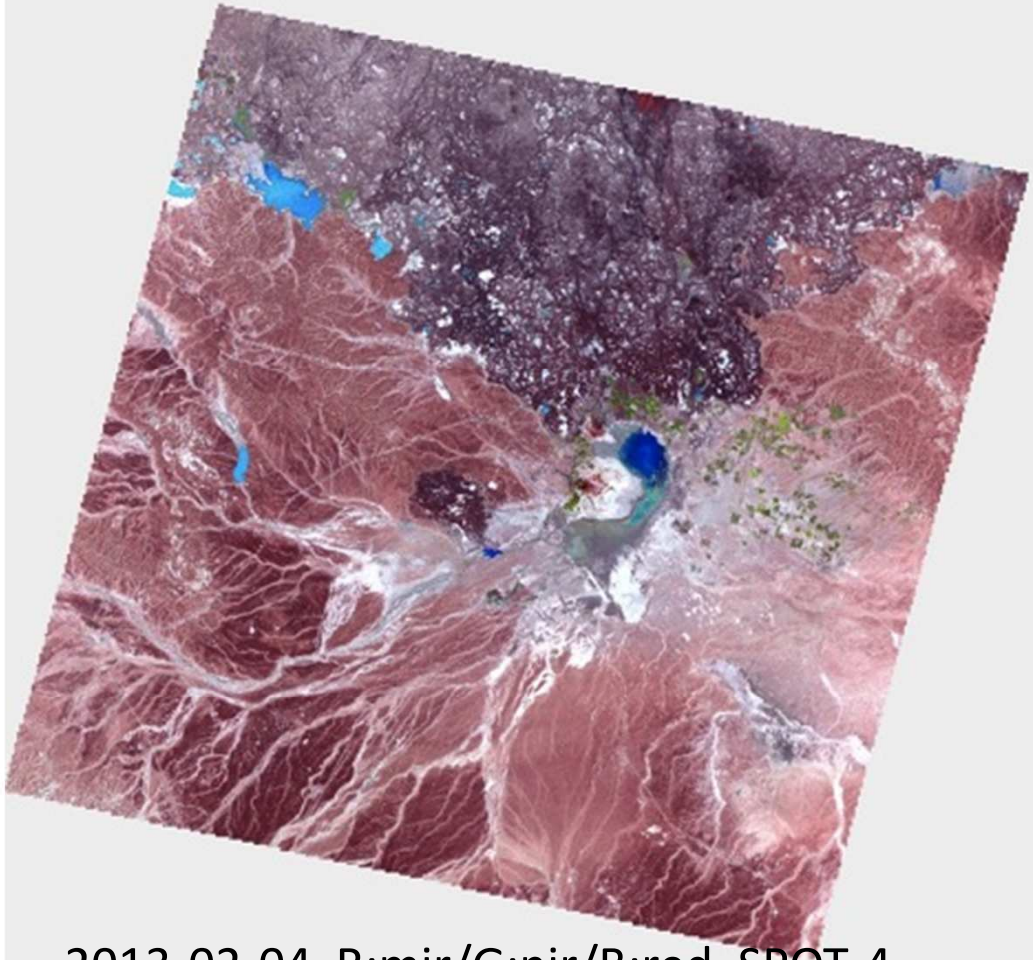


interpretation
2013-02-21 Rapideye

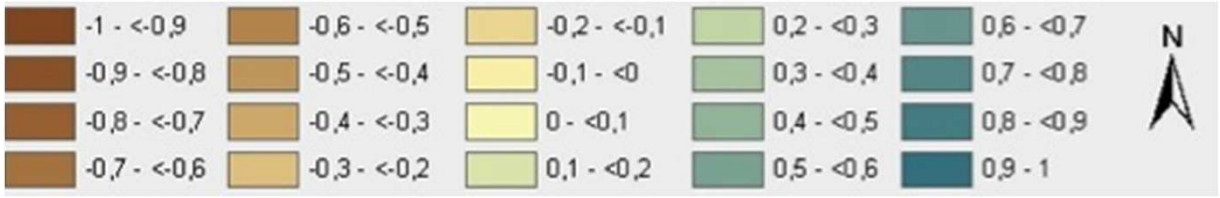
Azraq Wetland Reserve, Jordan



2013-02-04 MNDWI SPOT-4

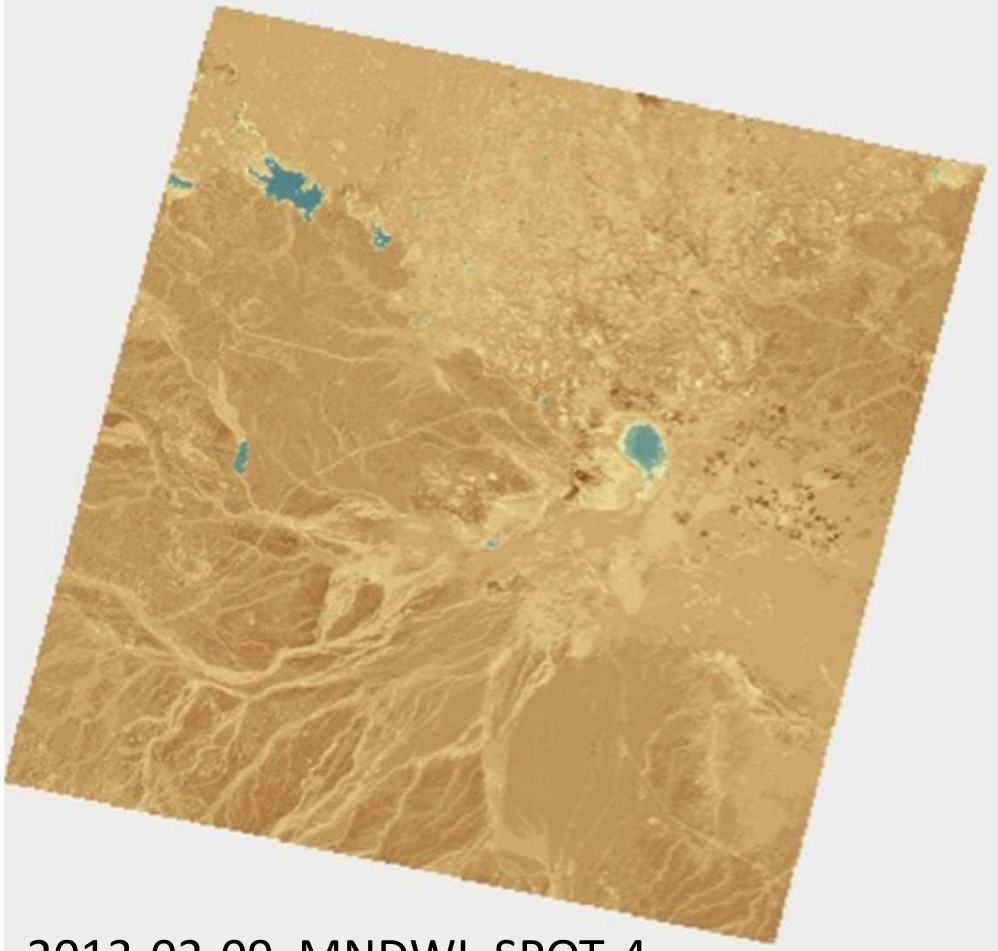


2013-02-04 R:mir/G:nir/B:red SPOT-4

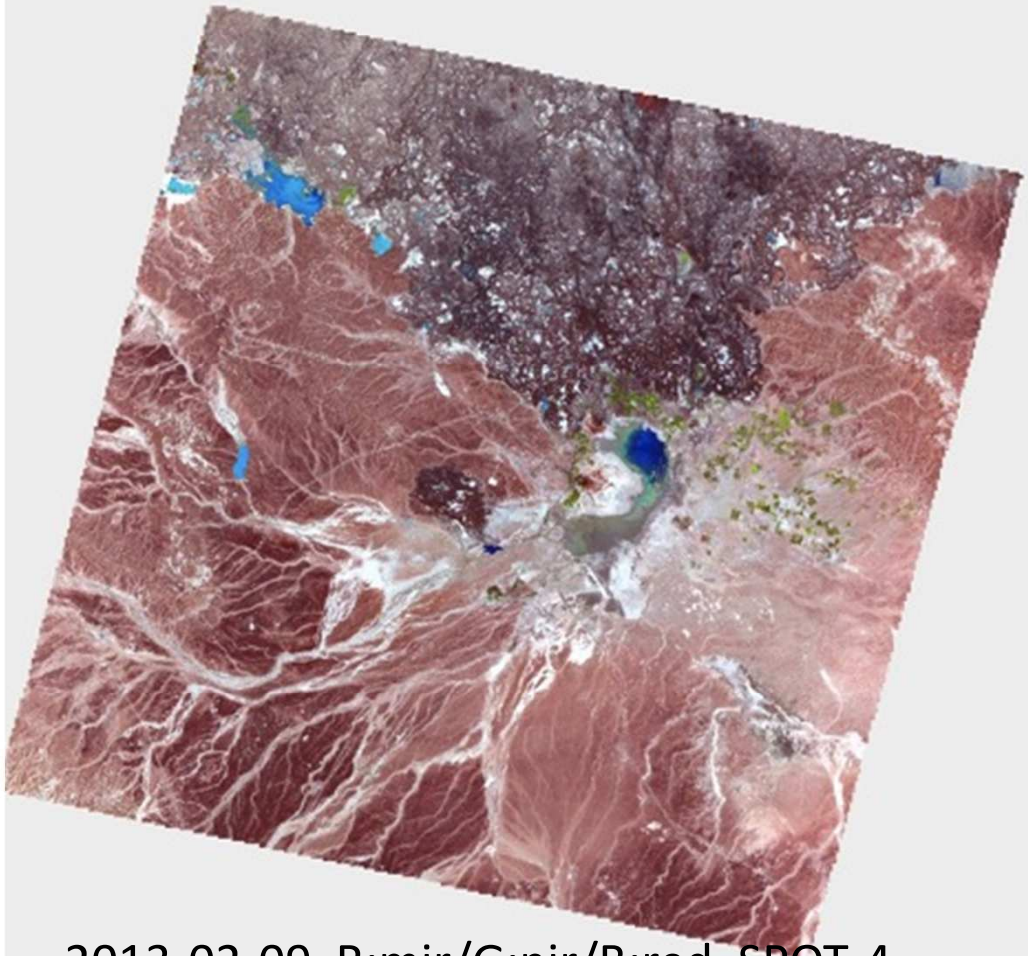


$$MNDWI = \frac{(mir - green)}{(mir + green)}$$

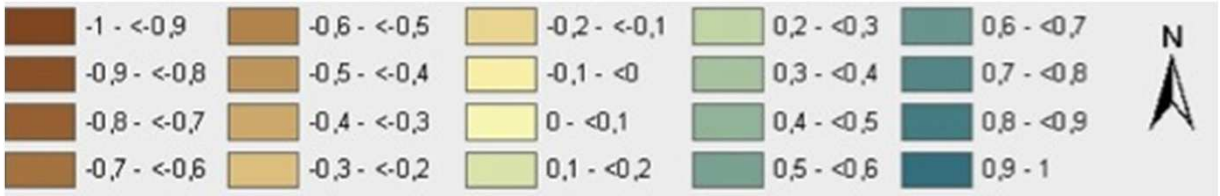
Azraq Wetland Reserve, Jordan



2013-02-09 MNDWI SPOT-4

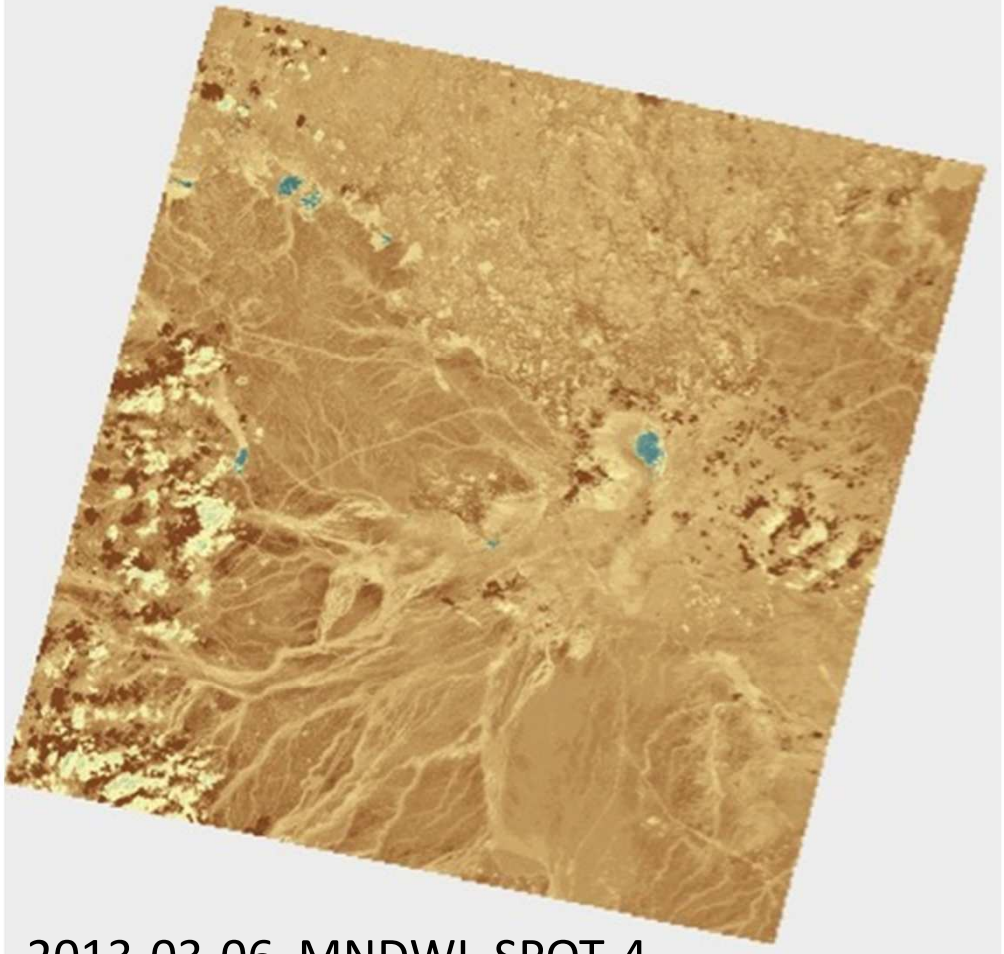


2013-02-09 R:mir/G:nir/B:red SPOT-4

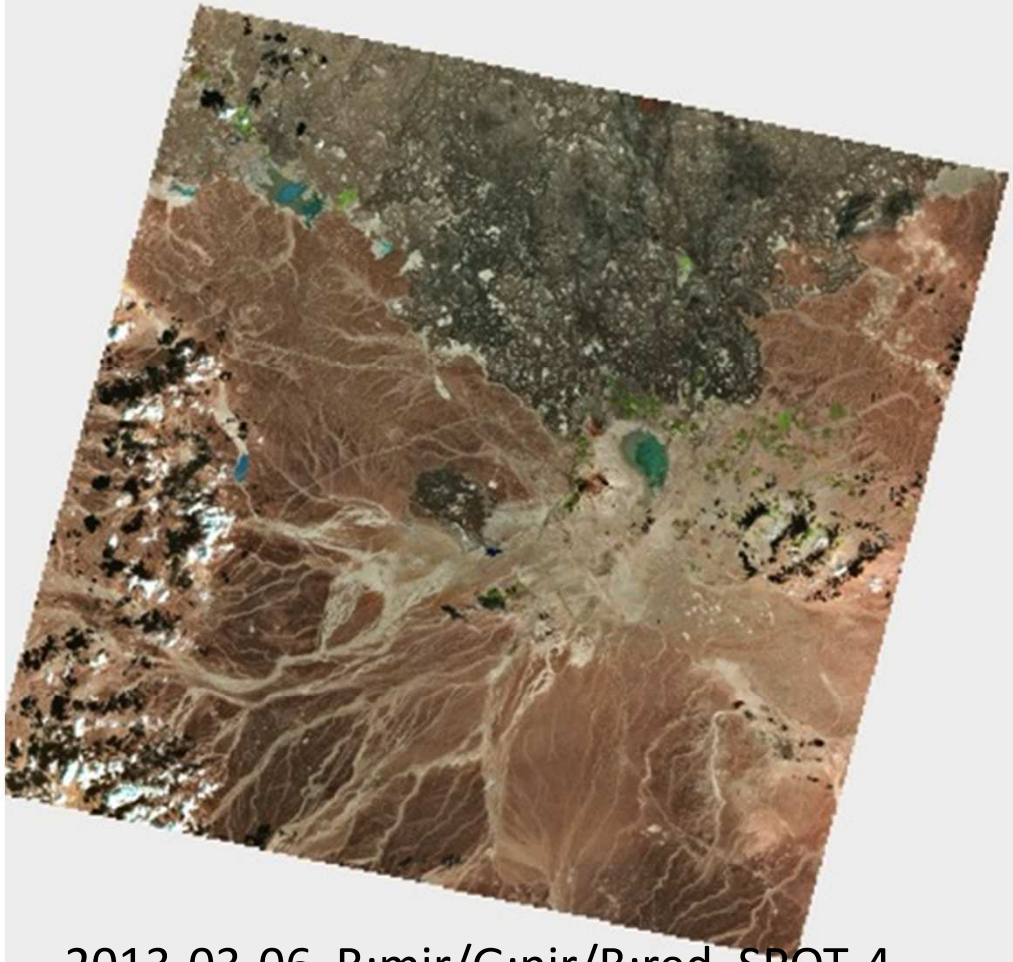


$$MNDWI = \frac{(mir - green)}{(mir + green)}$$

Azraq Wetland Reserve, Jordan



2013-03-06 MNDWI SPOT-4



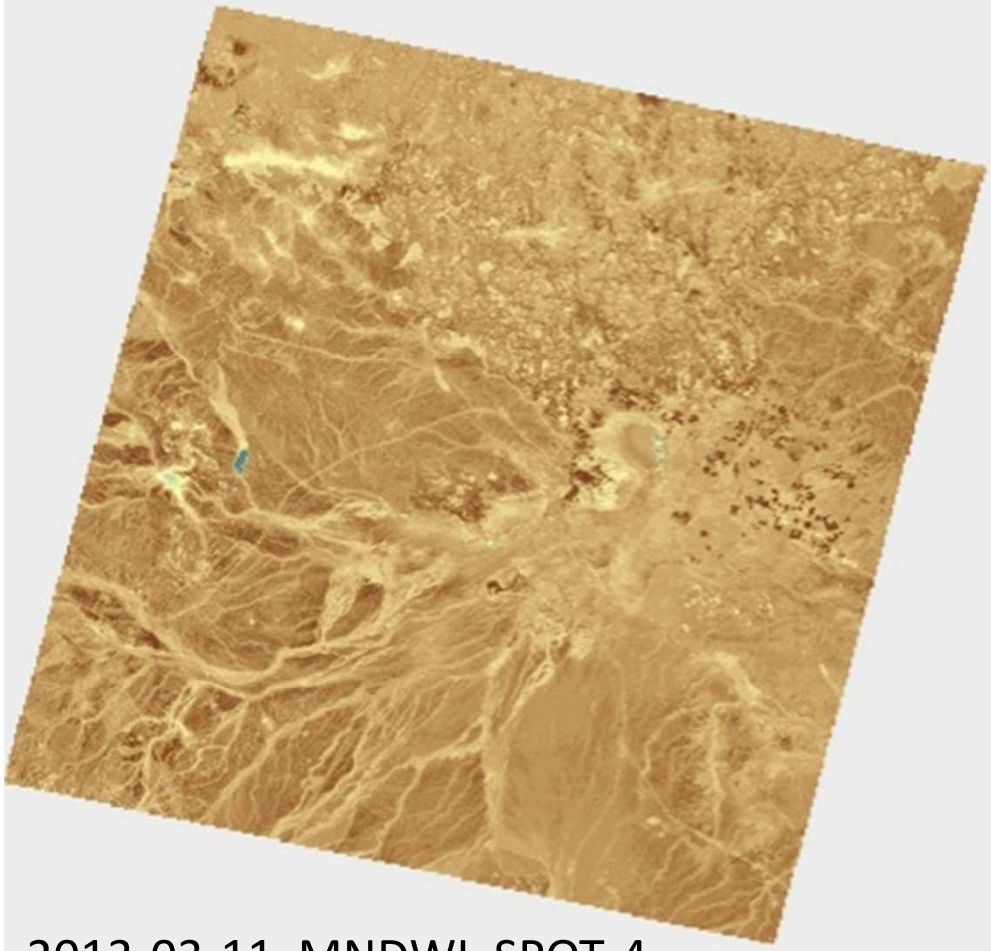
2013-03-06 R:mir/G:nir/B:red SPOT-4

-1 - <-0,9	-0,6 - <-0,5	-0,2 - <-0,1	0,2 - <0,3	0,6 - <0,7
-0,9 - <-0,8	-0,5 - <-0,4	-0,1 - <0	0,3 - <0,4	0,7 - <0,8
-0,8 - <-0,7	-0,4 - <-0,3	0 - <0,1	0,4 - <0,5	0,8 - <0,9
-0,7 - <-0,6	-0,3 - <-0,2	0,1 - <0,2	0,5 - <0,6	0,9 - 1

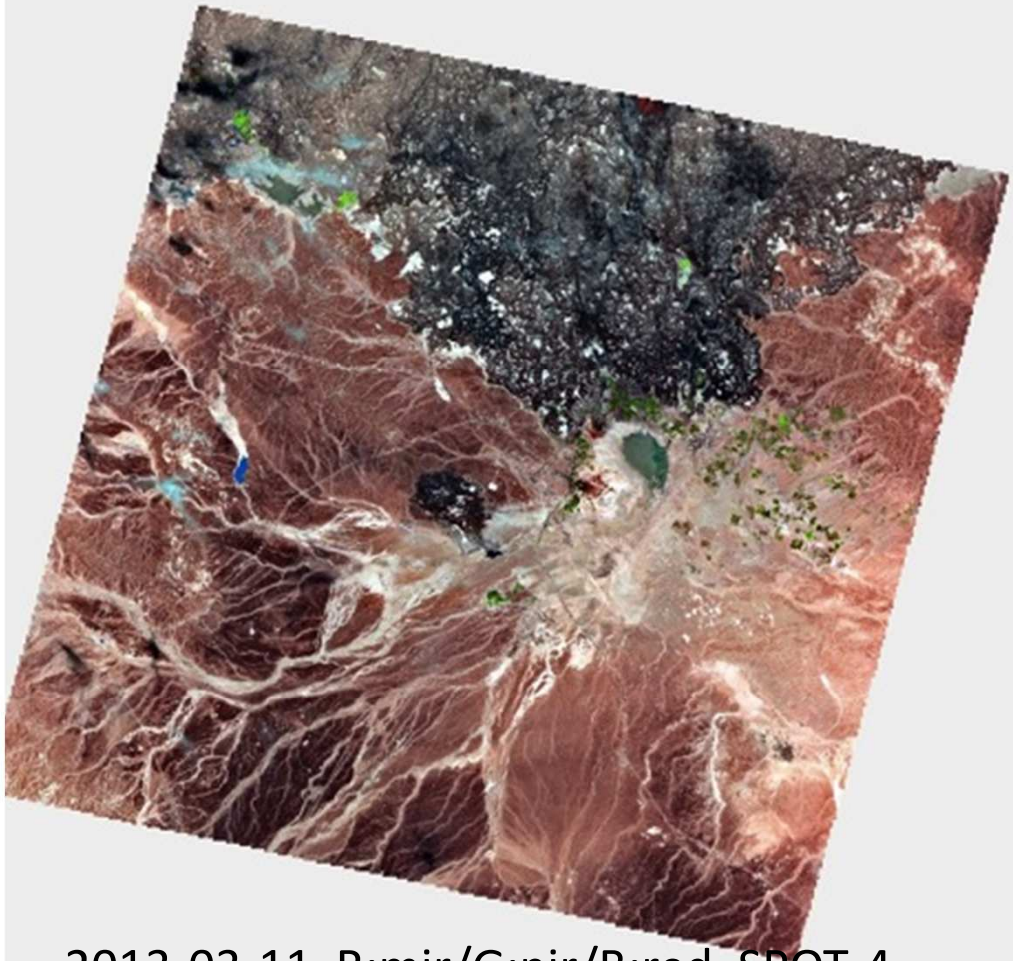
N

$$MNDWI = \frac{(mir - green)}{(mir + green)}$$

Azraq Wetland Reserve, Jordan



2013-03-11 MNDWI SPOT-4



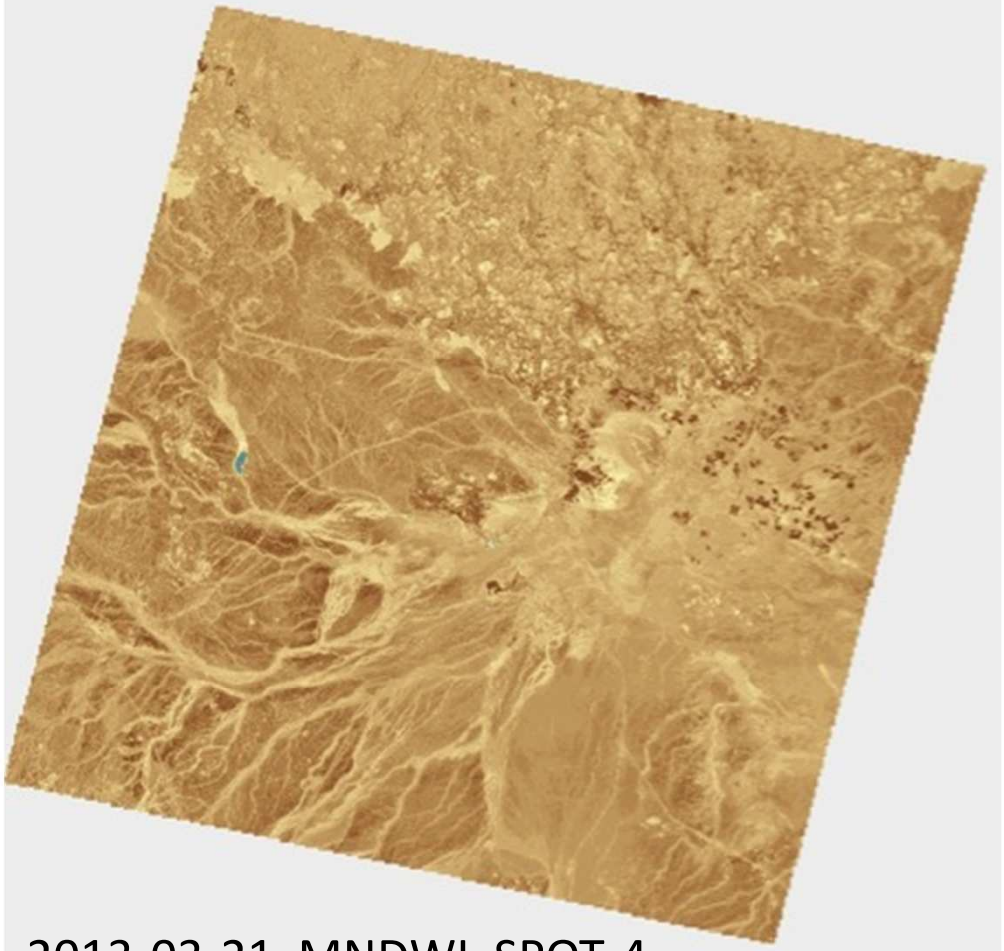
2013-03-11 R:mir/G:nir/B:red SPOT-4

-1 - <-0,9	-0,6 - <-0,5	-0,2 - <-0,1	0,2 - <0,3	0,6 - <0,7
-0,9 - <-0,8	-0,5 - <-0,4	-0,1 - <0	0,3 - <0,4	0,7 - <0,8
-0,8 - <-0,7	-0,4 - <-0,3	0 - <0,1	0,4 - <0,5	0,8 - <0,9
-0,7 - <-0,6	-0,3 - <-0,2	0,1 - <0,2	0,5 - <0,6	0,9 - 1

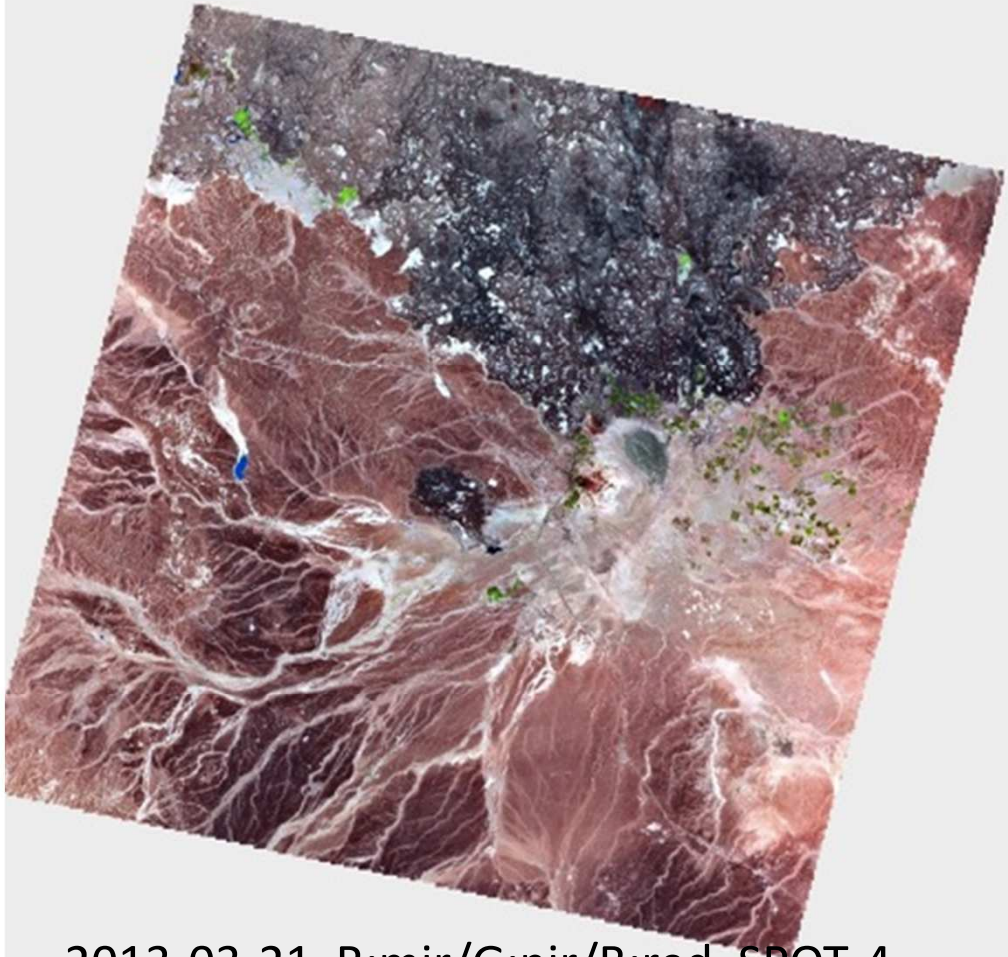
N

$$MNDWI = \frac{(mir - green)}{(mir + green)}$$

Azraq Wetland Reserve, Jordan



2013-03-21 MNDWI SPOT-4



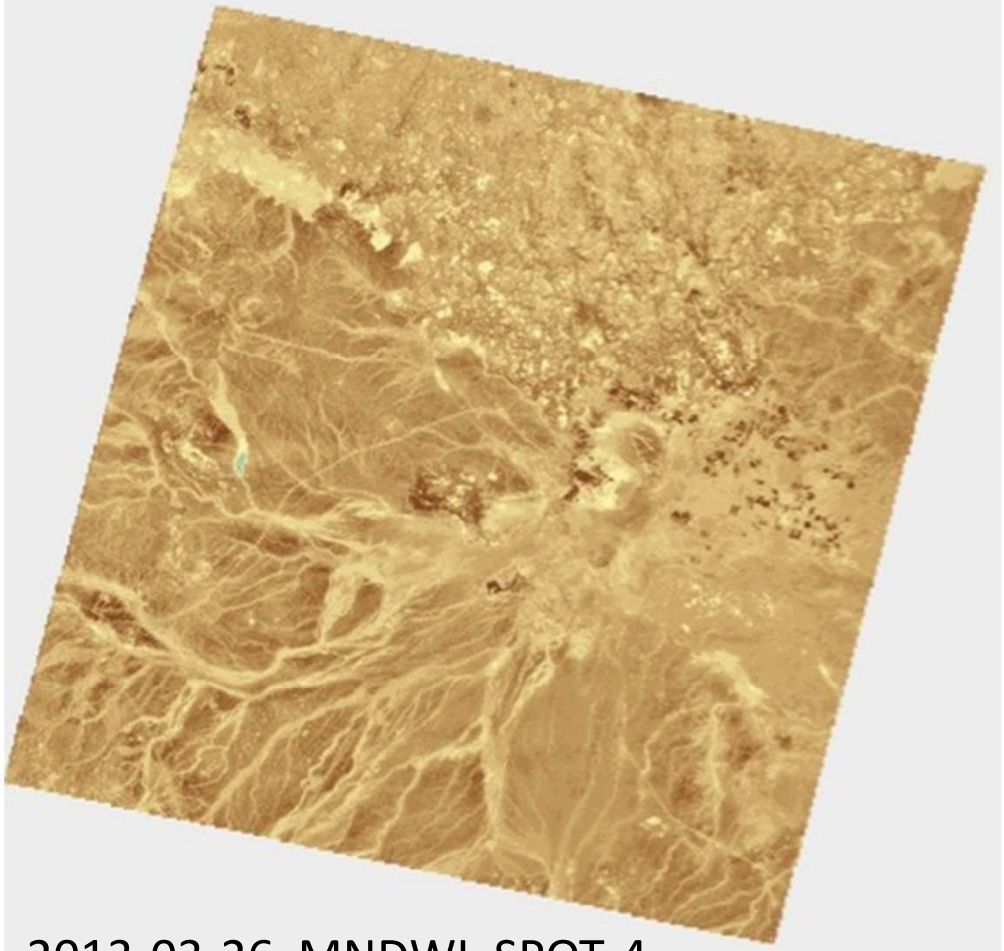
2013-03-21 R:mir/G:nir/B:red SPOT-4

-1 - <-0,9	-0,6 - <-0,5	-0,2 - <-0,1	0,2 - <0,3	0,6 - <0,7
-0,9 - <-0,8	-0,5 - <-0,4	-0,1 - <0	0,3 - <0,4	0,7 - <0,8
-0,8 - <-0,7	-0,4 - <-0,3	0 - <0,1	0,4 - <0,5	0,8 - <0,9
-0,7 - <-0,6	-0,3 - <-0,2	0,1 - <0,2	0,5 - <0,6	0,9 - 1

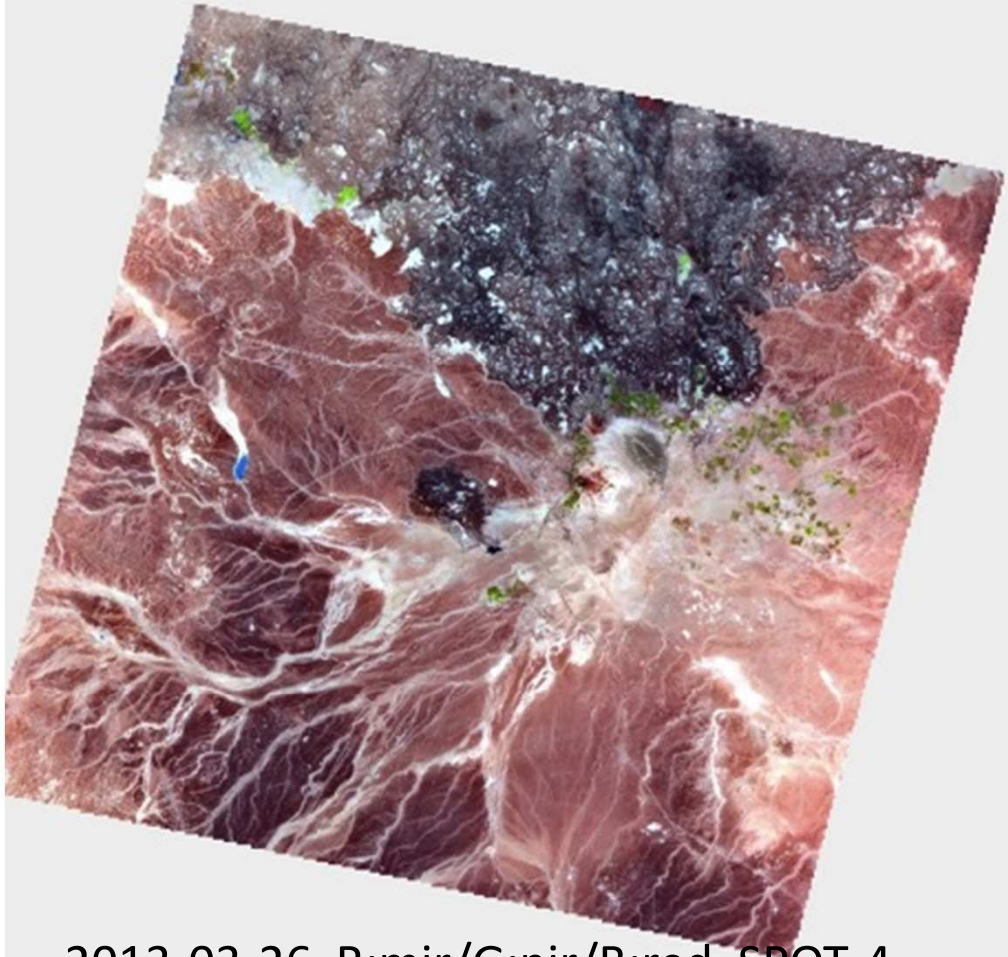
N

$$MNDWI = \frac{(mir - green)}{(mir + green)}$$

Azraq Wetland Reserve, Jordan



2013-03-26 MNDWI SPOT-4



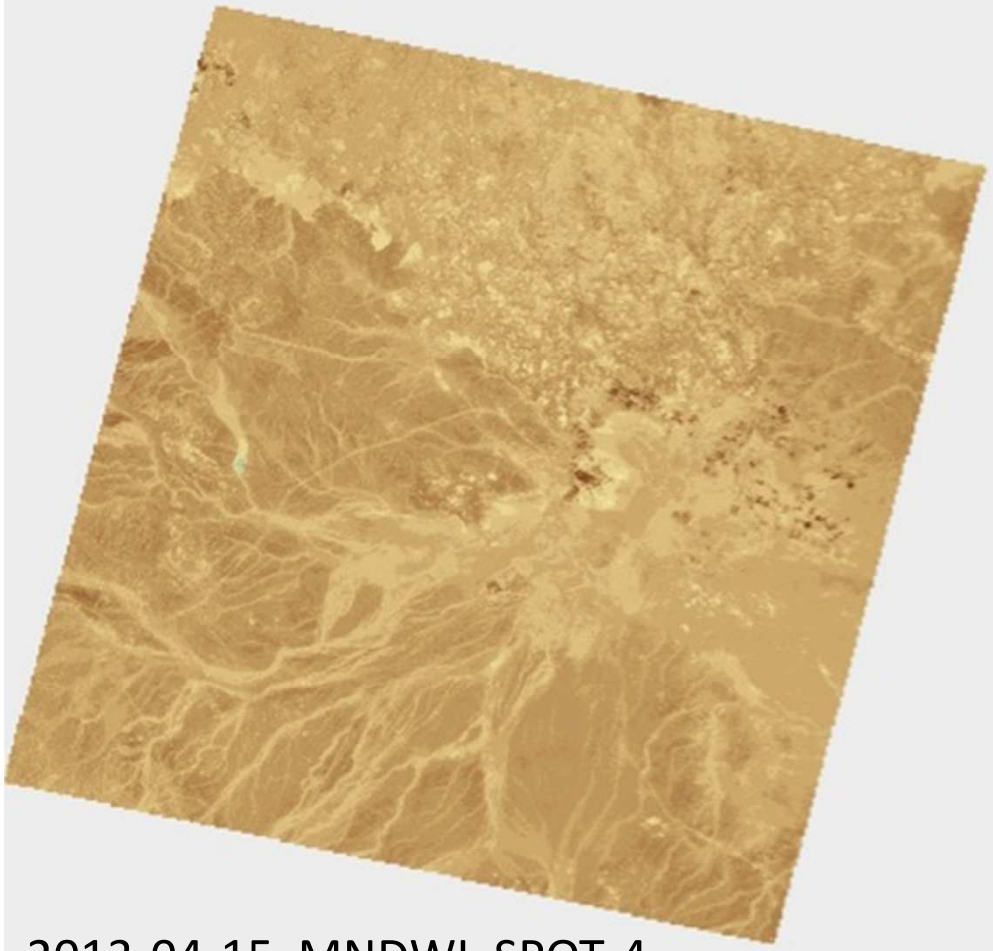
2013-03-26 R:mir/G:nir/B:red SPOT-4

-1 - <-0,9	-0,6 - <-0,5	-0,2 - <-0,1	0,2 - <0,3	0,6 - <0,7
-0,9 - <-0,8	-0,5 - <-0,4	-0,1 - <0	0,3 - <0,4	0,7 - <0,8
-0,8 - <-0,7	-0,4 - <-0,3	0 - <0,1	0,4 - <0,5	0,8 - <0,9
-0,7 - <-0,6	-0,3 - <-0,2	0,1 - <0,2	0,5 - <0,6	0,9 - 1

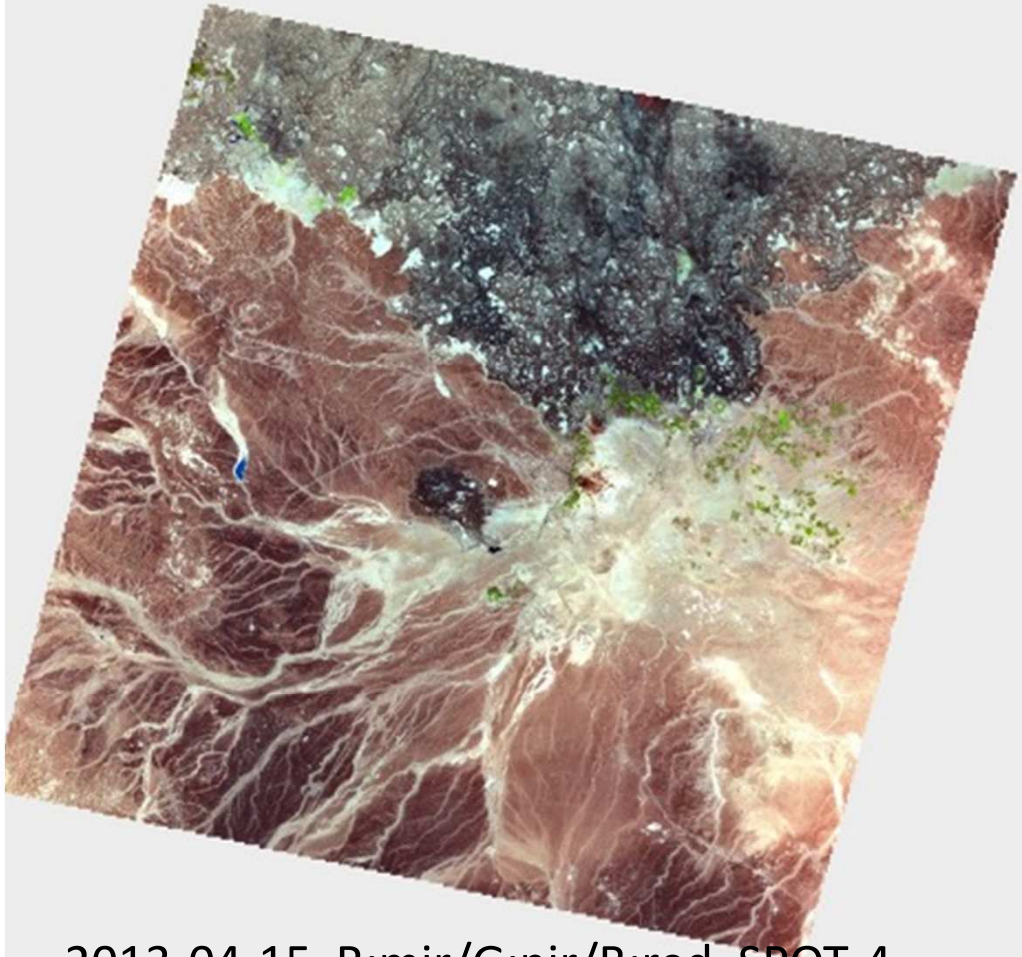
N

$$MNDWI = \frac{(mir - green)}{(mir + green)}$$

Azraq Wetland Reserve, Jordan



2013-04-15 MNDWI SPOT-4



2013-04-15 R:mir/G:nir/B:red SPOT-4

-1 - <-0,9	-0,6 - <-0,5	-0,2 - <-0,1	0,2 - <0,3	0,6 - <0,7
-0,9 - <-0,8	-0,5 - <-0,4	-0,1 - <0	0,3 - <0,4	0,7 - <0,8
-0,8 - <-0,7	-0,4 - <-0,3	0 - <0,1	0,4 - <0,5	0,8 - <0,9
-0,7 - <-0,6	-0,3 - <-0,2	0,1 - <0,2	0,5 - <0,6	0,9 - 1

N

$$MNDWI = \frac{(mir - green)}{(mir + green)}$$

Forestry: Requirements for S2

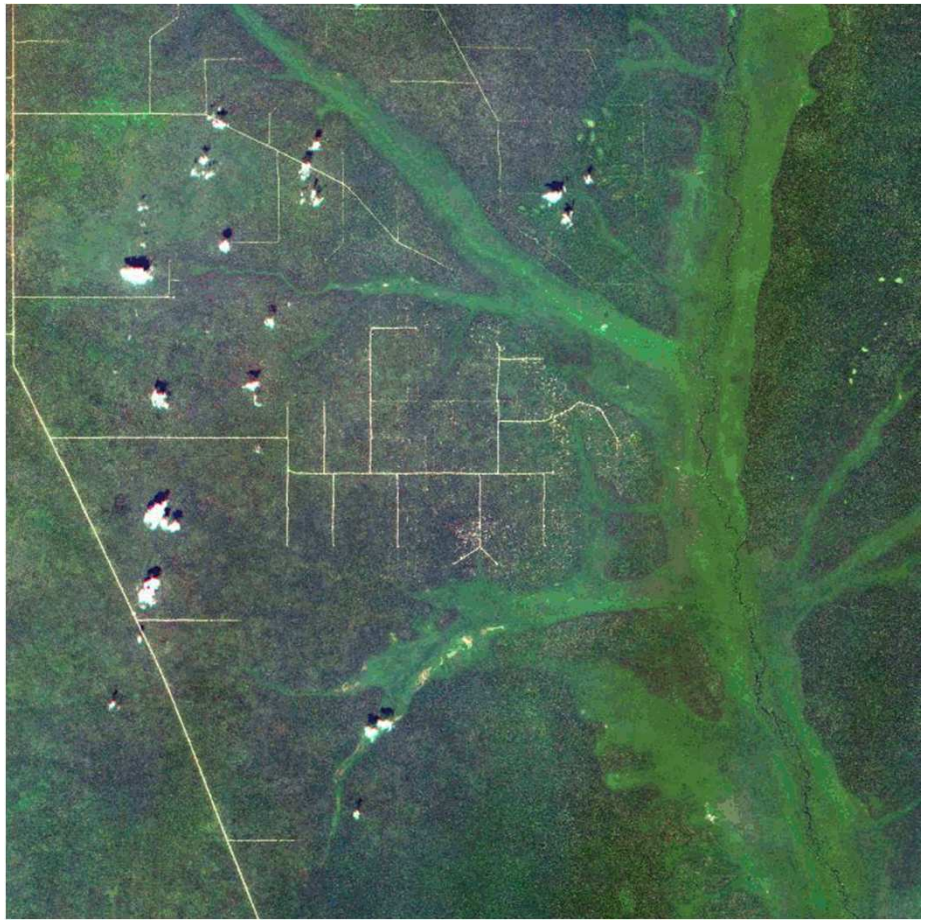
Key **observational benefits for forests** are all related to the exceptional combined improvements in temporal, spectral, radiometric and spatial resolutions of Sentinel-2:

- Improvement of **forest mapping** by spatial resolution of 10 m for small disturbances of forests and forest degradation (MMU < 1 ha)
- High revisit capacity of 5 days will allow **cloud free mosaics** in shorter time periods (annual for GHG, seasonal for illegal logging) and will lead to improved consistency, accuracy, timeliness and thematic detail of forest maps
- Dedicated red-edge bands opens new ways of **forest species discrimination**

Forestry: Multi-temporal Methods

Multi-temporal experiment will look specifically on 2 methods to:

- Reduce effects of clouds and cloud shadows by multi-temporal pixel mosaicking in cloud persistent areas
- Provide early warning of deforestation and detection of forest degradation based on frequent change detection



RapidEye over Congo

Planned Activities: Sentinel2 for Agriculture

- Algorithm development
- S2 prototypes for Crop masks, -type & -status

sentinel-2 agriculture

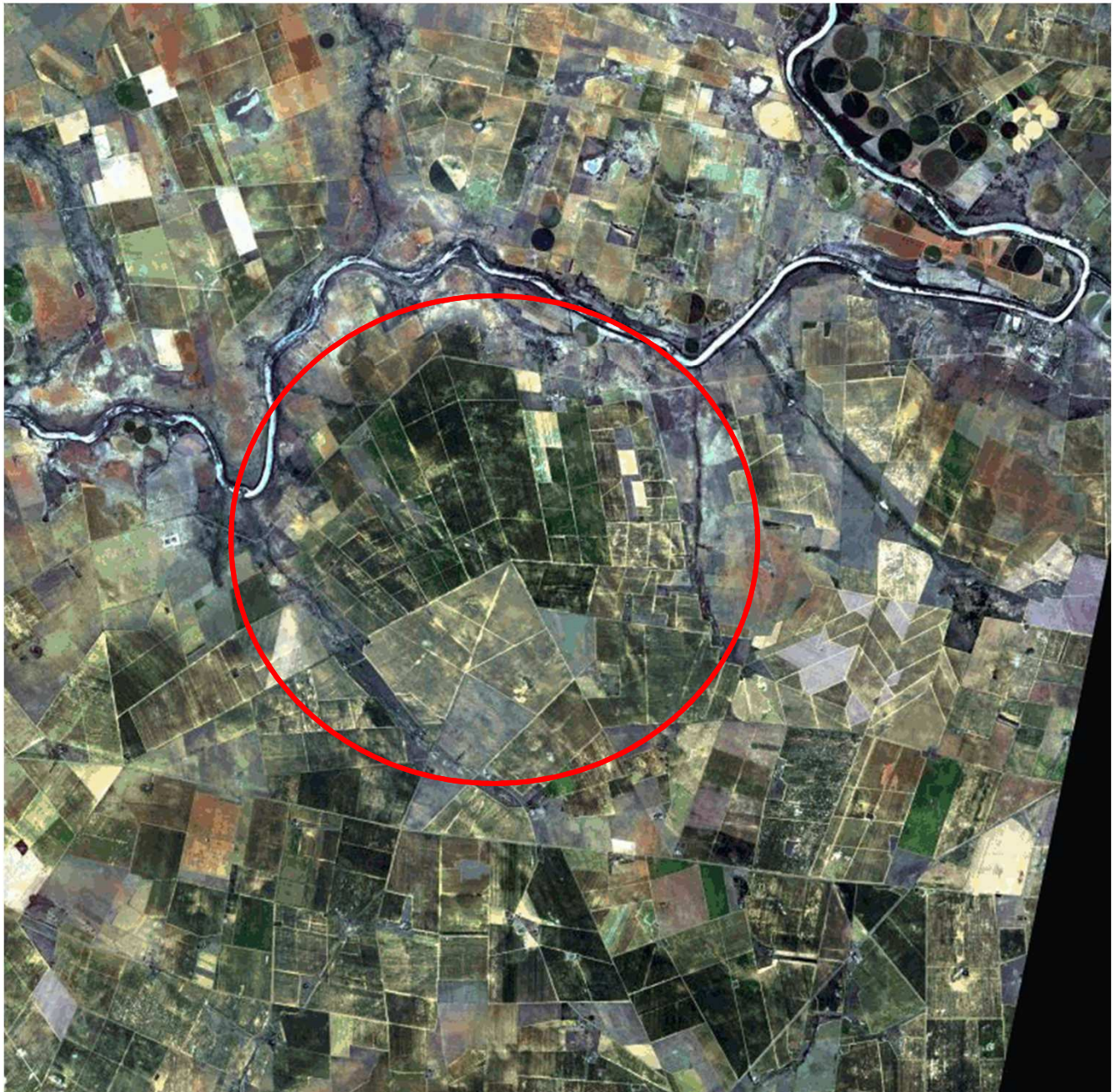
- KO November 2013
- 1.5 Meuro budget

South African JECAM site

RapidEye data Feb-July 2013

JECAM Joint Experiment for Crop Assessment and Monitoring

GEOGLAM Global Agricultural Monitoring



Planned Activities: Innovator Call

- **Open call** to the end-users, industry & research community
- develop and demonstrate **innovative EO services & products** using existing ESA, ESA TPM and other data
- require a **targeted end-user** or end-user community involved
- Specific focus on **S2 preparatory activities**

- Call foreseen **Q2 2014: ≈10-20 studies** to be funded

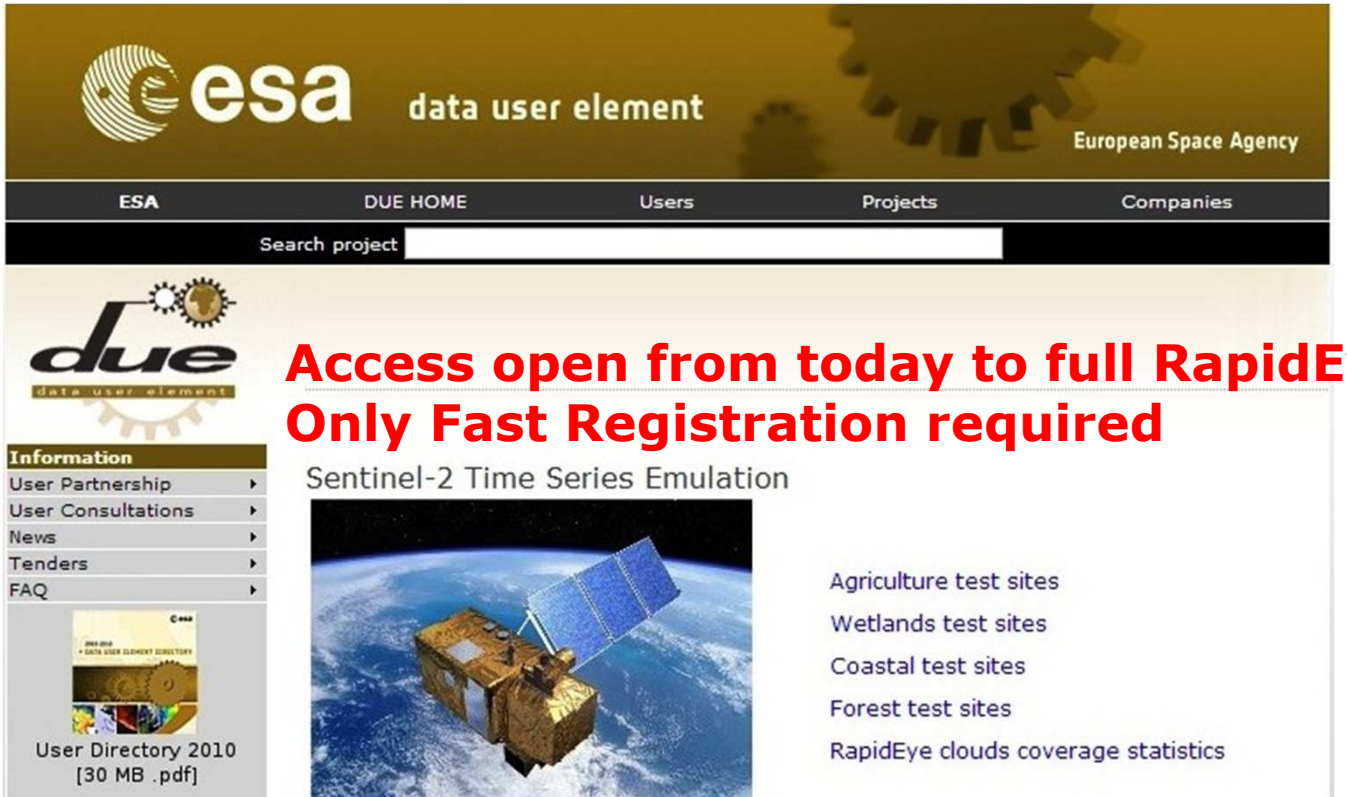
Planned Activities: TIGER Fellowships

- **2-3 scientific fellowships** for African scientists
- Funded by the Alcantara Initiative of ESA's General Study Programme
- At least one fellowship dedicated to S2 time series
- **Call end of the year 2013:** 1 year, 100keuro

Multi-temporal & Multi-sensor data set

Free & Open complementary data over 14 of the Take5 test sites

	Swath Width	Spatial Resolution	Nr. of Bands	Revisit Time
Sentinel-2	***290 km***	***10 m - 20 m***	***13***	***5 days***
RapidEye	*65 km*	***5 m***	*5*	***5 days***
SPOT-4	*60 km*	*20 m*	*4*	***5 days***
Landsat-8	*185 km*	*30 m*	***11***	*16 days*



European Space Agency

Conclusions

- Building on DUE heritage that include a wide diversity of applications & user communities for the **preparation of Sentinel-2 exploitation**
  - Support for dedicated algorithm development
  - Demonstration and preparation of user communities
- **Preliminary results:** Time series show under-exploited information dimension for applications from marine - agriculture
- **Dense Multi-temporal/sensor data sets available:** SPOT4, RapidEye, Landsat-8 covering most S2 capabilities

- **S2 Time Series workshop** planned in spring 2014
  - Global Scientific Community (200+ participants expected)