→ EARTH OBSERVATION FOR SUSTAINABLE DEVELOPMENT

Agriculture and Rural Development

InfoSession
25 July 2018 | ADB, Manilla, Philippines

Session 2 - Optimize water use efficiency

EO4SD consortium, presented by Arjen Vrielink, Satelligence

agriculture and rural development
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The consortium of EO4SD – Agriculture and Rural Development

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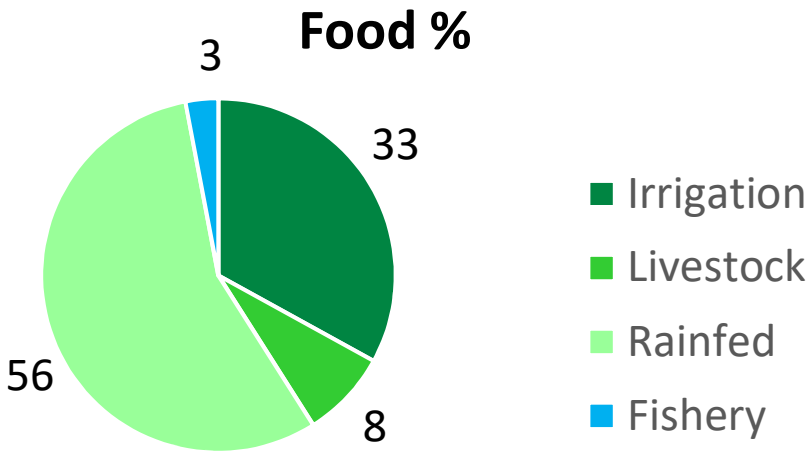
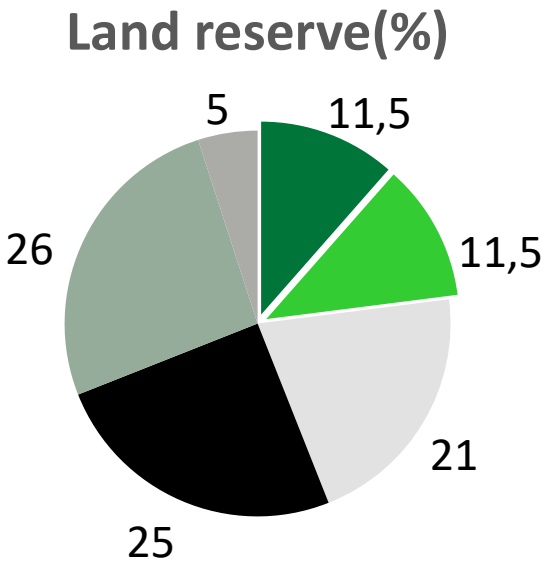
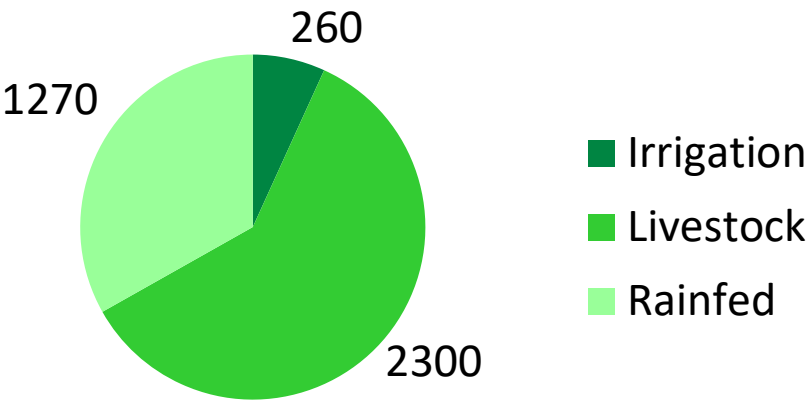
Setting the stage - World food production







Setting the stage – irrigation as cornerstone of food security

Improved water management holds the key to sustainable production of food towards the world population in 2030.

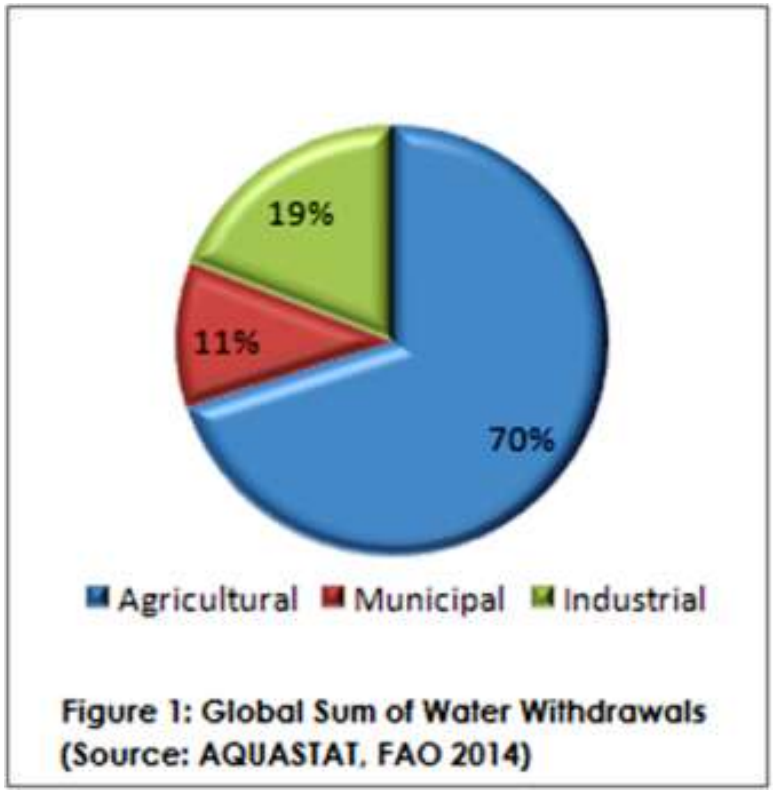


Figure 1: Global Sum of Water Withdrawals (Source: AQUASTAT, FAO 2014)

Globally the entire sector is being challenged to produce approximately 70% more food to feed 9 billion people by 2050. It has been acknowledged that most of this increase will need to come from greater land and water productivity as well as expansion of arable and irrigated areas.

Achieving higher food production levels requires:

- the expansion of irrigated area
- improvement of crop productivity
- Improvement of irrigation efficiency

Irrigation is a cornerstone of food security and poverty reduction:

- Irrigation allows farmers to evolve from one rainfed crop per annum to one or two irrigated crop cycles in addition to one rainfed crop cycle

Role of Earth Observation

- Provide estimates of the already irrigated area acreage,
- Help identify land suitable for irrigation,
- Estimate the impact of land use change on the water balance by comparing actual crop water use with irrigation water requirements.

- Indicators like crop water consumption by evapotranspiration help to optimize water distribution by providing the spatial insight into the water use and needs of an irrigation system.
- Irrigation managers can monitor crop water consumption on a semi real-time basis, or alternatively they can evaluate accumulated numbers over an entire season, or analyse the spatial crop water consumption from year to year. This allows for precision farming at field and scheme scale.

Introduction: In the context of the Sustainable Development Goals

target 6.4:
Substantially increase water use efficiency

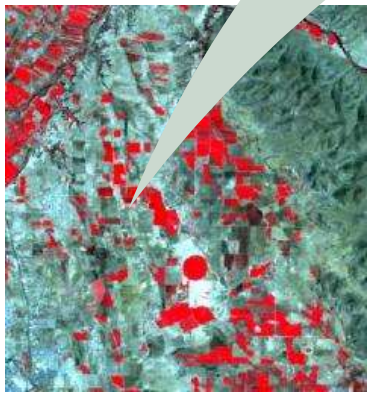
target 2.4:
Increasing agricultural productivity

target 15.3:
Combat desertification and achieve a land degradation neutral world

target 17.18:
Increase the availability of high-quality, timely, and reliable data

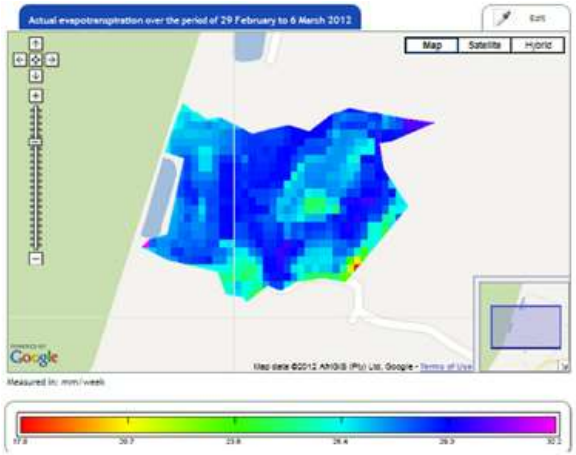
EO tooling and datasets

Remote sensing data



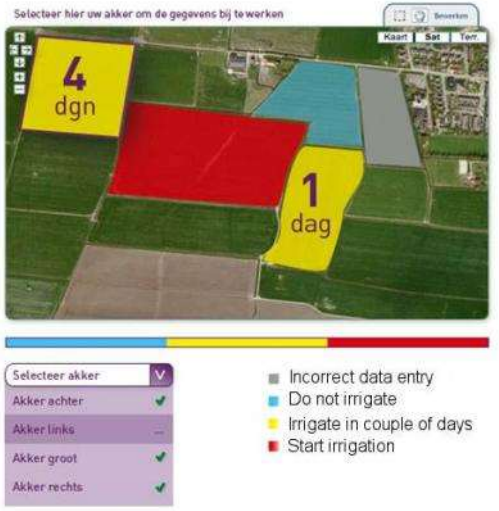
e.g. Sentinel

Intelligent pixels



e.g. Crop water requirement

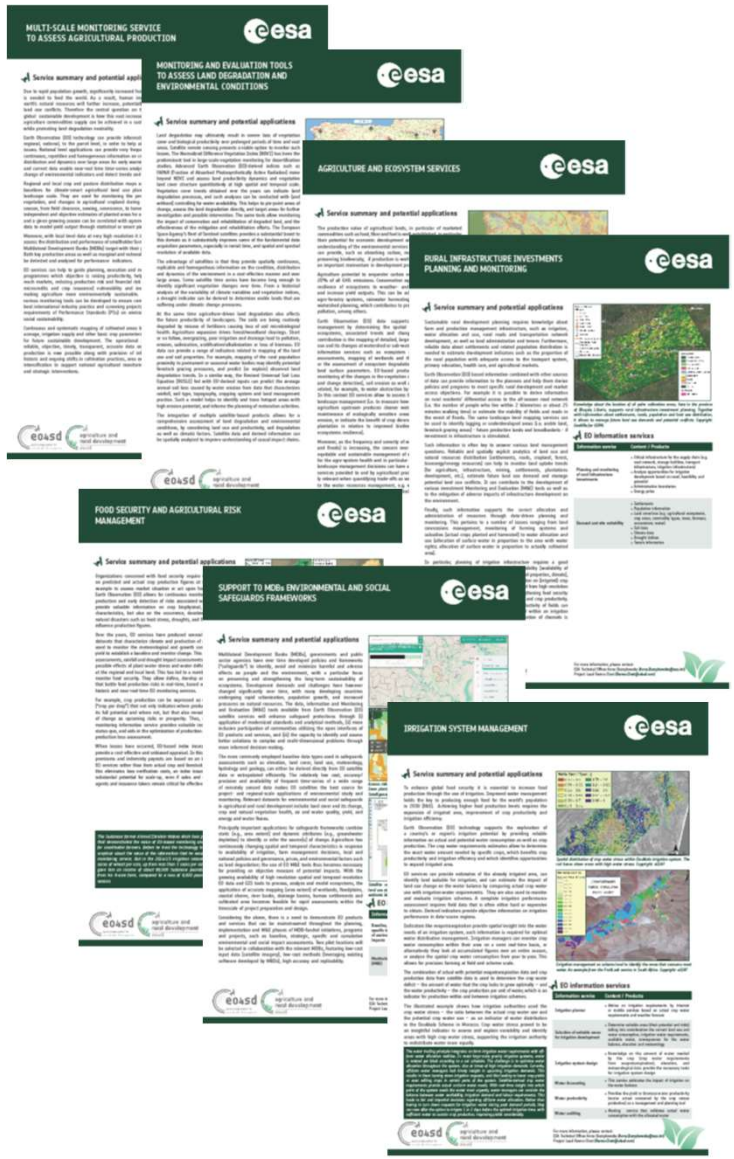
Instructive tools



e.g. Irrigation advice

EO can contribute to water management at:

- **Basin scale**
  (ie. Trends and anomalies in rainfall -> droughts, distribution of water)
- **System scale**
  (ie. Irrigation scheme management: head tail analysis, distribution of water, water allocation, irrigation efficiency, water productivity)
- **Field scale**
  (ie. In-field variations, irrigation advise, water productivity, crop development)
- **Evaluation**
  (ie. Irrigation performance, (water) productivity)

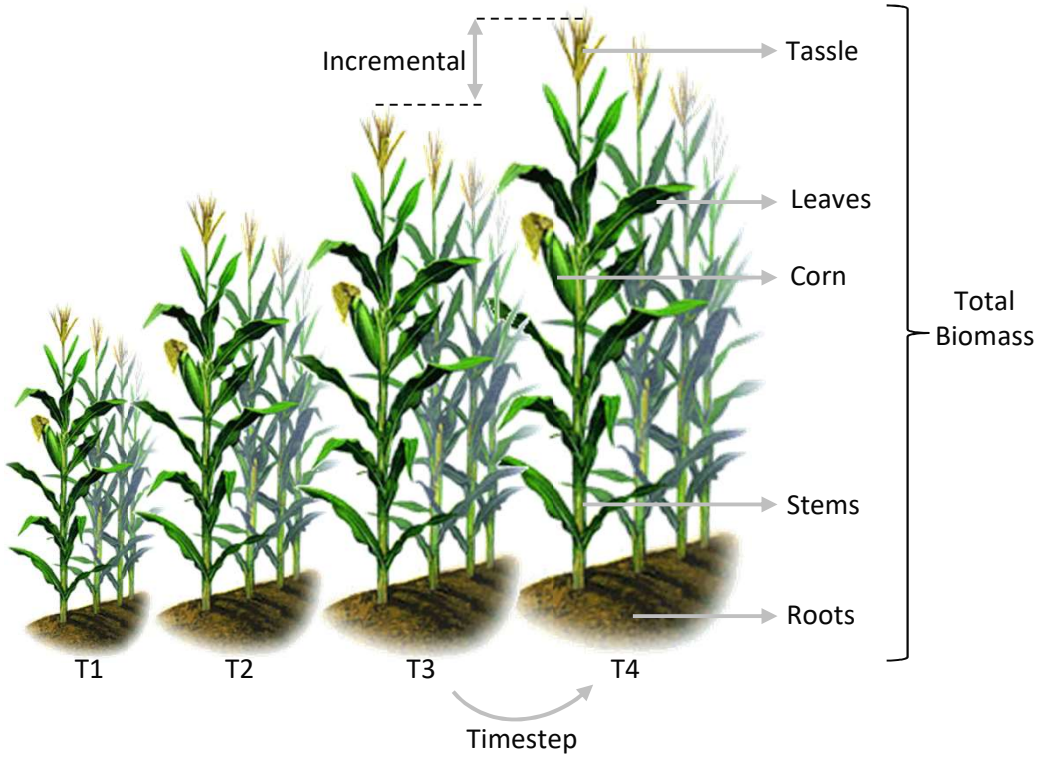


Indicators of irrigation performance

- **Biomass production**: Biomass production refers to the growth of total living plant material above and below the ground (such as stems, leaves, roots, fruits and grains). It is defined as *dry matter* and is measured as *incremental* biomass production per time step (kg/area/time step).
- **Actual evapotranspiration:** The quantity of water removed from the land surface through evaporation of water. (mm/time step)
- **Biomass water productivity:** The biomass water productivity shows how much (dry matter) biomass has been produced per unit of water (kg/m3) consumed by the crop. The biomass water productivity helps to determine pathways towards more crop per drop → Bio / ETact
- **Evapotranspiration deficit**: the difference between actual and potential ET, which reflects the crop's shortfall in what it can potentially achieve under ideal conditions. It is an indicator of plant stress (mm/time step) → ETpot - ETact

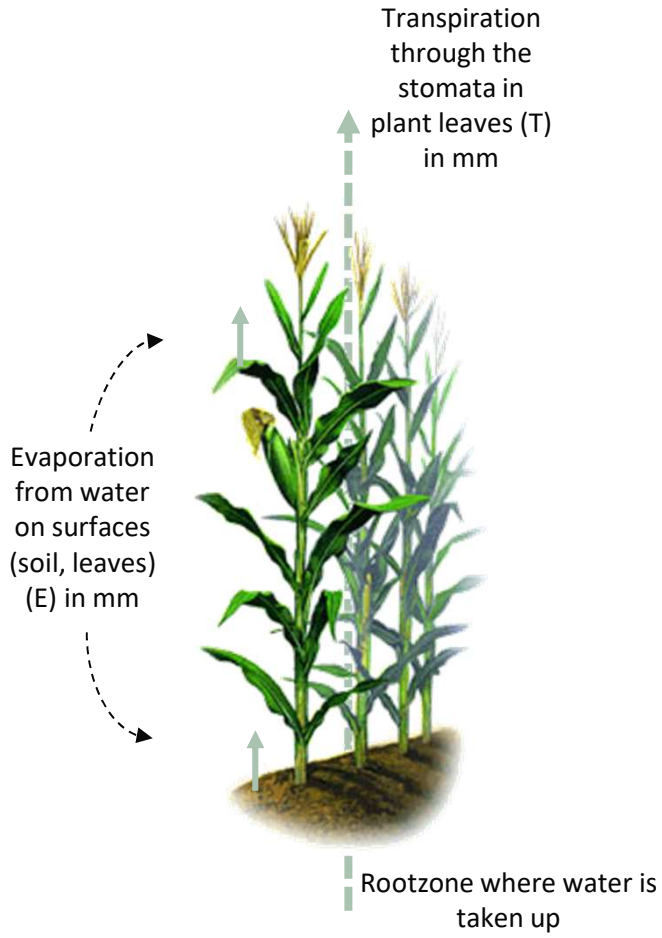
STRATEGY DEFINITION	PROJECT IDENTIFICATION & PREPARATION	IMPLEMENTATION	EVALUATION
Identify areas with water stress and/or low water productivity	Identify hotspots to prioritize investments	Monitor project progress	Map increase in productivity and water productivity

Biomass Production



Volume of **biomass** produced
(kg/ha/timestep)

Crop Water Consumption



Total volume of **water** used for crop production (mm/timestep)

Definitions used

- Potential Evapotranspiration (ET_{pot})

The quantity of water vaporization through stomata of the plant leaves if unlimited water were available.

- Actual Evapotranspiration (ET_{act})

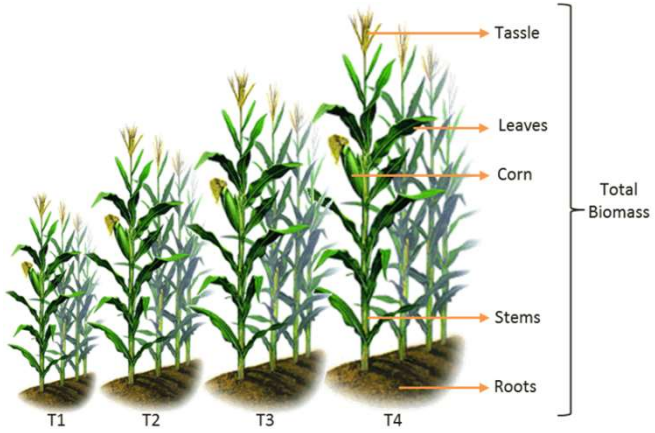
The quantity of water actually consumed by the crop growing process (E+T)

- Evapotranspiration deficit (ET_{def})

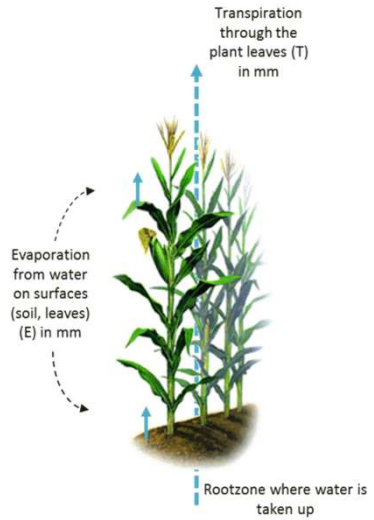
The difference between actual transpiration and potential transpiration.

→ **All are satellite based**
→ All in mm/time step

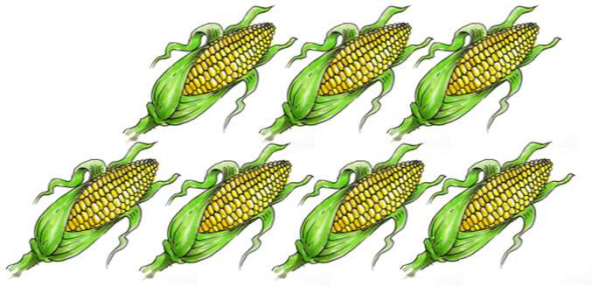
(Biomass) Water Productivity



$$\frac{\text{Total Biomass produced}}{\text{Volume of water consumed } (ET_{act})} = \text{in } \frac{kg}{m^3} \quad \text{(per time step)}$$

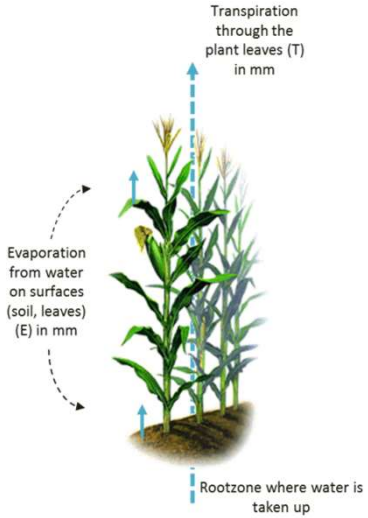


Water Productivity



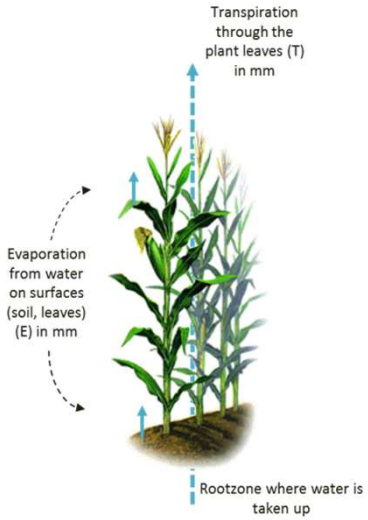
$$\frac{\text{Yield}}{\text{Volume of water consumed } (ET_{act})} = \frac{\text{Yield}}{\text{Volume of water consumed } (ET_{act})} \text{ in } \frac{kg}{m^3}$$

(per time step)



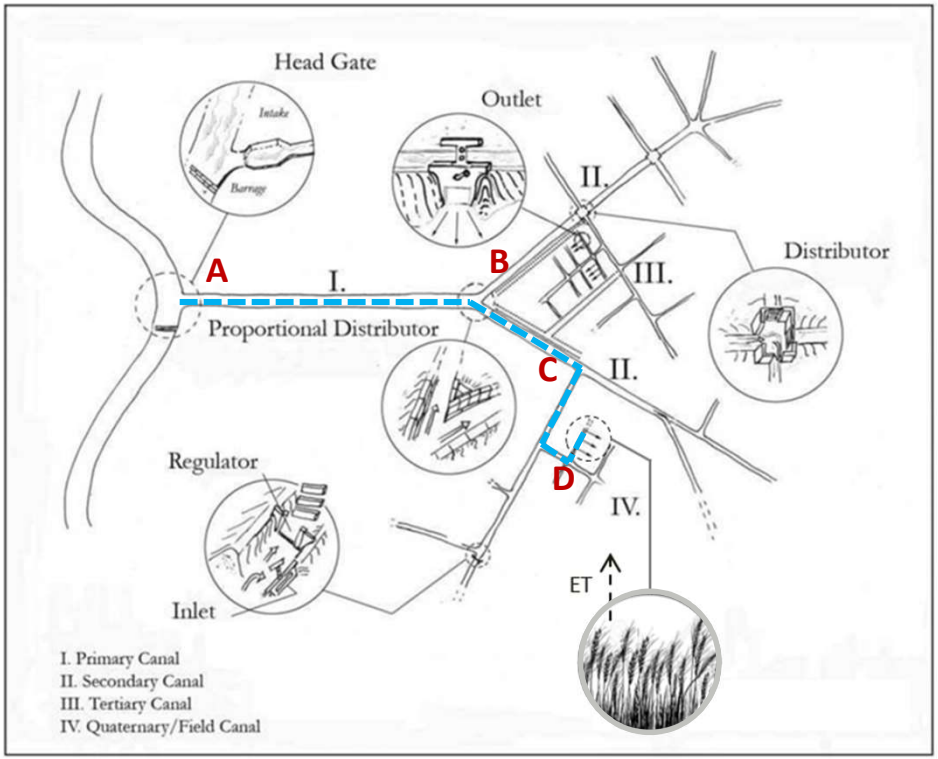
Economic Water Productivity

$$\frac{\text{Monetairy Value}}{\text{Volume of water consumed } (ET_{act})} \text{ in } \$/m^3 \quad \text{(per time step)}$$



Water ..Allocation? ..Use? ..Consumption?

...Depending who you talk to a different definition will be used...
And they might all be right!



...Water allocations in the primary, secondary, tertiary or field canals (A,B,C,D)?

...Water quota per field? ...Per person? ...Per season?

...Water consumed by the plants growth process?

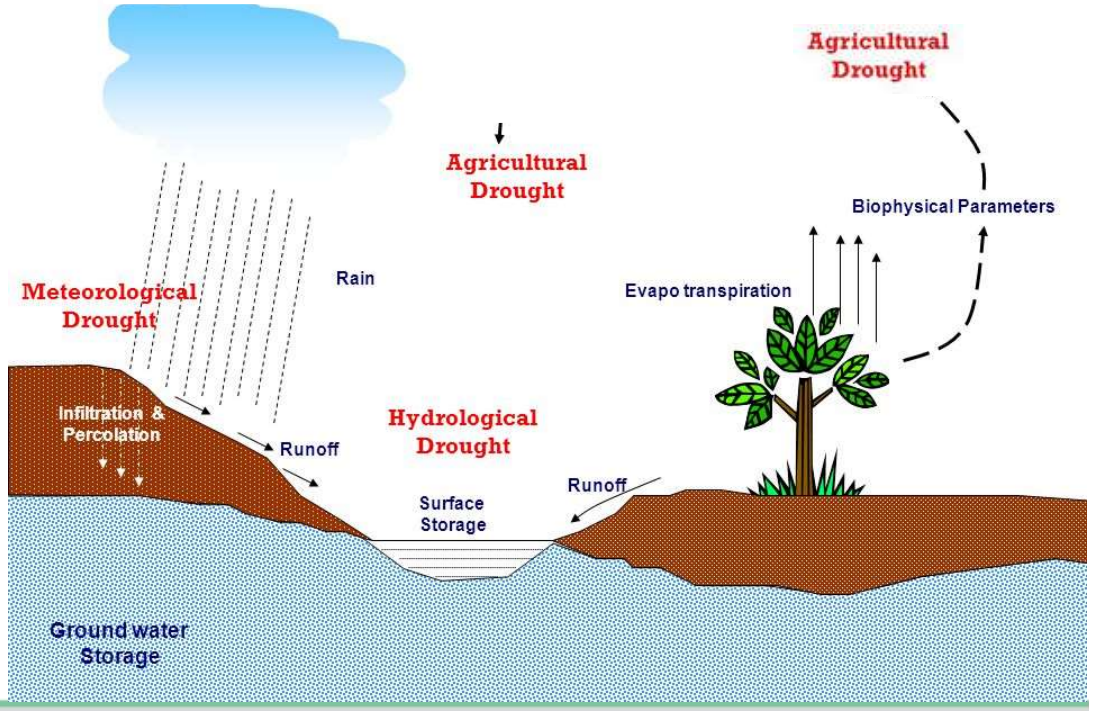
...What about irrigation efficiencies?

COMMUNICATION!

Droughts and water stress

From Earth Observation:

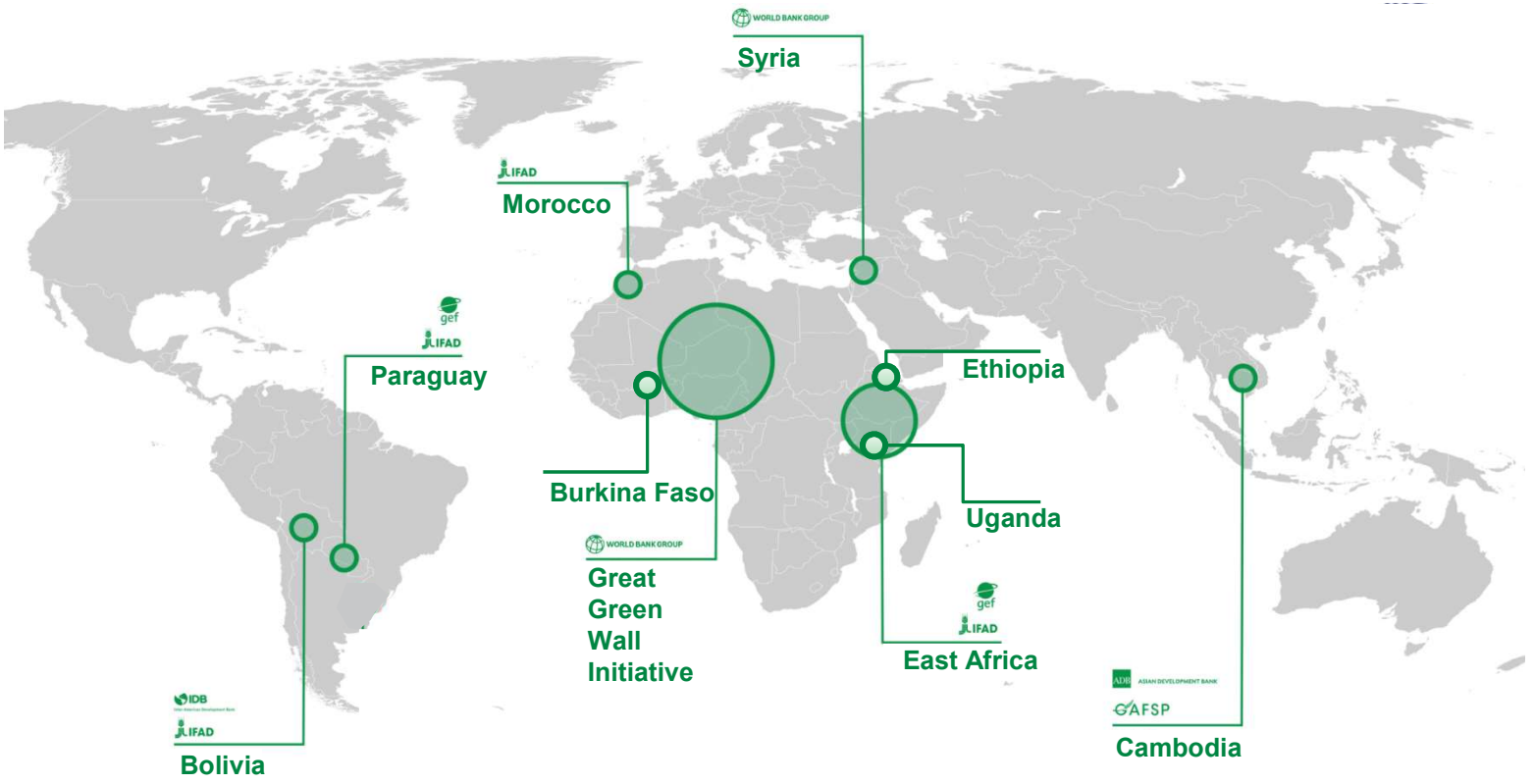
- Rainfall (anomalies)
- Evapotranspiration
- Evapotranspiration deficit
- Biophysical parameters such as vegetation cover and biomass production

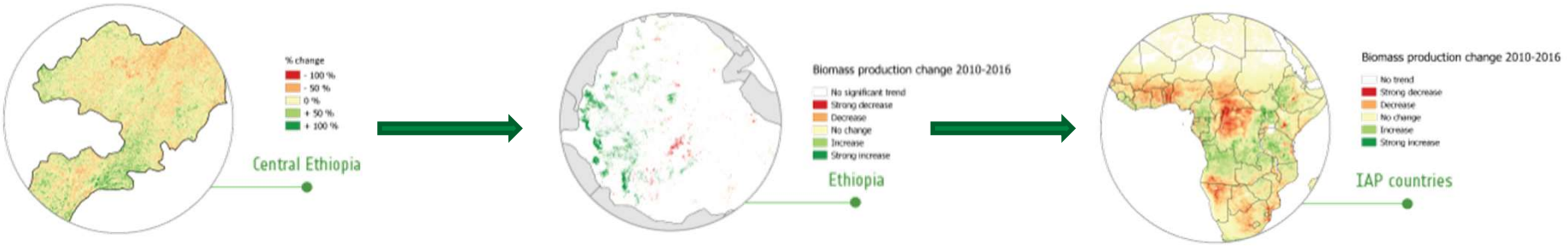


Measuring agricultural production and productivity with EO – service examples

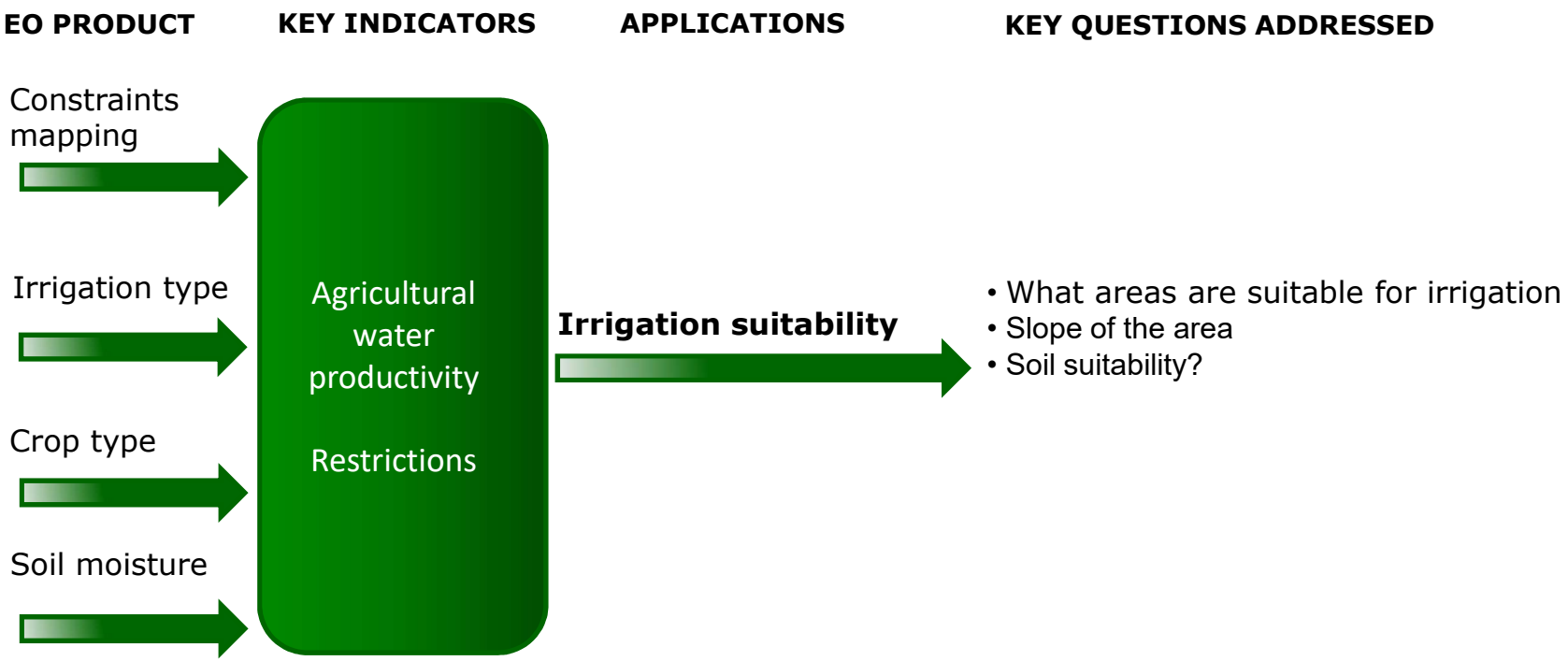
EO product	Pro	Con
Actual/ deficit evapotranspiration	▪ Quantitative measure of plant water consumption ▪ Independent of field data	▪ Relatively complicated to generate ▪ Interpretation is difficult, especially when no crop map is available
Biomass production, NPP	▪ Quantitative measure of plant production ▪ Independent of field data	▪ Relatively complicated to generate ▪ Interpretation is difficult, especially when no crop map is available
Crop yield	▪ Clear relation to existing datasets (agricultural output)	▪ Difficult to generate ▪ Models are crop and location (and often also year) specific ▪ Field data needed
Biomass water productivity	▪ Shows agricultural productivity of water resources	▪ See biomass production
Crop map	▪ Input for interpretation and analysis	▪ In situ data needed ▪ Small fields hamper accuracy

EO4SD (local) demonstrations that showcase the continental potential





Assessment of irrigation suitability



Related projects:	
Ethiopia	Sustainable land management project 2 (SLMP-2)
	2nd Agricultural Growth Project (AGP-2)
	Participatory Small-scale Irrigation Development Programme II (PASIDP II)
	Integrated Landscape Management to Enhance Food Security and Ecosystem Resilience in Ethiopia (GEF/IFAD IAP Food Security child project)

Irrigation suitabillity: decision tree

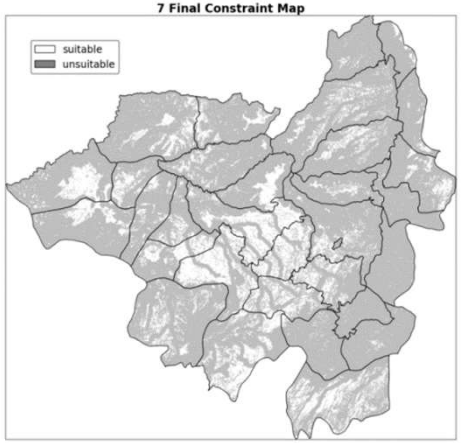
(1) Constraints | (2) Irrigation type | (3) Crop type | (4) Clustering

(1) Constraints

Mask agricultural restrictions:

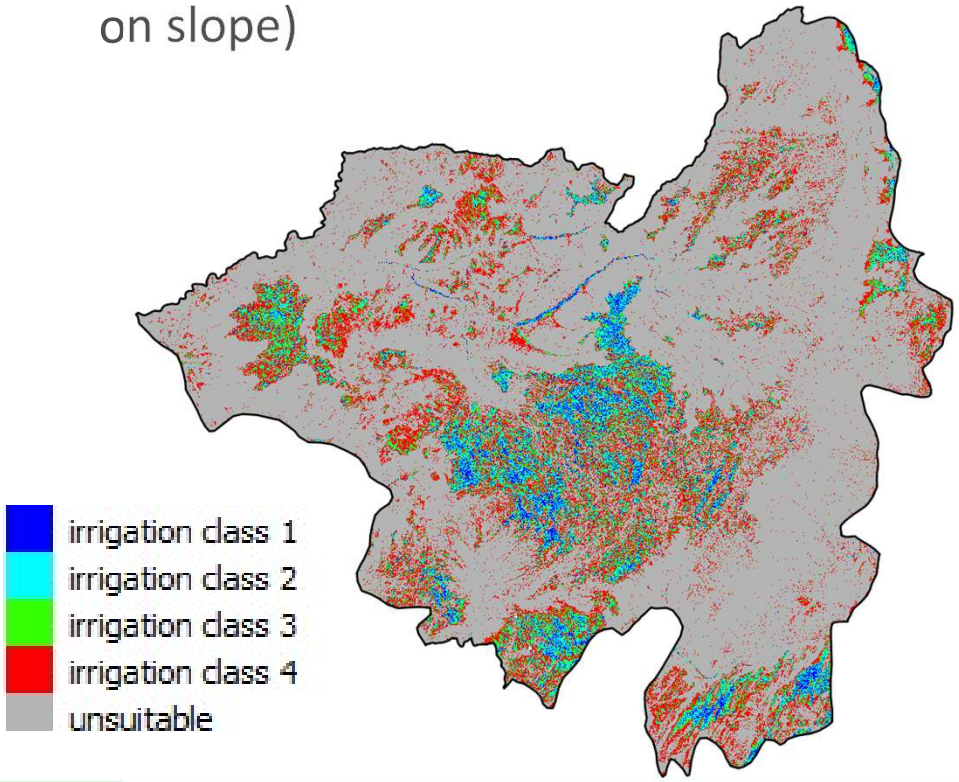
- steep slopes
- riverine corridors
- protected and urban areas
- degraded land
- unsuitable soils

Constraint map



(2) Irrigation type

Create an irrigation type map (based on slope)



Irrigation suitability – decision tree (2)

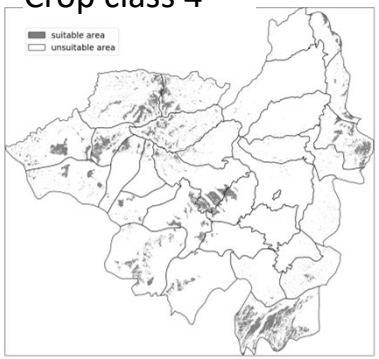
(1) Constraints | (2) Irrigation type | (3) Crop type | (4) Clustering

(3) Crop type
Determine suitability for crop types

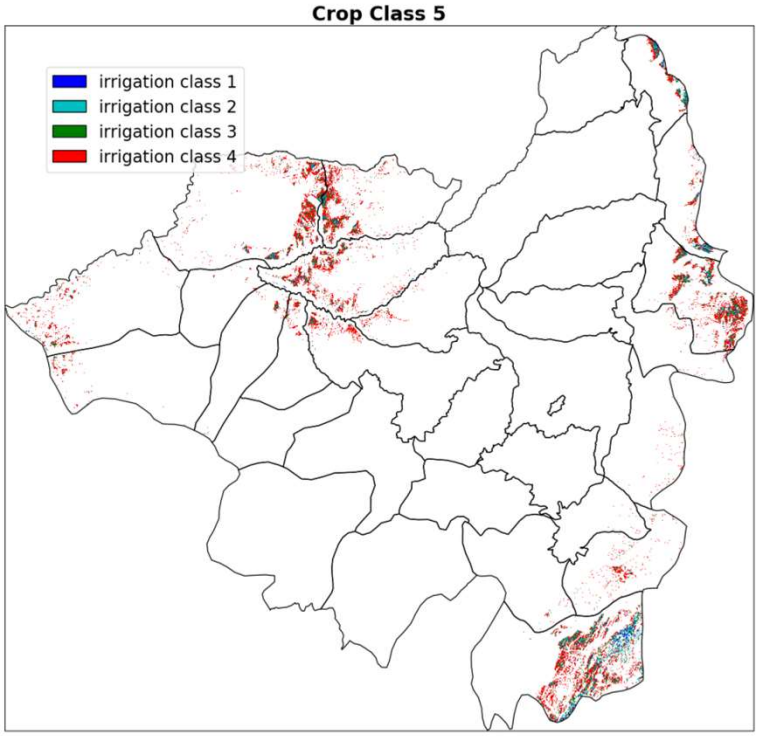
Crop class	T_{min} (°C)	T_{max} (°C)	T_{mean} (°C)
1	10	27	17.4
2	10	35	22.5
3	15	35	25.4
4	5	35	20.0
5			
6			

1	Potato, pea, cabbage, onion, shallot, wheat, sugarbeet, tomato, bean, teff, barley, oats, fenugreek, faba bean,
2	Sunflower, chick pea, green chili pepper, lentil, safflower, cotton, nigerseed, fingermillet, tomato
3	Maize, sorghum, soybean, sweet potato, tobacco, groundnut, paddy rice, water melon
4	Olive, grape, jatropha
5	Pine apple, citrus, mango, coffee, khat, lemon, peach
6	Sugarcane, alfalfa, banana, sesame, ginger, papaya, guava

Crop class 4

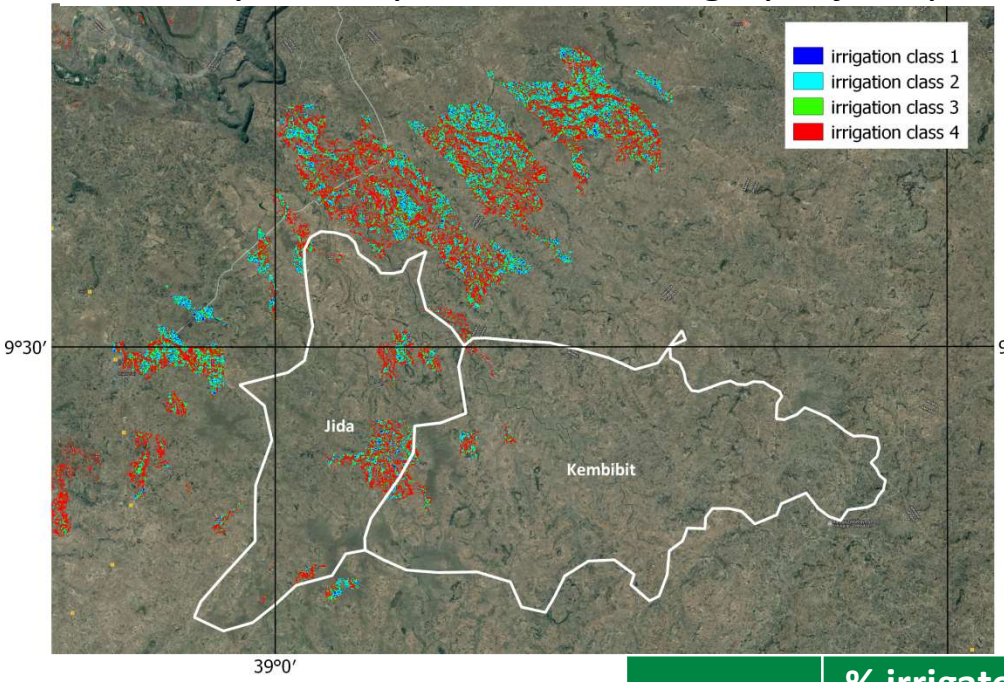


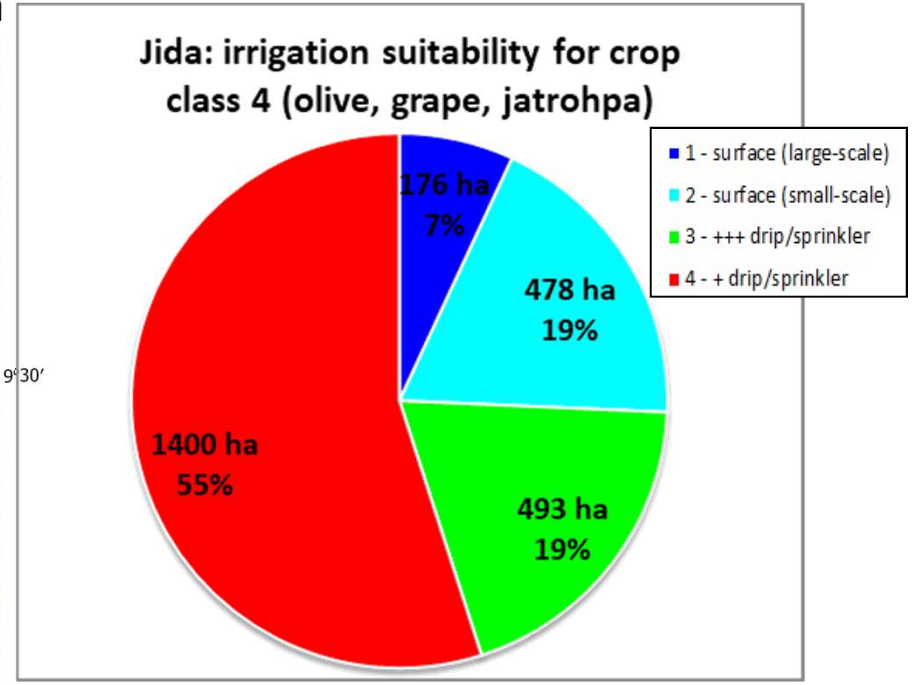
(4) Clustering
Sieve results (only select areas > 10 ha)

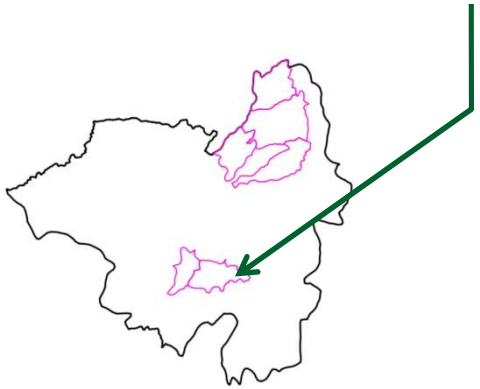


Irrigation suitability – decision tree (3)

Suitability for crop class 4: Olive, grape, jatropha

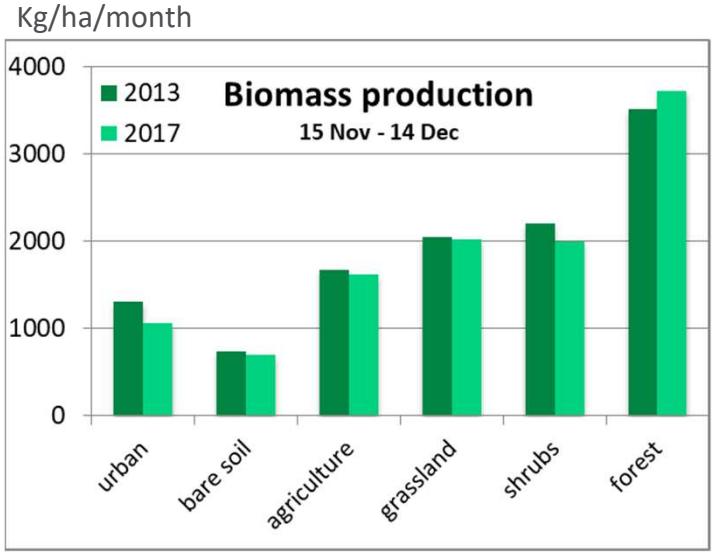




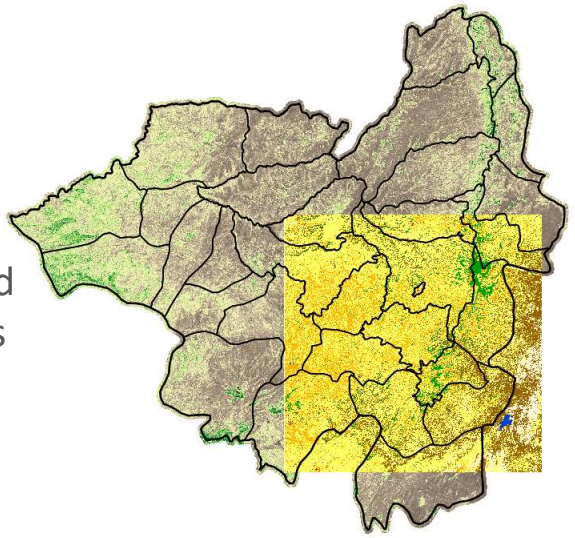


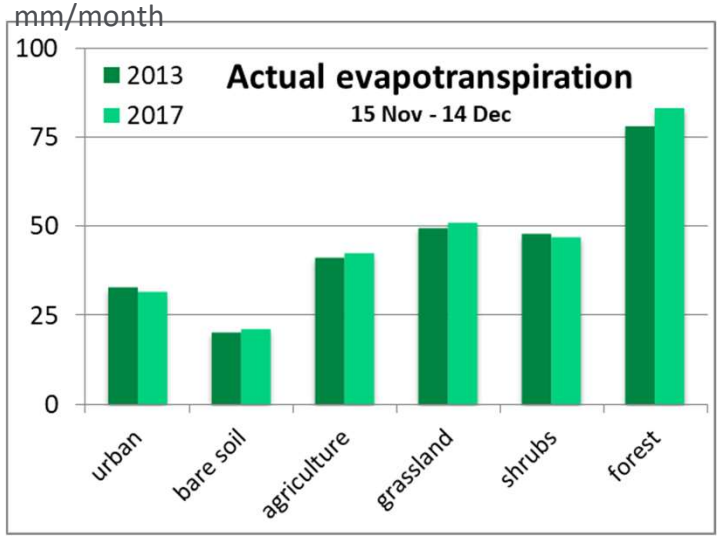
Irrigation class	% irrigated area in Northern Shewa suitable for crop class:						Total area (ha)
	1	2	3	4	5	6	
1	18	56	25	80	34	8	11,166
2	20	57	24	81	34	6	35,887
3	21	58	25	83	36	4	39,302
4	21	64	28	86	40	2	136,501
total	21	62	27	85	38	3	222,856

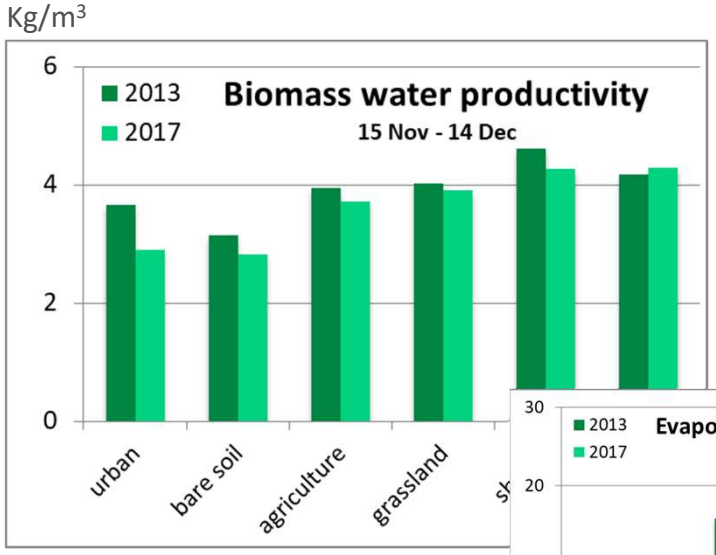
Production and water consumption per land cover

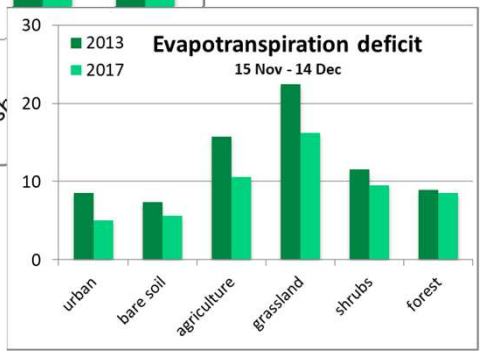


- Generally production went down except for forest
- Water consumption increased for agriculture and grasslands and forest
- Biomass water productivity decreased except for forest





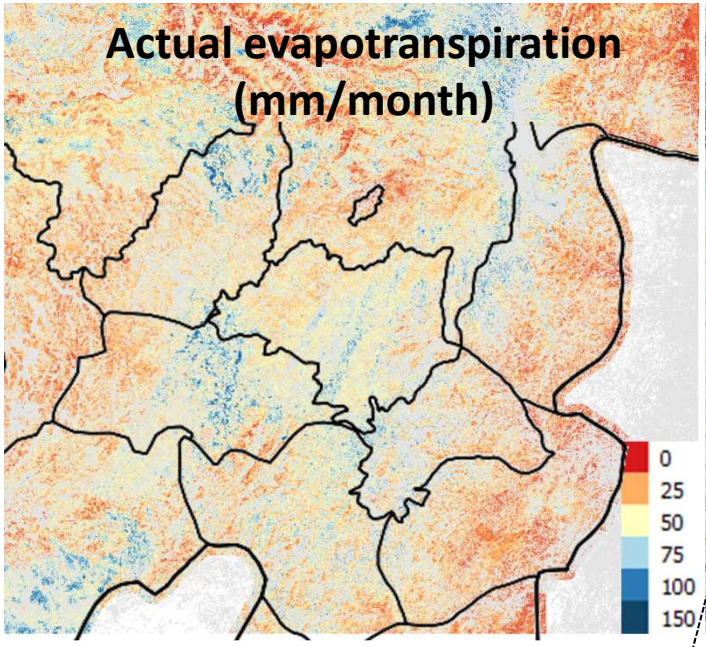


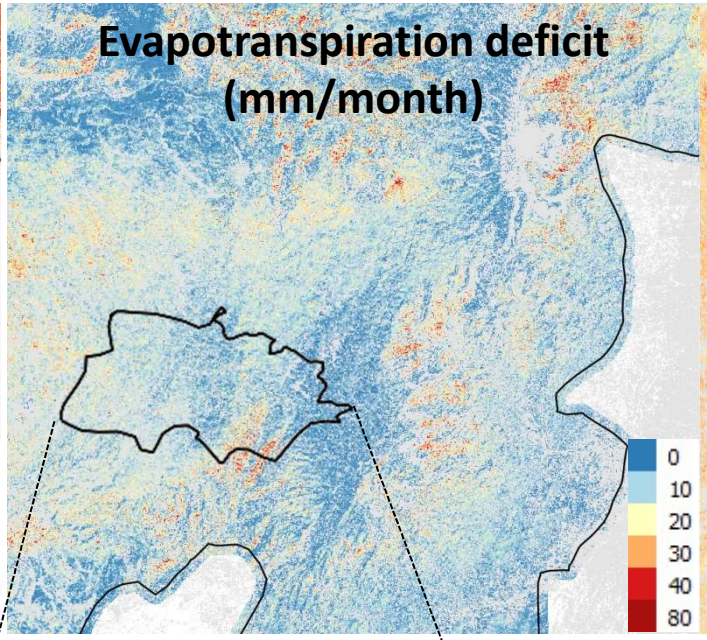


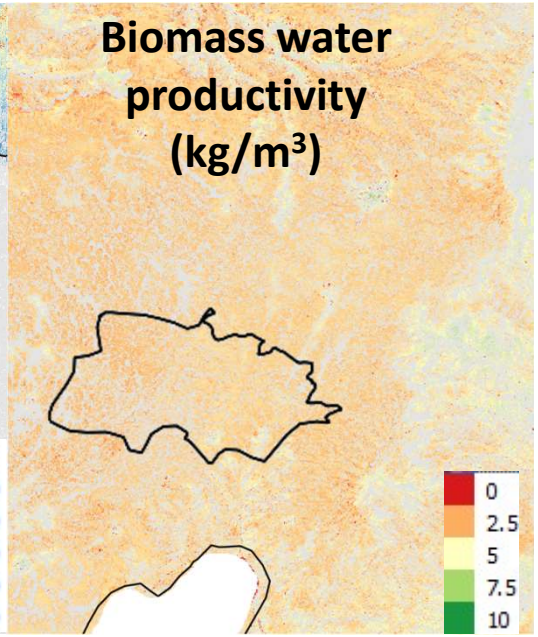
mm/month

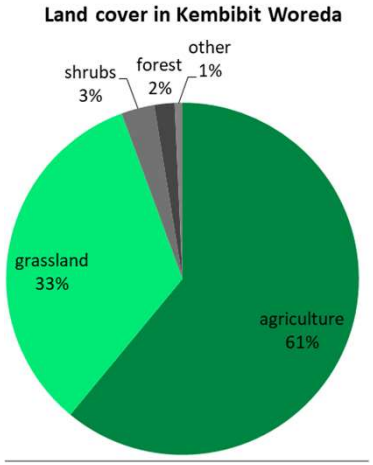
Water consumption in agricultural areas (early Bega season)

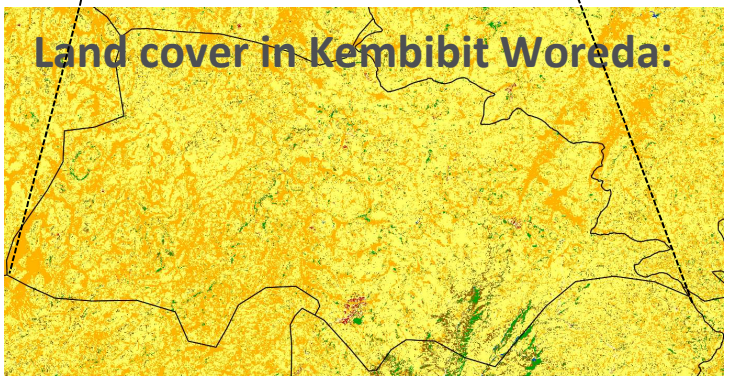
15 Nov - 15 Dec 2017 (Non-agricultural areas in grey)







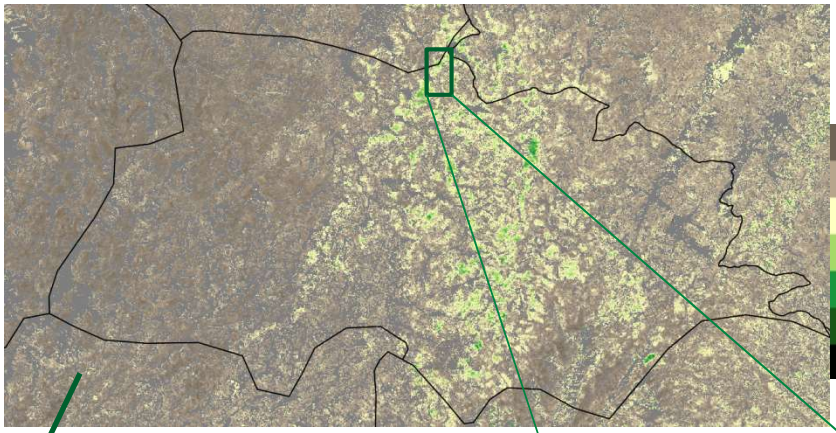




Agricultural productivity in Kembibit woreda

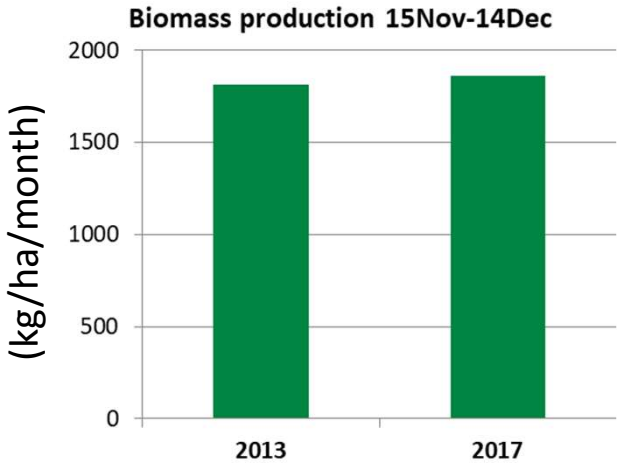
15 Nov - 15 Dec 2013

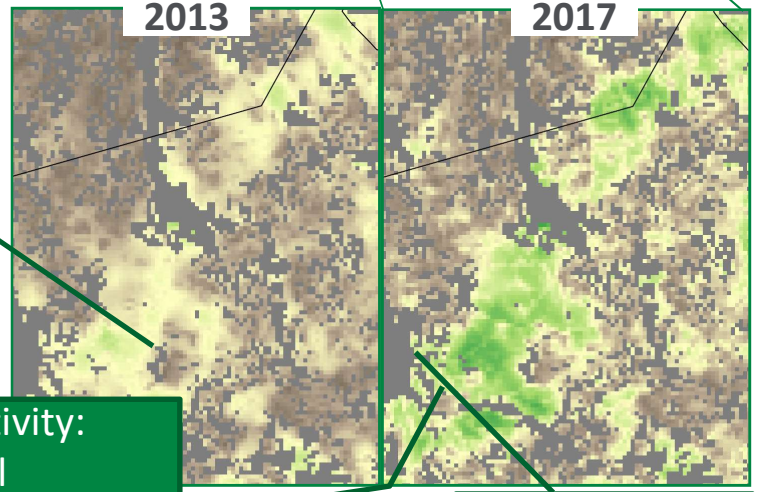
15 Nov - 15 Dec 2017



No obvious changes in biomass production between 2013 & 2017 (early Bega season)

Non-agricultural areas in grey





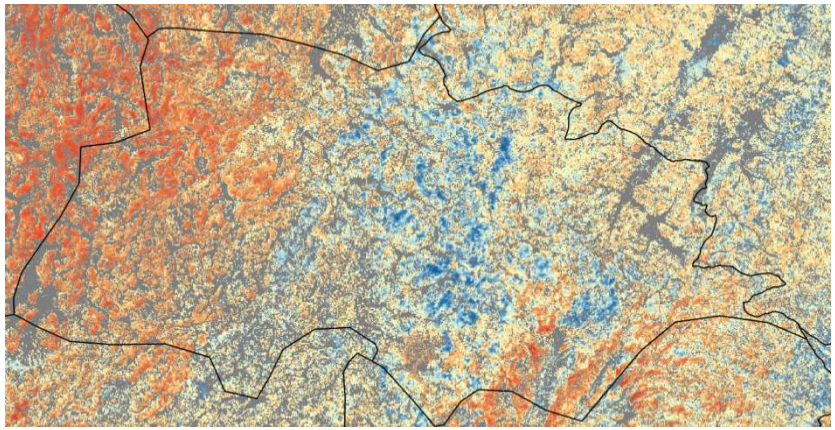
3435 kg/ha/month

Increased productivity: due to agricultural development and introduction of irrigation?

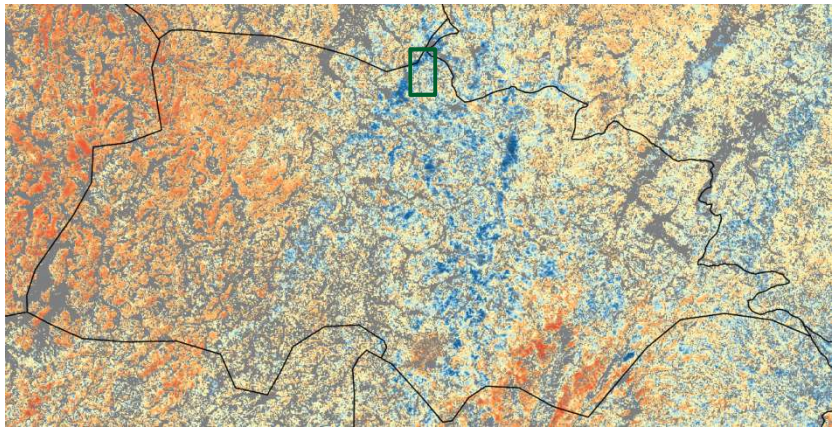
4962 kg/ha/month

Agricultural water consumption in Kembibit woreda

15 Nov - 15 Dec 2013



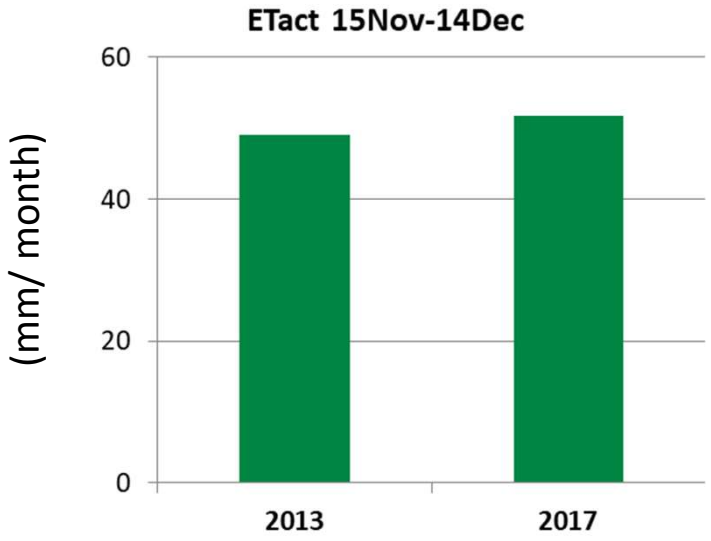
15 Nov - 15 Dec 2017

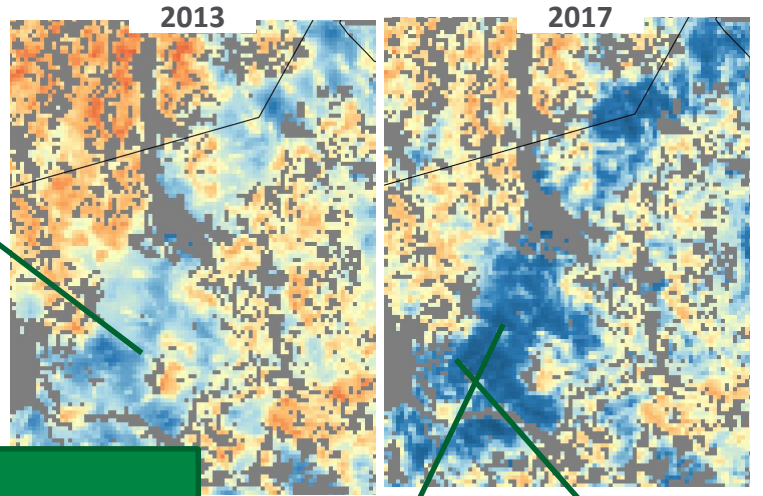


mm/ month)

0
25
50
75
100
150

Non-agricultural areas in grey





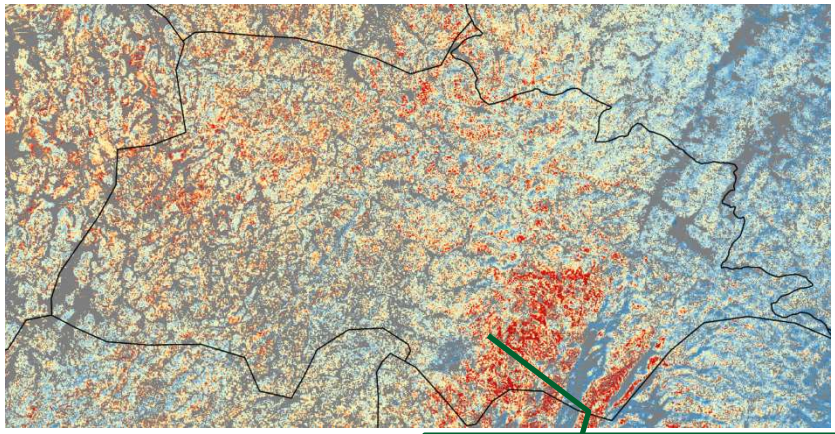
90 mm/month

118 mm/month

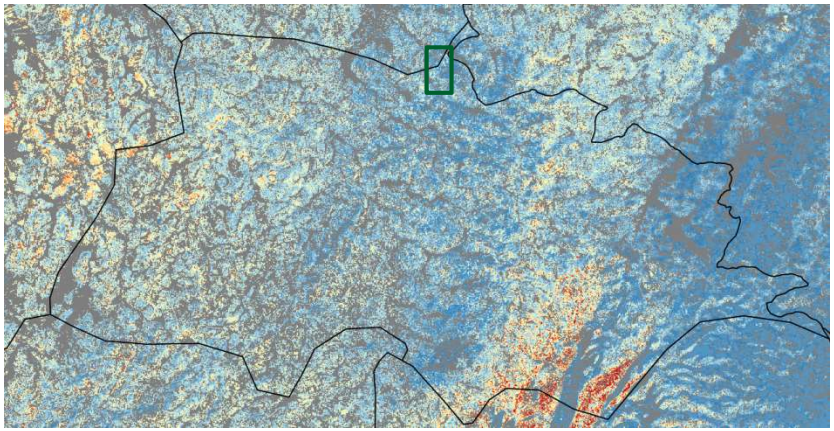
Increased water consumption by more productive crop

Agricultural water stress in Kembibit woreda

15 Nov - 15 Dec 2013



15 Nov - 15 Dec 2017

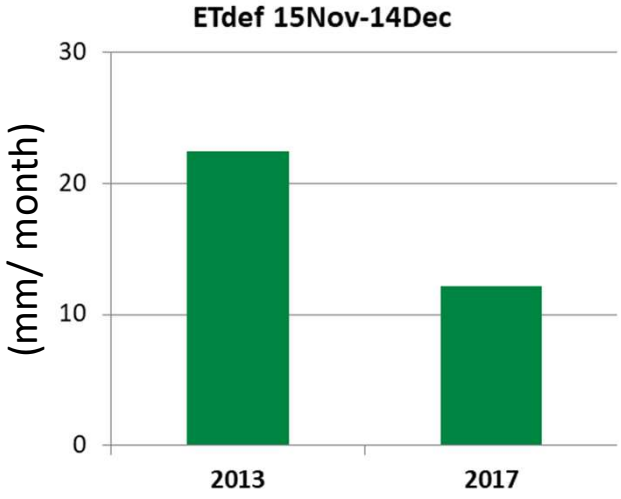


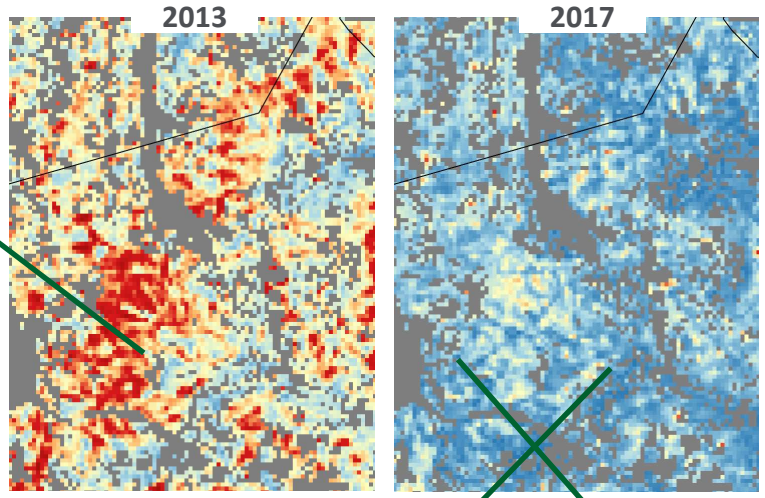
(mm/ month)

0
10
20
30
40
80

Non-agricultural areas in grey

Water stressed areas





27 mm/month

4 mm/month

No water stress, due to introduction of irrigation or climatic differences?

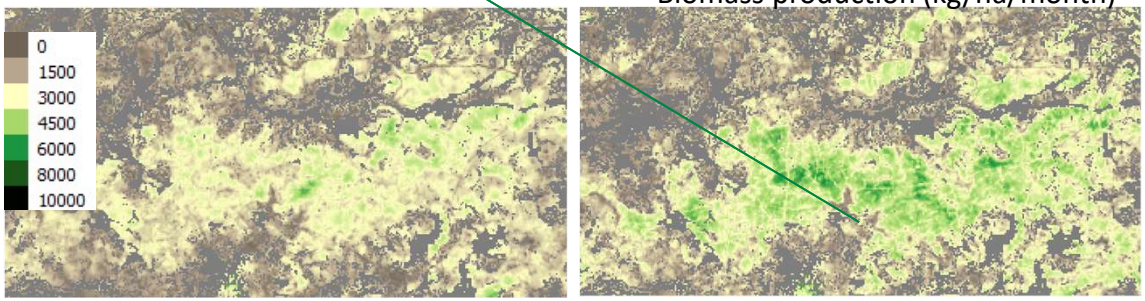
Northeast of Sasit, Tarmaber

Spatial and temporal patterns:

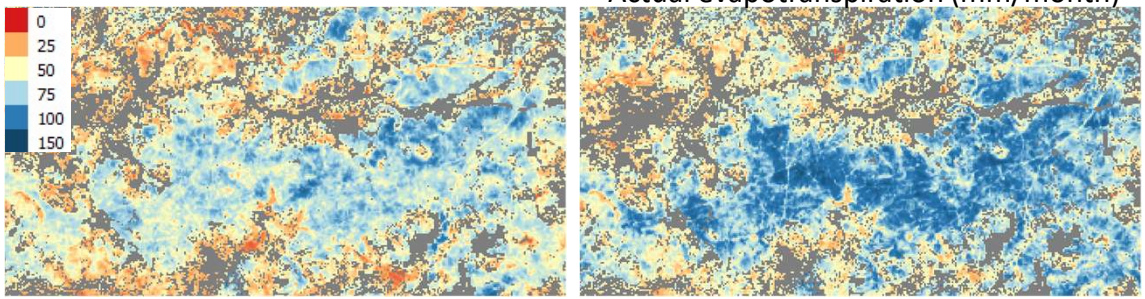
Increased production and water consumption, water productivity remains the same

Observation of new (?) irrigated area

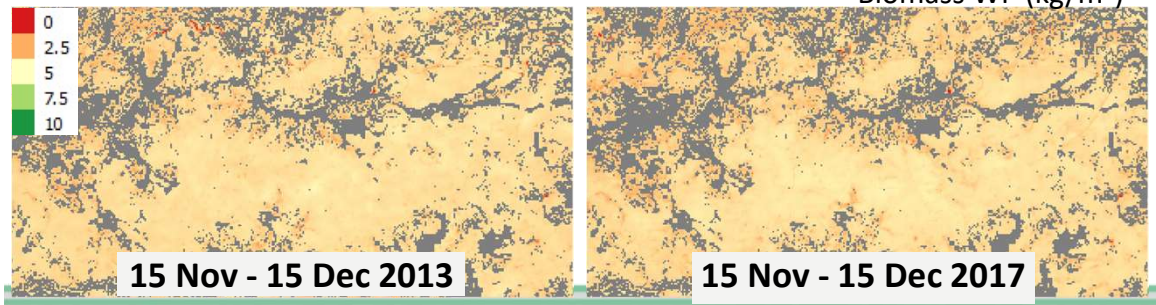
Biomass production (kg/ha/month)



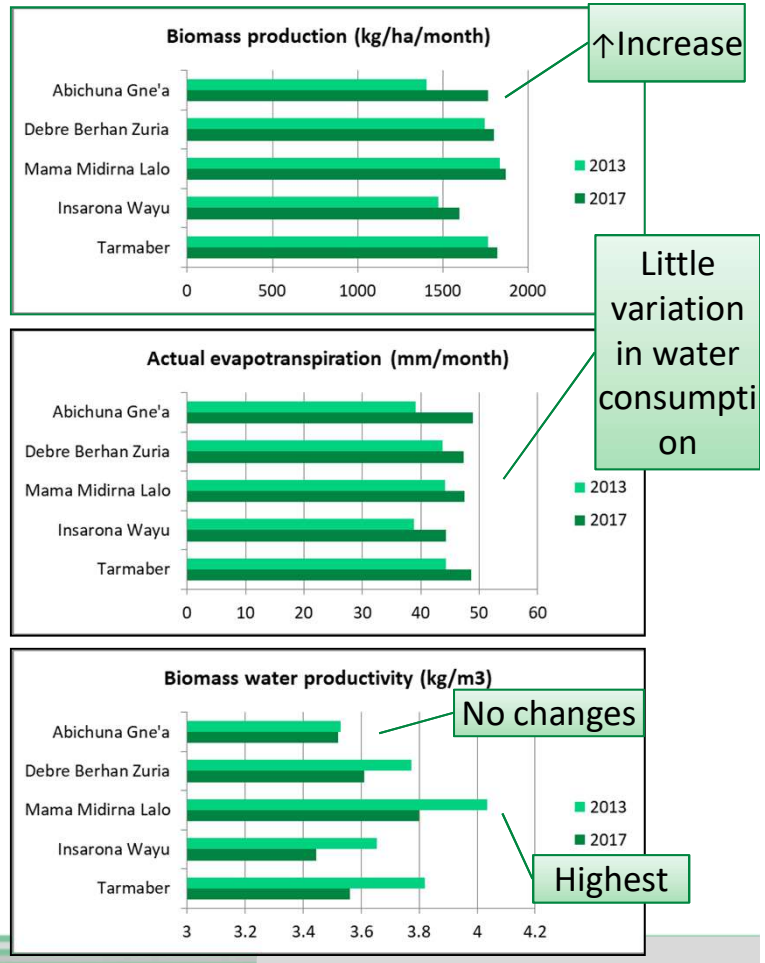
Actual evapotranspiration (mm/month)



Biomass WP (kg/m^3)



In relation to other areas:

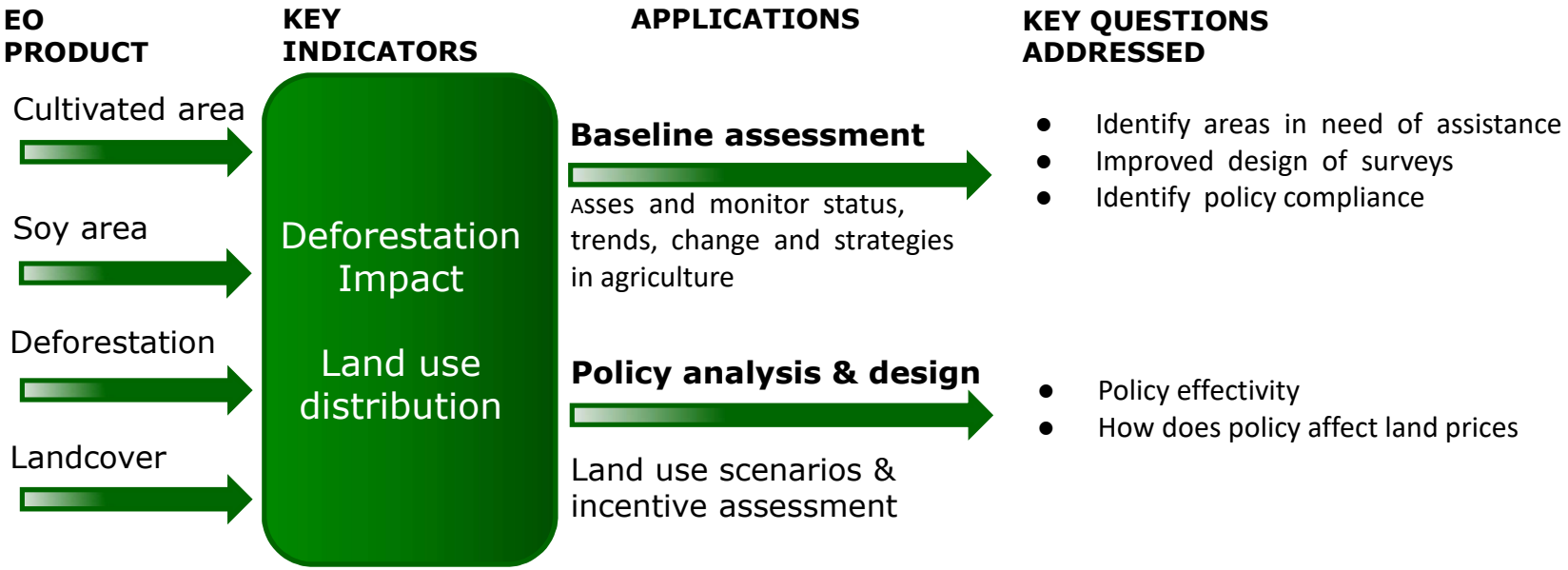


Service fact sheet

EO product	Constraints mapping	Irrigation type	Crop type	Soil moisture
Detail	medium/high			low
Period	Historic / NRT			Historic / NRT
Frequency	yearly/custom			Weekly/monthly/yearly/custom
Delivery type	Table/map/graph/report			Table/map/graph/report
Source	Open/Commercial			Open/Commercial
Cost range (USD)	on request			1-10 USD/ha | 0.5-1.0 USD/km2, minimum order size 25,000 USD

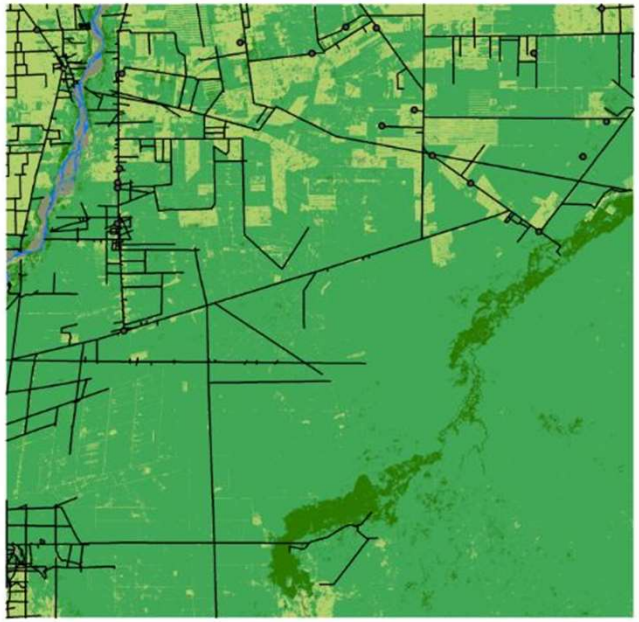
EO indicator	Irrigation suitability
Detail	low/medium/high
Period	Historic / NRT
Frequency	Daily/weekly/monthly/yearly/custom
Delivery type	Table/map/graph/report
Source	Open/Commercial
Cost range (USD)	0 - x/unit/ example / on request

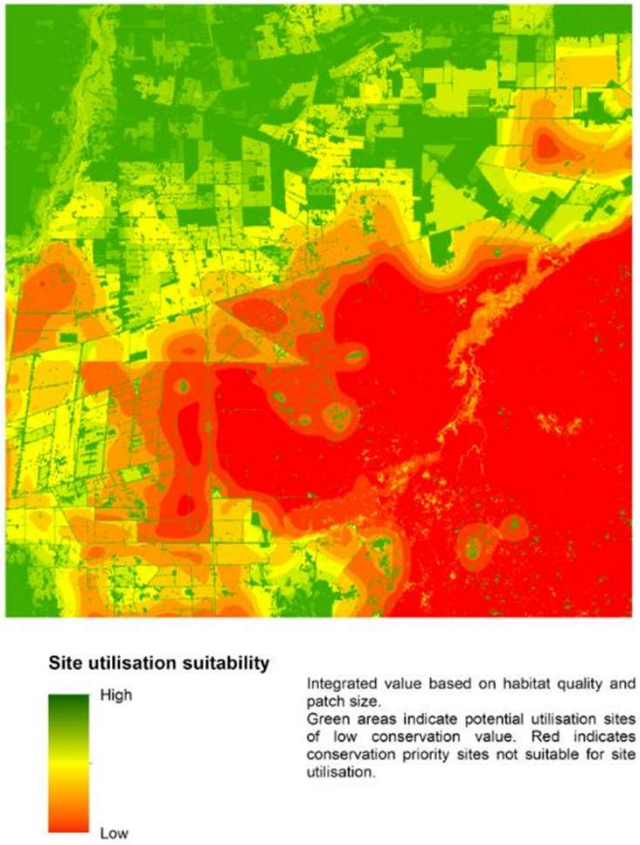
Land titling and pricing



Related demonstrations:	
Bolivia	Rural Land Regularization and Titling Program (Land Administration Program II)
	IAP Commodities

Demonstration: Land cover





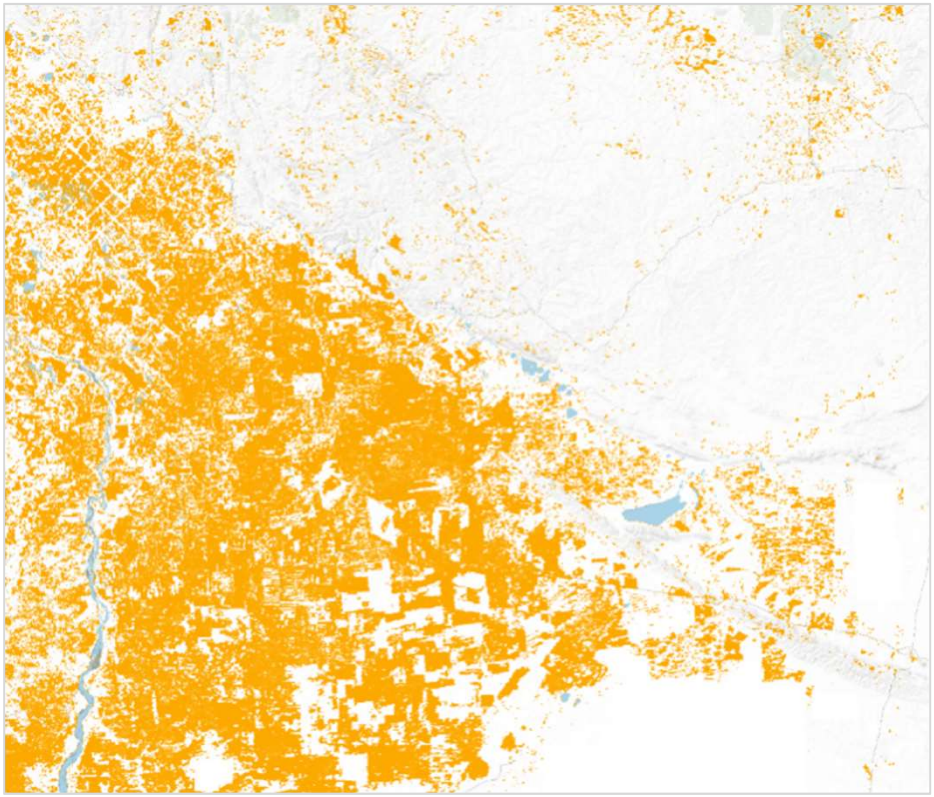
Map indicating suitability for utilisation purposes

Advantage: first assessment and comparison of different landscapes and their variety.

Support land allocation

Demonstration: cultivated area

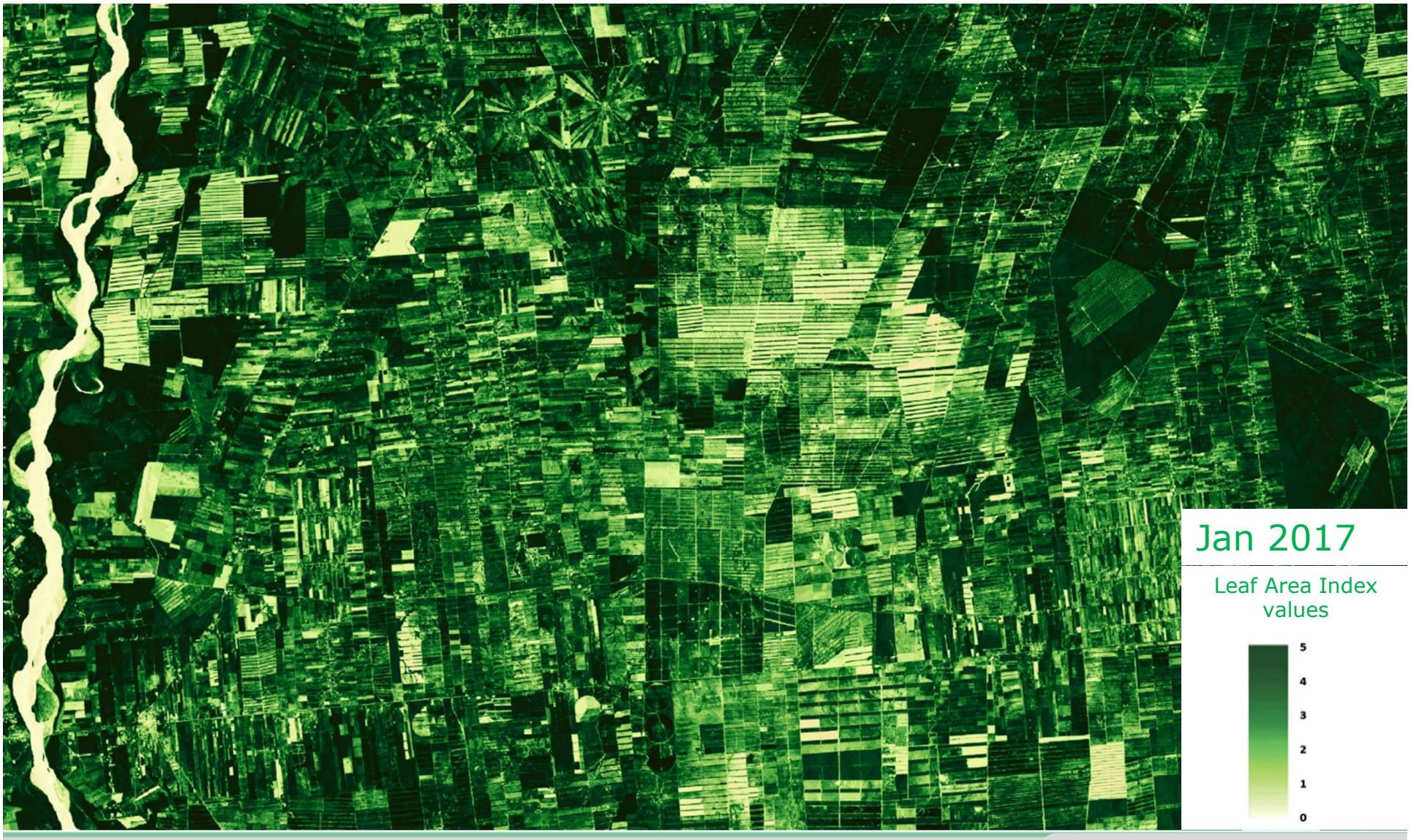
Sentinel-2 10m (Santa Cruz)



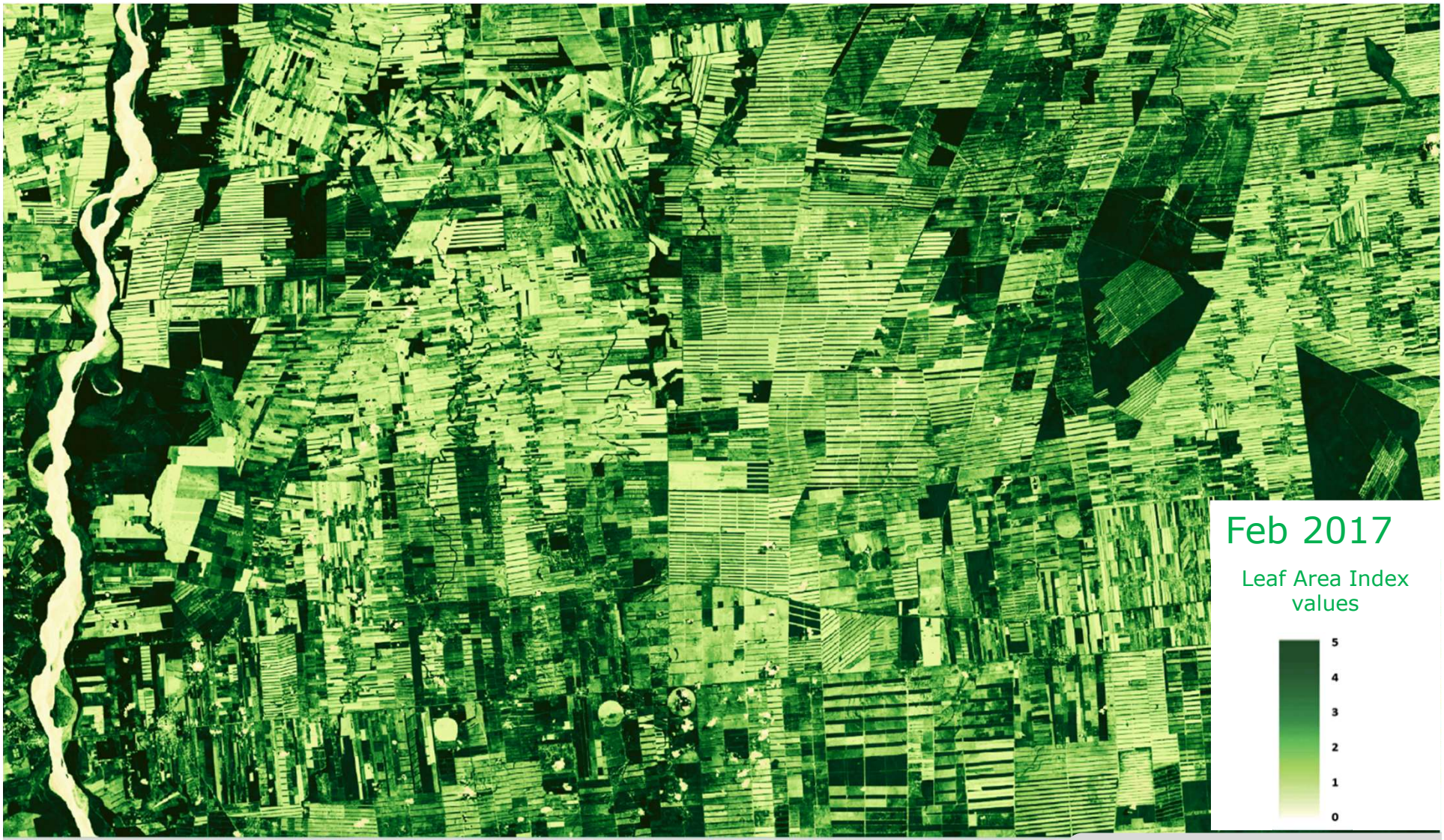
Result

Cultivated area

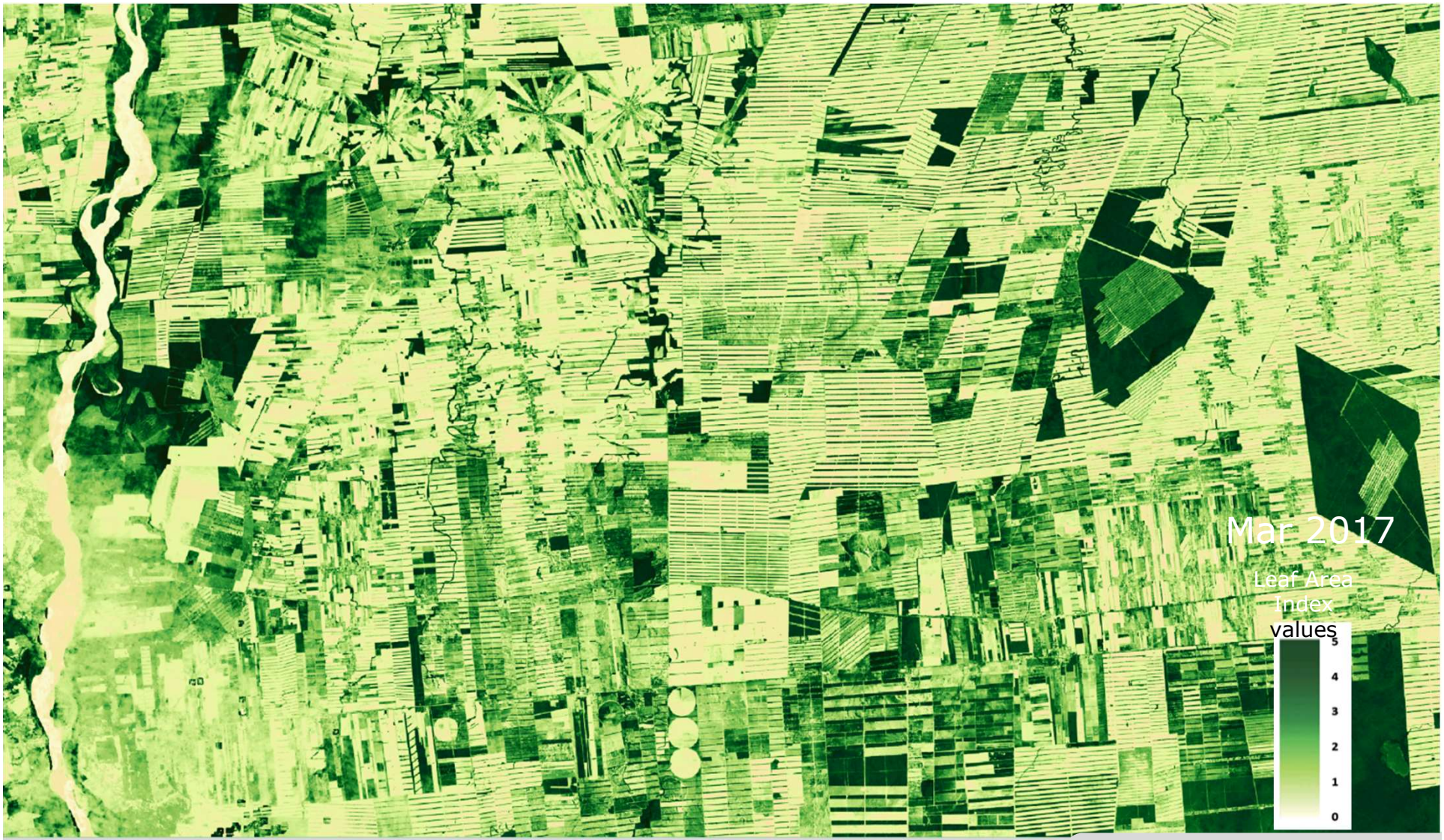
Demonstration: crop performance



Demonstration: crop performance



Demonstration: crop performance

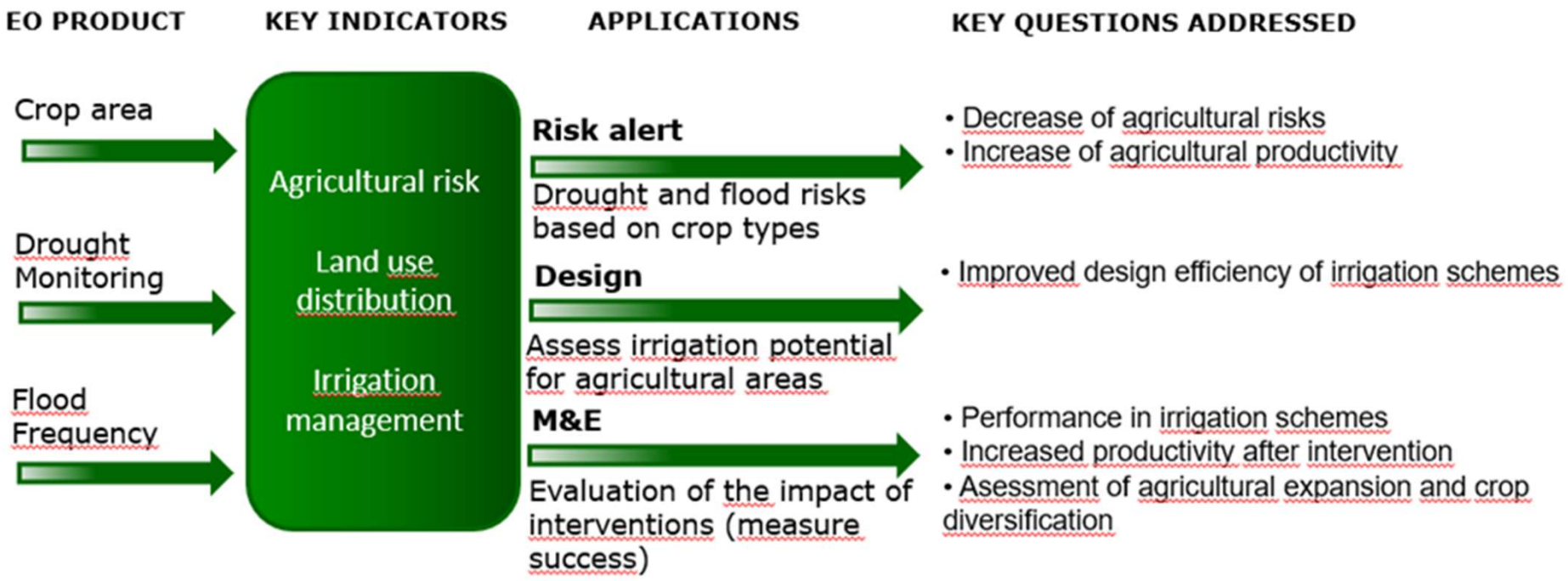


Service fact sheet

EO product	Cultivated area	Soy area	Deforestation	Land cover
Detail	medium/high	medium/high	medium/high	medium/high
Period	Historic / NRT	Historic / NRT	Historic / NRT	Historic / NRT
Frequency	monthly/quarterly/yearly	monthly/quarterly/yearly	monthly/quarterly/yearly	monthly/quarterly/yearly
Delivery type	Table/map/graph/report	Table/map/graph/report	Table/map/graph/report	Table/map/graph/report
Source	Open/Commercial	Open/Commercial	Open/Commercial	Open/Commercial
Cost range (USD)	0,5 - 2,5 $ / km2 / year	0,5 - 2,5 $ / km2 / year	0,5 - 2,5 $ / km2 / year	0,5 - 2,5 $ / km2 / year

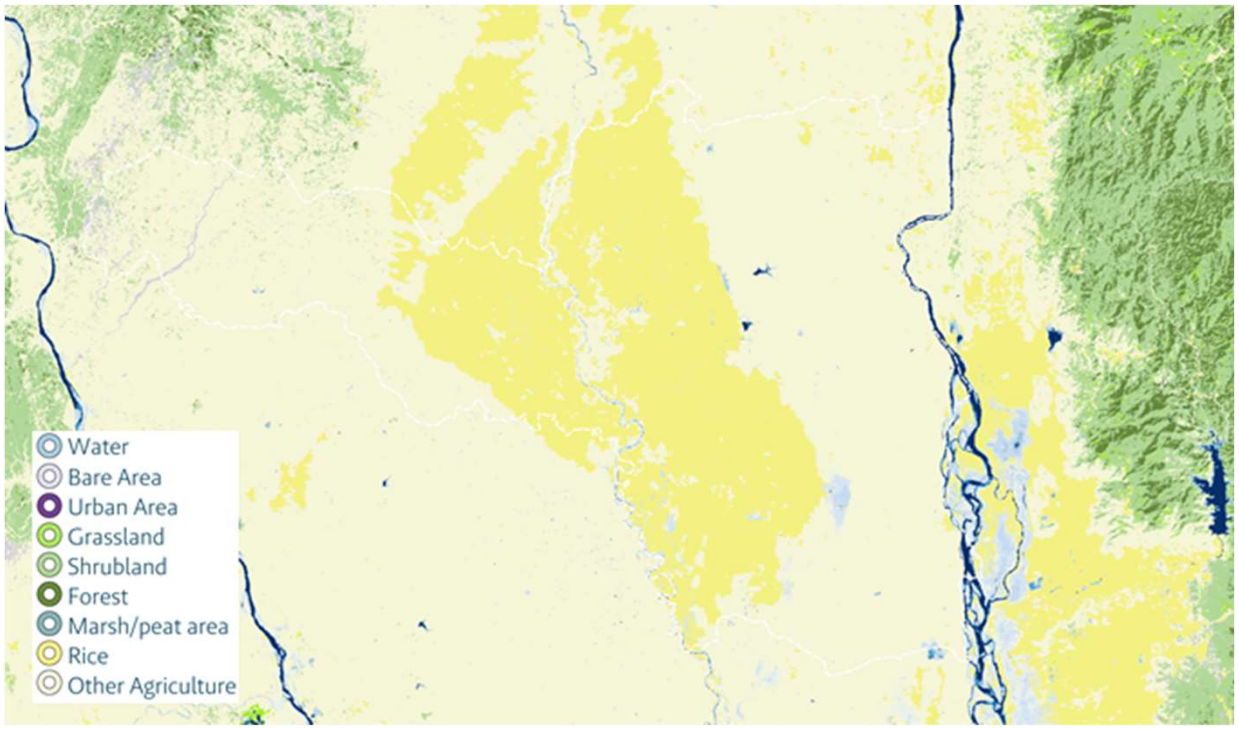
EO indicator	Deforestation impact	Land use distribution
Detail	medium/high	medium/high
Period	Historic / NRT	Historic / NRT
Frequency	monthly/quarterly/yearly	monthly/quarterly/yearly
Delivery type	Table/map/graph/report	Table/map/graph/report
Source	Open/Commercial	Open/Commercial
Cost range (USD)	0,5 - 2,5 $ / km2 / year	0,5 - 2,5 $ / km2 / year

Irrigational development and increased agricultural productivity



Related demonstrations:	
Myanmar	Irrigated Agriculture Inclusive Development Project (Asian Development Bank) Agricultural Development Support Project (World Bank)

Crop area and crop pattern



Content

- Basic land cover
- Crop type
- Crop intensity

Geographic coverage

- Central Dry Zone Myanmar

Temporal coverage

- Seasonal 2016 - 2018

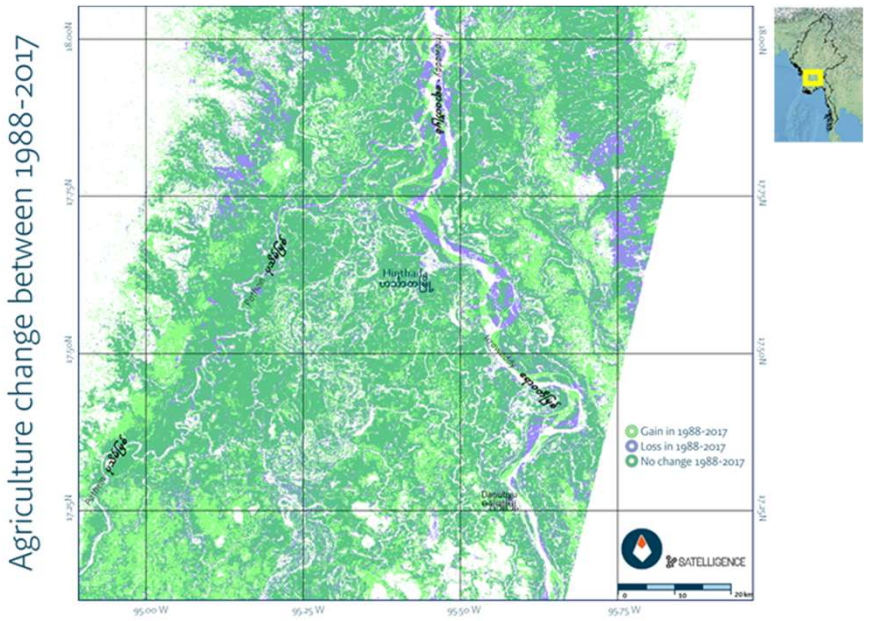
Spatial resolution

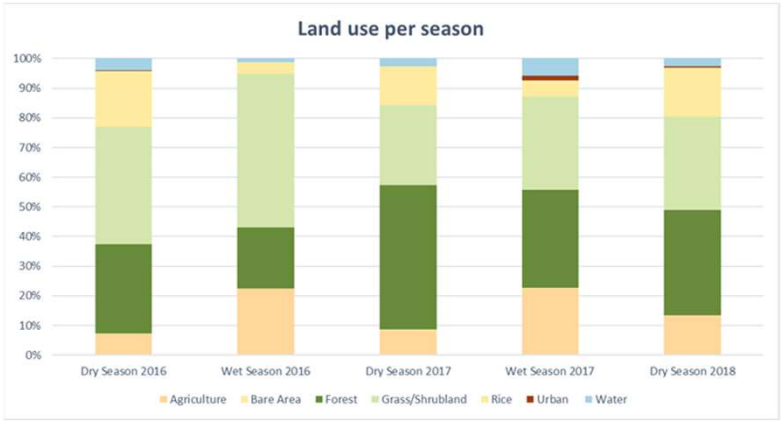
- 10 - 30m

Limitations

- Cloud cover and temporal gaps
- Ground truth availability

Crop area and crop pattern





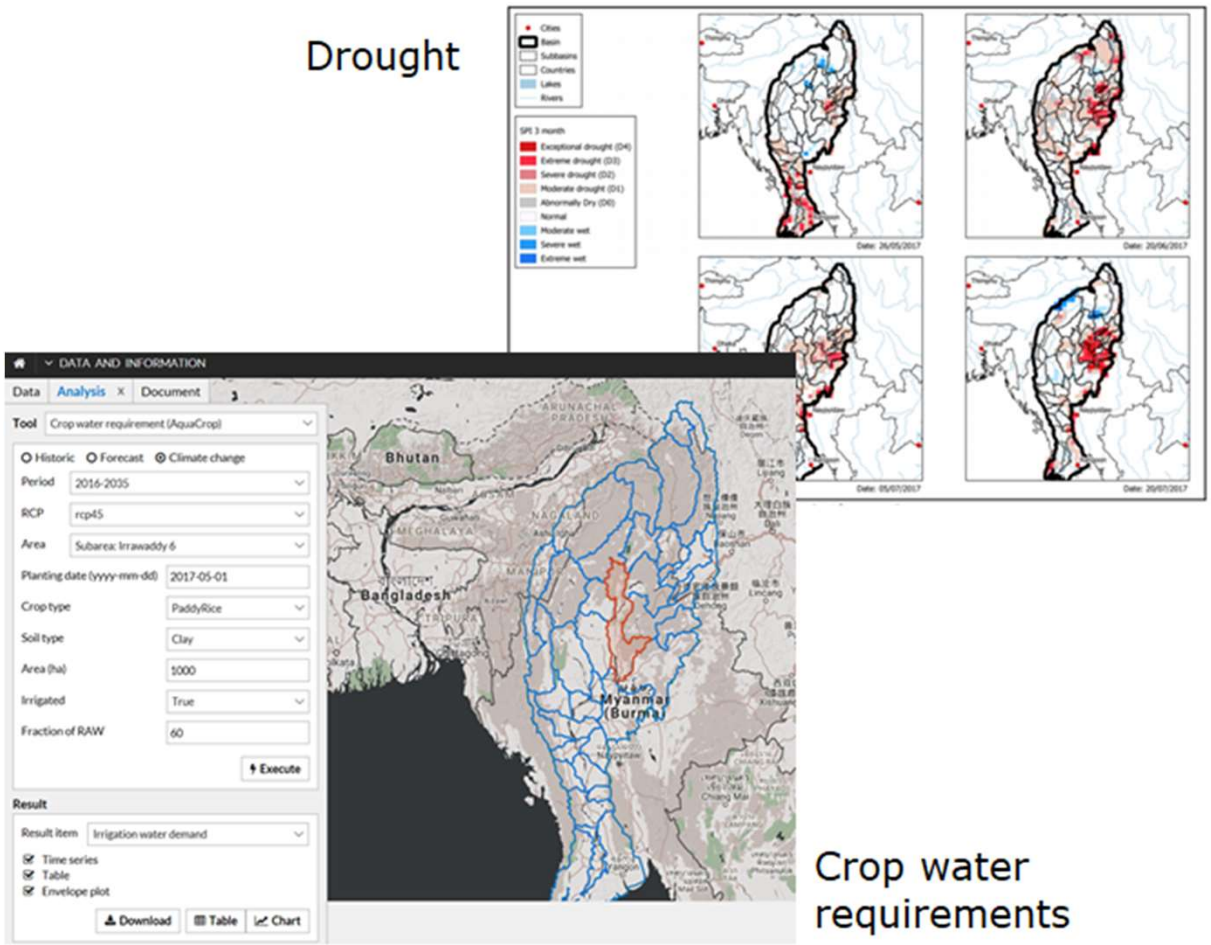
Benefits

- Improved accuracy through the combination of optical & SAR imagery
- High resolution (10 - 30m)
- Monitoring intra-annual changes on a large scale

Impacts

- Contribute to a better understanding of the ongoing changes in crop type and pattern distribution, including crop intensity; help assess planned crop diversification and increase in irrigated areas; support improved seed supply and extension of good agricultural practices.
- Improved extension services, increased crop productivity and poverty reduction.

Crop area and crop pattern



Content

- Monitoring of drought and crop water stress and requirements as input for irrigation management

Geographical coverage

- Central Dry Zone Myanmar

Temporal coverage

- Weekly to Monthly 2017 – 2019

Spatial resolution

- Blend (250 – 5000m)

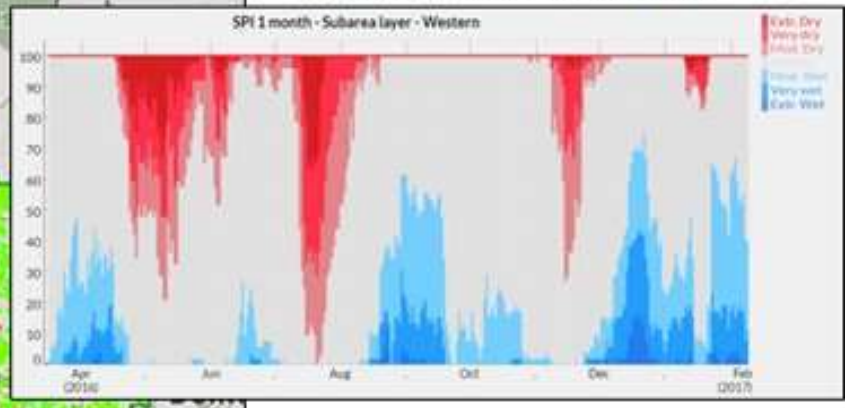
Limitations

- Validation of crop water requirements require in-situ observations at specific locations.

Drought monitoring and crop water requirements

Vegetation Health Index based on NDVI and temperature

Temporal variation of SPI 1-month based on rainfall



Crop water requirement (current and forecasted)

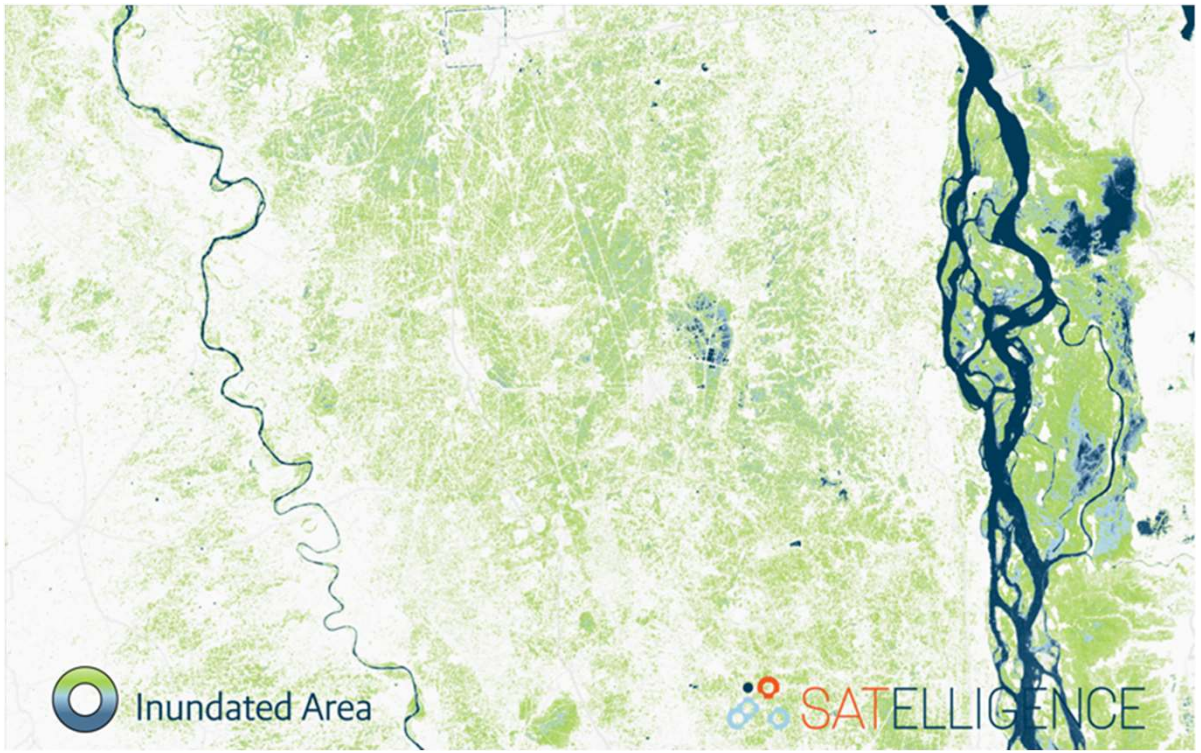
Benefits

- Freely available web based portal
- The system is implemented with focus on national and regional catchments (250 – 5000m), but could later be extended with high resolution data.

Impact

- Specific utilization of satellite data providing added value for national stakeholders and decision makers

Flood frequency



Content

- Flood frequency supports development of agricultural risk management plans. When overlaid with maps of agricultural areas and critical (irrigation) infrastructure the historical flood maps can be used for impact and vulnerability assessments.

Geographical coverage

- Central Dry Zone Myanmar

Temporal coverage

- Historical surface water 1980 – 2015
- Seasonal 2015 - 2018

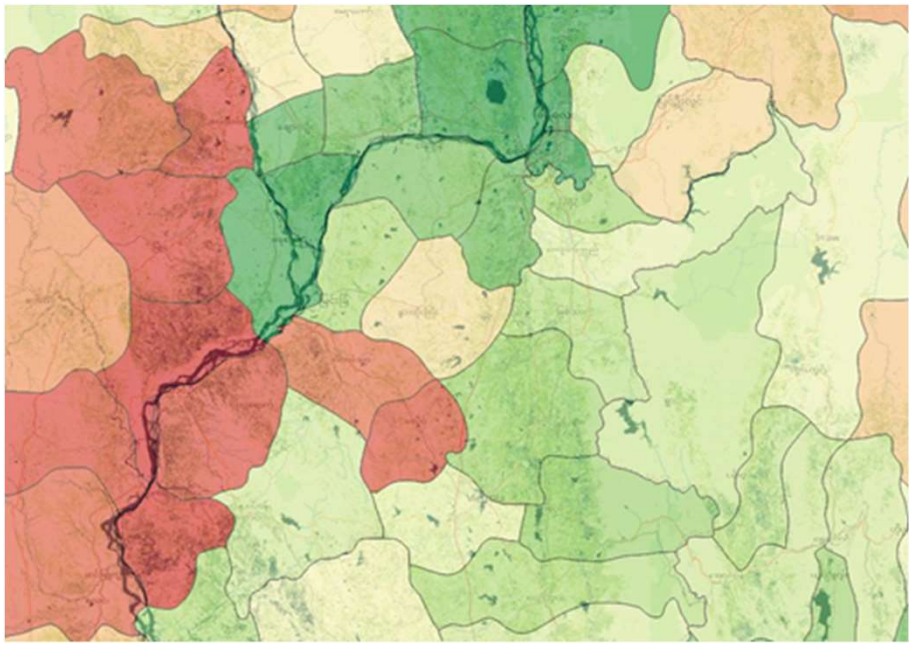
Spatial resolution

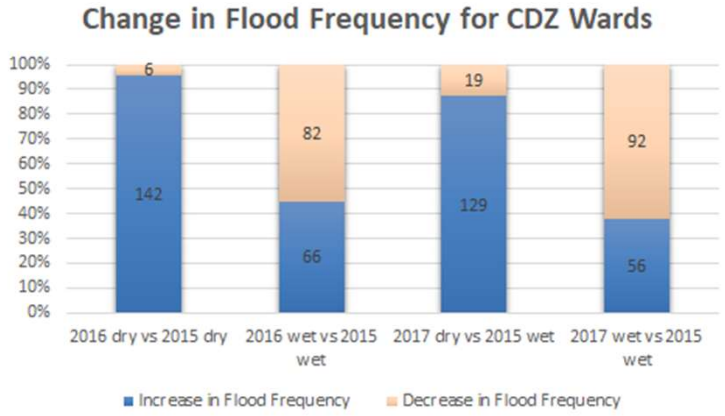
- 10 – 30m

Limitations

- Cloud cover and temporal gaps

Flood frequency





Benefits

- Multi-sensor approach allows for frequent information on flooding
- Improved accuracy through the combination of optical & SAR imagery
- High resolution

Impacts

- Allows detection of smaller than before water bodies
- Provides information on spatial and recurrence changes over time

Service fact sheet

EO product	Crop area and crop pattern	Drought monitoring and crop water requirements	Flood frequency
Detail	medium/high	low/medium (high possible on request	medium/high
Period	Historic / NRT	Historic / NRT / Forecast	Historic / NRT
Frequency	monthly/quarterly/yearly	daily/weekly/monthly	monthly/quarterly/yearly
Delivery type	Table/map/graph/report	Web based portal	Table/map/graph/report
Source	Open/Commercial	Open/Commercial	Open/Commercial
Cost range (USD)	0.5 - 2,5 $ / km2 / year	On request	0.5 -2,5 $ / km2 / year

EO indicator	Risk alert	Design	M&E
Detail	medium/high	medium/high	medium/high
Period	Historic / NRT / Forecast	Historic / NRT / Forecast	Historic / NRT
Frequency	daily/weekly/monthly/quarterly/ yearly/customized	quarterly/yearly	daily/weekly/monthly/quarterly/ yearly/customized
Delivery type	Table/map/graph/report/web based portal	Table/map/graph/report/web based portal	Table/map/graph/report/web based portal
Source	Open/Commercial	Open/Commercial	Open/Commercial
Cost range (USD)	0,5 - 2,5 $ / km2 / year, on request	0,5 - 2,5 $ / km2 / year	0,5 - 2,5 $ / km2 / year

Round table questions

- Evaluate requirements for successful embedment of EO services in the project cycle
- Discuss opportunities in upcoming projects and programmes for EO services
- Discuss what additional support from EO specialists is required
  - Access to (demo)services
  - Project preparation
  - Capacity building

agriculture and rural development
eo4sd

Thank you!

For more information
http://eo4sd.esa.int/agriculture
http://eo4sd.Lizard.net