Geospatial technology in the food supply chain

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Geospatial Knowledge Infrastructure training

May 9, 2022

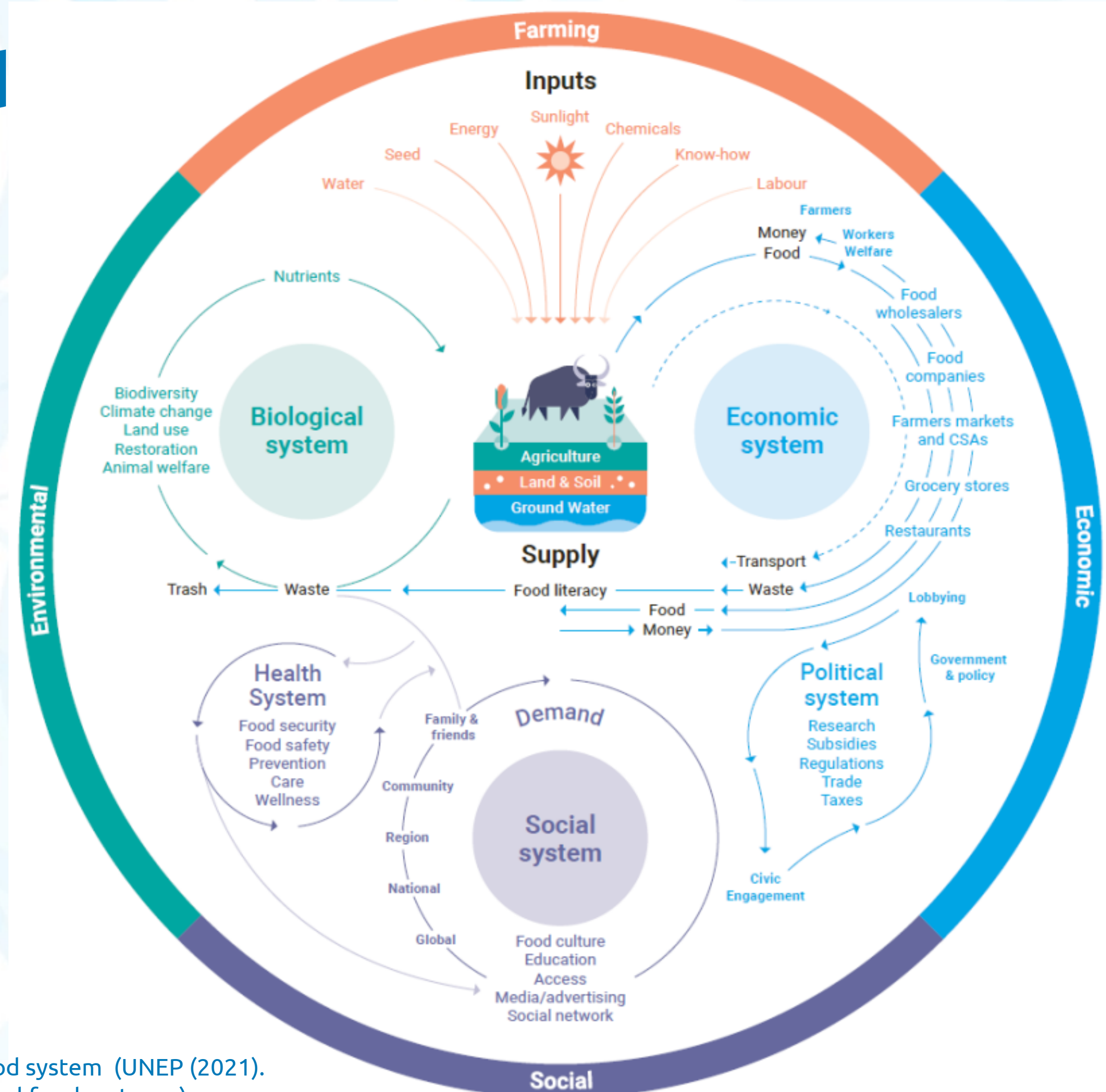
The dream:

On-farm measurements of weather, soil moisture & soil fertility

- New developments with low-cost sensors
- Calculated @ 10 US$/month for a smallholder farmer with 1.0 – 1.5 ha (sharing with 10 – 15 farmers)

Credit for discussion: Unni Nair (Bayer Asia – Pacific), Frank Annor (TAHMO)

The food system



Schematic of the global food system (UNEP (2021). The role of business in global food systems.)

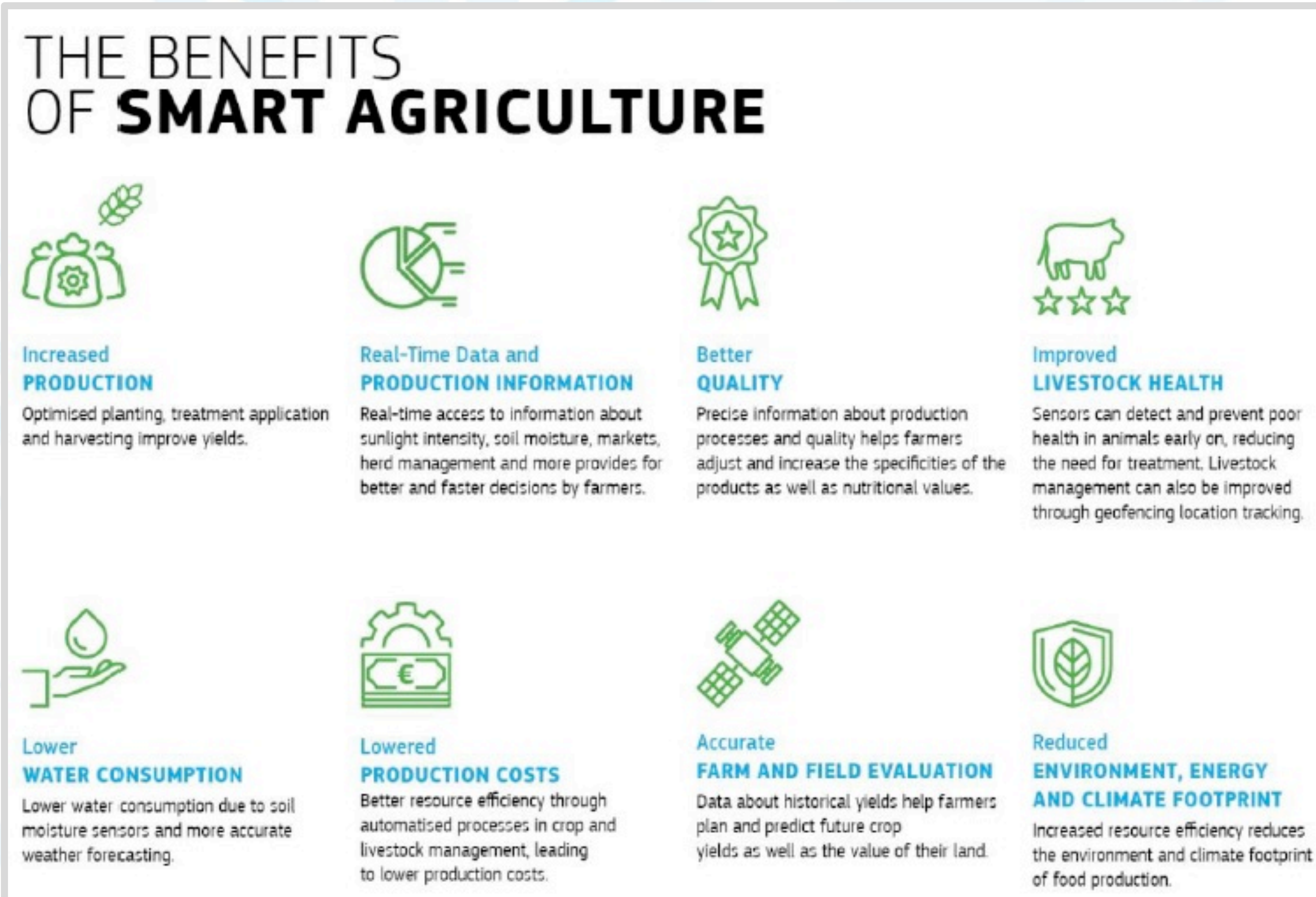
Factors to take into account related to achieving food security for future generations

- Population growth: the 70% increase in production will have to be achieved, while the available agricultural land has is declining: from 0,5 ha per capita in 1960 to 0.23 ha per capita in 2012 (partly caused by urbanisation, but mainly by population growth);
- Urbanisation: around 70% of the world population is expected to be urban by 2050;
- Food losses: roughly one-third of the food produced in the world every year, or approximately 1.3 billion ton, gets lost or wasted;
- Climate change: conditions for agriculture may improve in some places and deteriorate in others, while changes in the frequency and severity of droughts and floods pose great challenges.
- Scarcity of resources: intensification and expansion of agriculture may lead to soil erosion, land degradation and unsustainable use of water resources.

Source: FAO; 2017

Challenges

1. Sustainably improving agricultural productivity to meet increasing demand
2. Ensuring a sustainable natural resource base
3. Addressing climate change and intensification of natural hazards
4. Eradicating extreme poverty and reducing inequality
5. Ending hunger and all forms of malnutrition
6. Making food systems more efficient, inclusive and resilient
7. Improving income earning opportunities in rural areas and addressing the root causes of migration
8. Building resilience to protracted crises, disasters and conflicts
9. Preventing transboundary and emerging agriculture and food system threats
10. Addressing the need for coherent and effective national and international governance



The benefits of smart agriculture. (European Commission (2017). The future of food and farming. (Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions.)

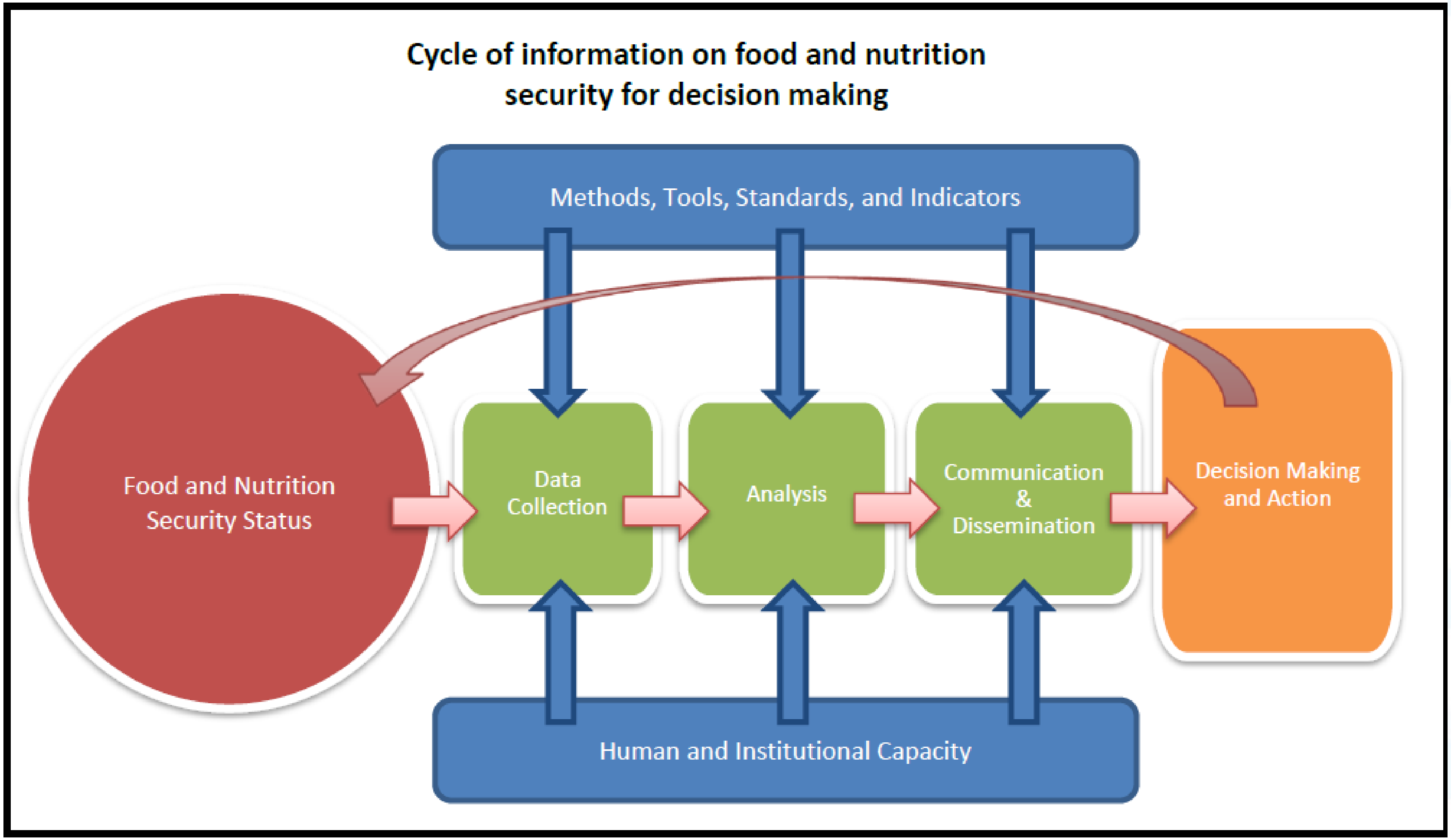
A Sustainable intensification of agriculture

B Land-management tools and appropriate land-use policies

are required to ensure food supplies

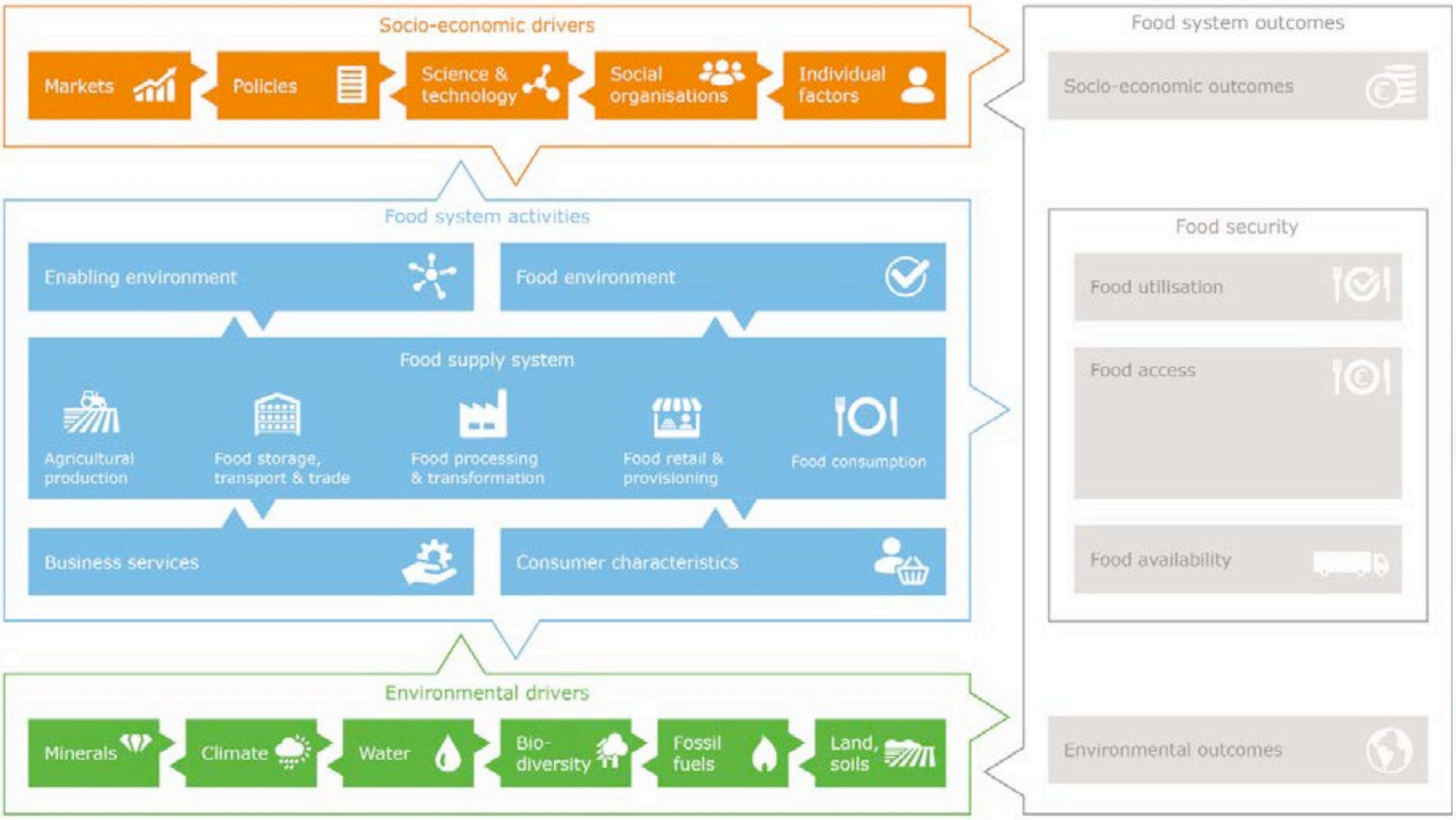
C Accurate data on agricultural production (area, yields, location) and food prices

help planning, competition and more stable pricing



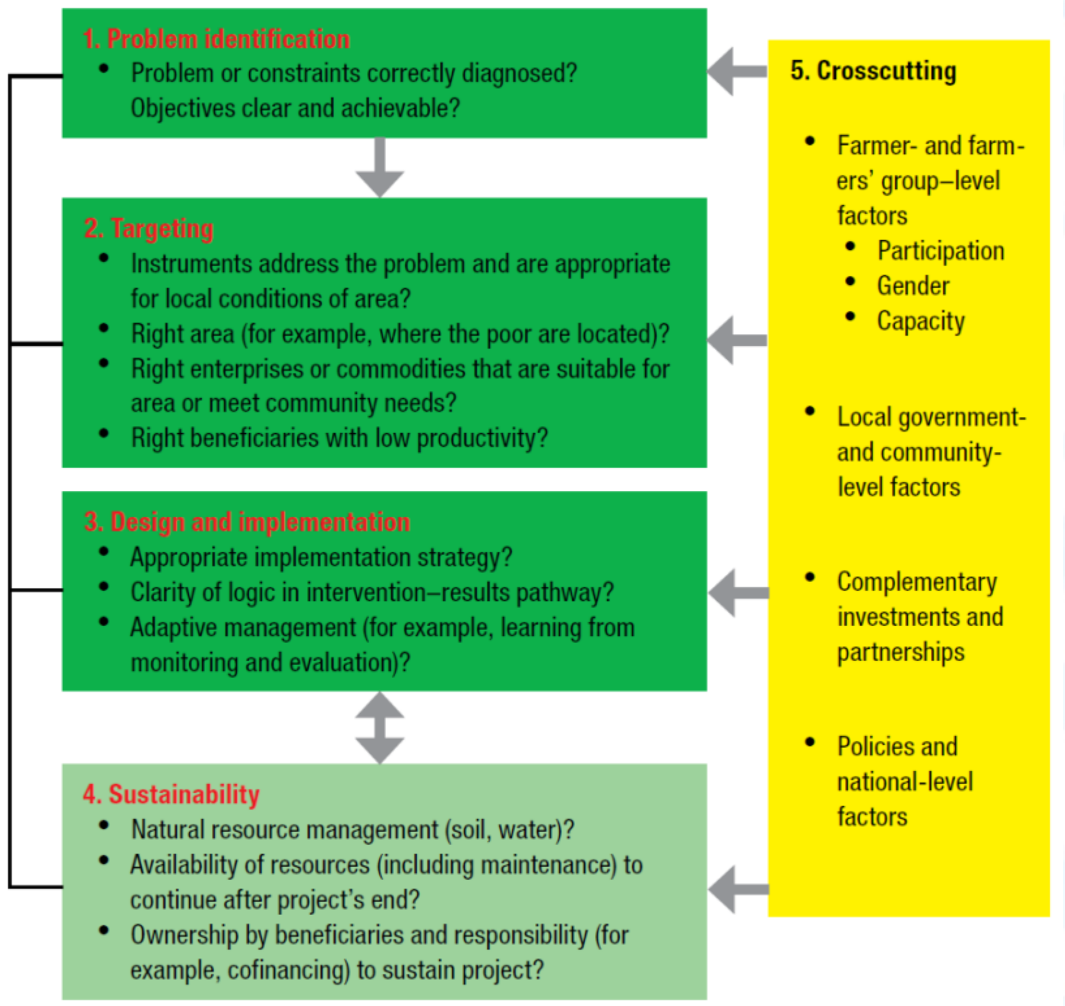
Cycle of information on food and nutrition security for decision making. (FSIN (2013). FSIN landscape of key actors producing and sharing information for food and nutrition security – Global overview.)

Food system drivers



A way of mapping the relationships of the food system to its drivers (Berkum, S. van, et al. (2018). The food systems approach: sustainable solutions for a sufficient supply of healthy food. WUR.)

Agricultural productivity-enhancing interventions

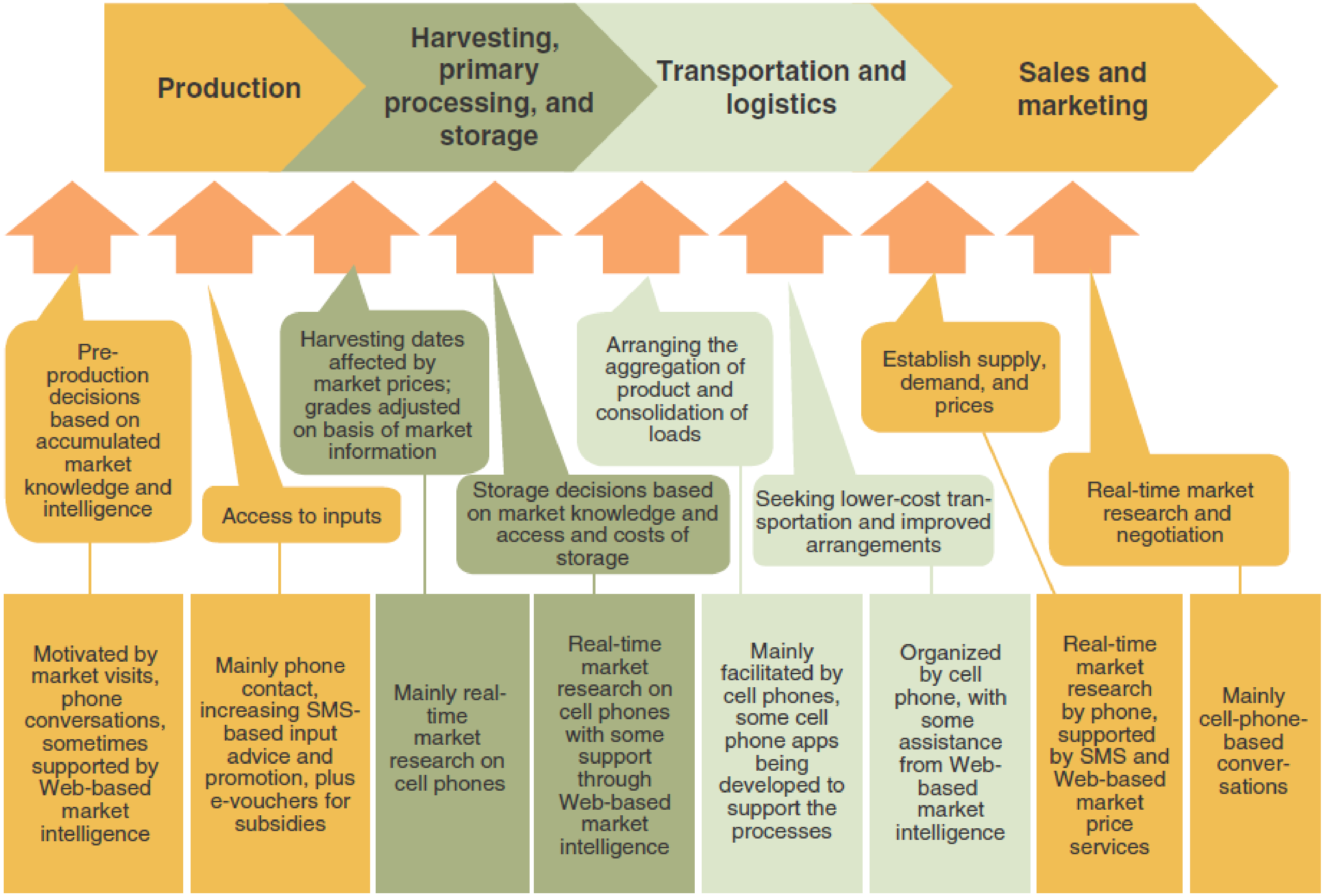


Factors influencing the success or failure of agricultural productivity-enhancing interventions (Breman, H. et al. (2019). From fed by the World to food security – Accelerating agricultural development in Africa. Wageningen University.)

Types of intervention in farming

- Information systems
- ICT-enabled learning & knowledge exchange
- Modelling solutions
- Sensory & proximity devices
- ICT-enabled networking solutions
- Online commerce tools

ICT in agriculture



ICT input for marketing along the agricultural value chain. (World Bank (2017). ICT in agriculture – Connecting smallholders to knowledge, networks and institutions. e-Sourcebook.)

Why are digital solutions and agriculture data (D4Ag) potentially so transformative? (1)

For farmers they offer:

- Access to tailored information and insights that allow individuals to optimise their production
- Access to appropriate products and services
- Exploration of new linkages with markets

D4Ag provides enterprises deeper understanding of their target segments, allowing them to better tailor their interventions to the needs of smallholder farmers.

Source: (CTA (2019). The digitalisation of African agriculture – Report 2018 – 2019. Dalberg.)

Why are digital solutions and agriculture data (D4Ag) potentially so transformative? (2)

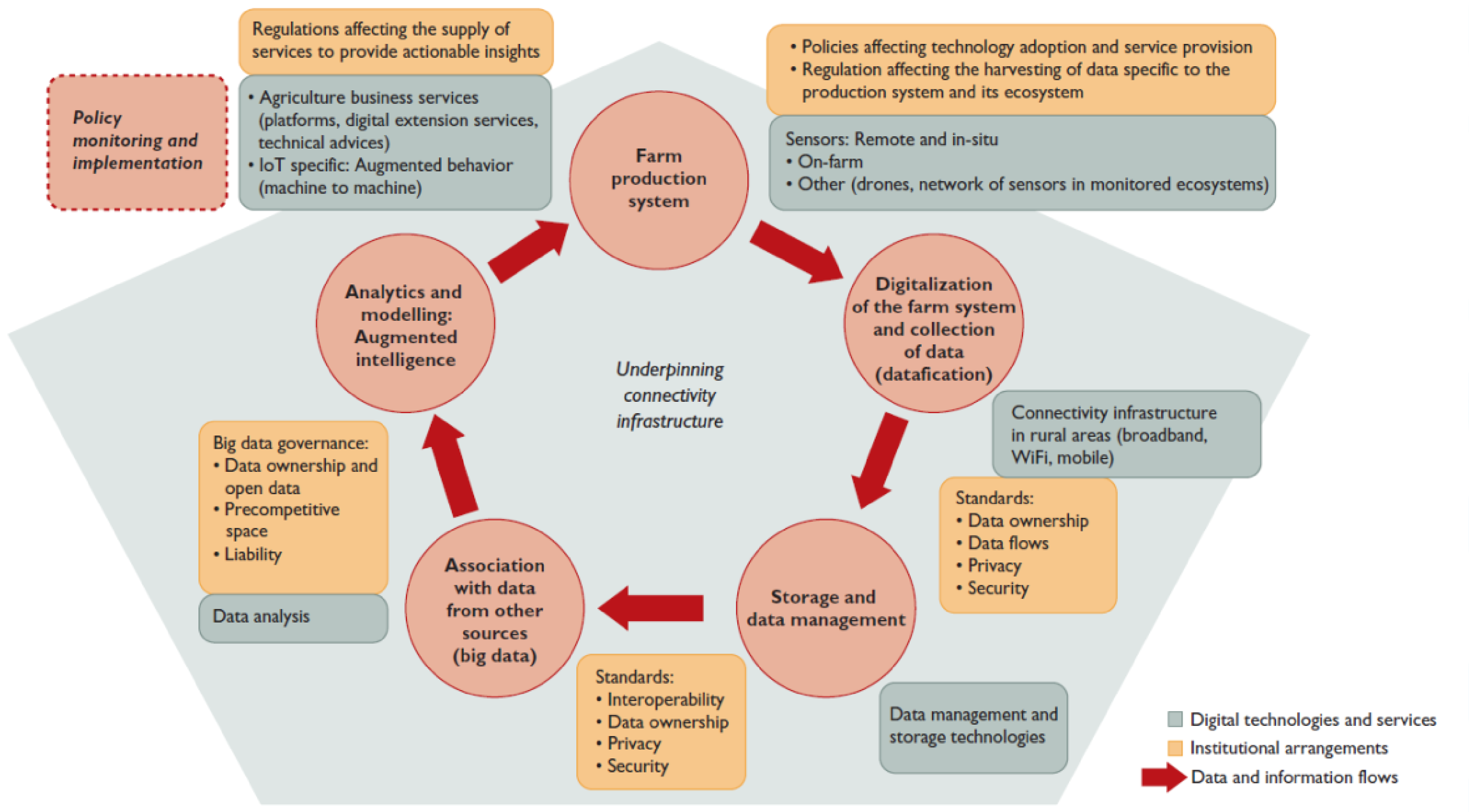
Governments, likewise, can use improved understanding of farmer segments to improve macro- decision policy-making, as well as the design and implementation of their programmes.

The result – if fully implemented at scale – would be a highly connected, intelligent, real-time agricultural ecosystem that is vastly more productive, efficient, and transparent than ever before. The growing quantity and quality of agricultural data and digital agricultural solutions significantly reduce the costs of service, inputs, and information delivery for farmers and other value chain intermediaries. This enables them to productively transform their traditional business models.

D4Ag is not a replacement for physical infrastructure, human networks and human interaction.

Source: (CTA (2019). The digitalisation of African agriculture – Report 2018 – 2019. Dalberg.)

Data infrastructure for agriculture



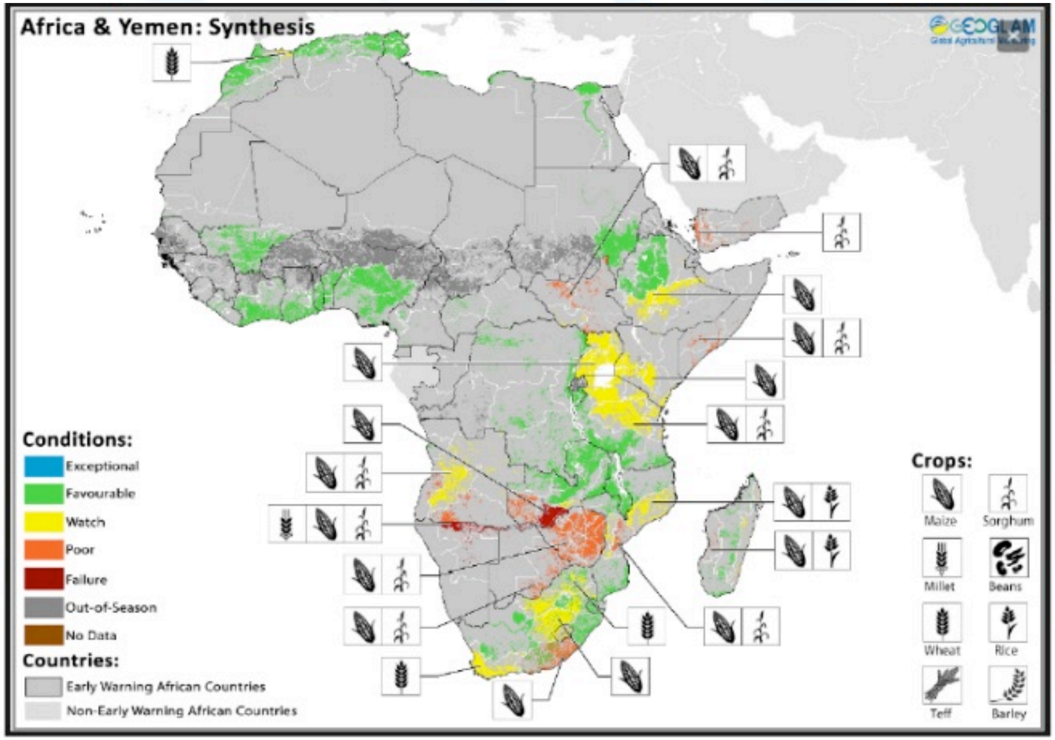
The data infrastructure for agriculture. (Schroeder, K. et al. (2021). What's cooking: Digital transformation of the agrifood system. World Bank.)

General food security monitoring (GEOGLAM)

A global community effort to produce relevant, timely and accurate projections of agricultural production at national, regional and global scales.

Food security monitoring for

- Wheat
- Maize
- Soybeans
- Rice



GEOGLAM Global Agricultural Monitoring

General food security monitoring (GEOGLAM)

Focus on

- Information for policy and decision making
- Increase of production and productivity
- Risk reduction
- Anticipation of future trends, including adaptation to climate change

GEOGLAM
Global Agricultural Monitoring

Advantages satellite information

- Repeated coverage of large areas (including places that are difficult to reach)
- Reasonably accurate, geo-located information
- Huge amounts of satellite data are becoming available free of charge

Some possible complications for the use of satellite data for agriculture

- Very High Resolution (VHR) imagery is costly – needed for precision agriculture (machine guidance, etc.)
- The appropriate data may not be available for / at the right time and / or place
- The processing of data and the transformation of data into actionable information depends on the work of specialists
- Validation and calibration on the ground is needed

New opportunities on the horizon

- For a long time the application of solutions involving satellite data was considered only appropriate for large, commercial farms
  - machine guidance
  - where and when to use which fertiliser
  - where and when to irrigate
  - early detection and advice on dealing with pests and diseases

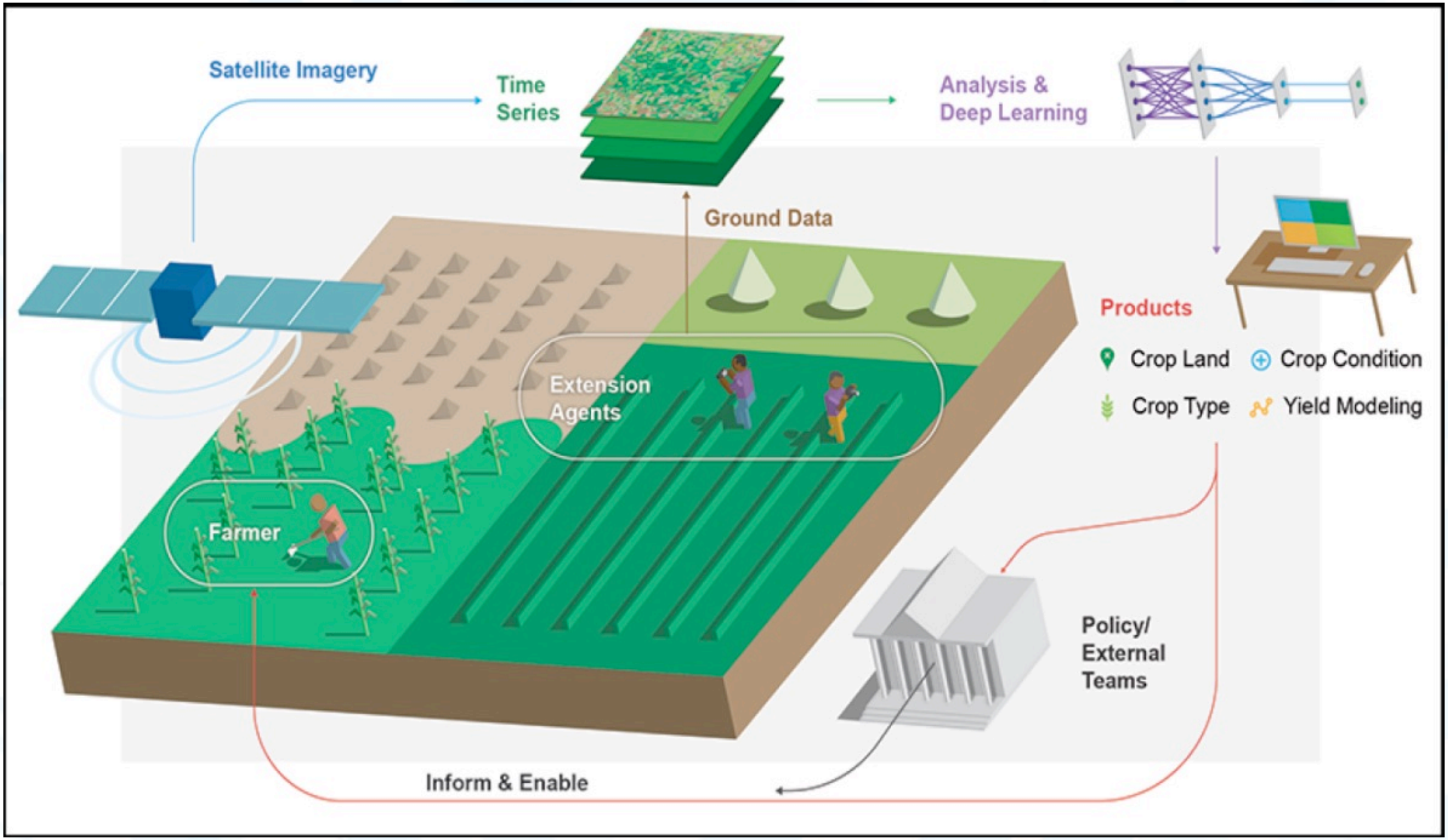
- Thanks to advances in mobile communication, availability of free data and innovation programmes, such as the Geodata for Agriculture (G4AW) Facility, satellite applications have become feasible for smallholders in developing countries

Source: STARS; 2016

Examples of opportunities

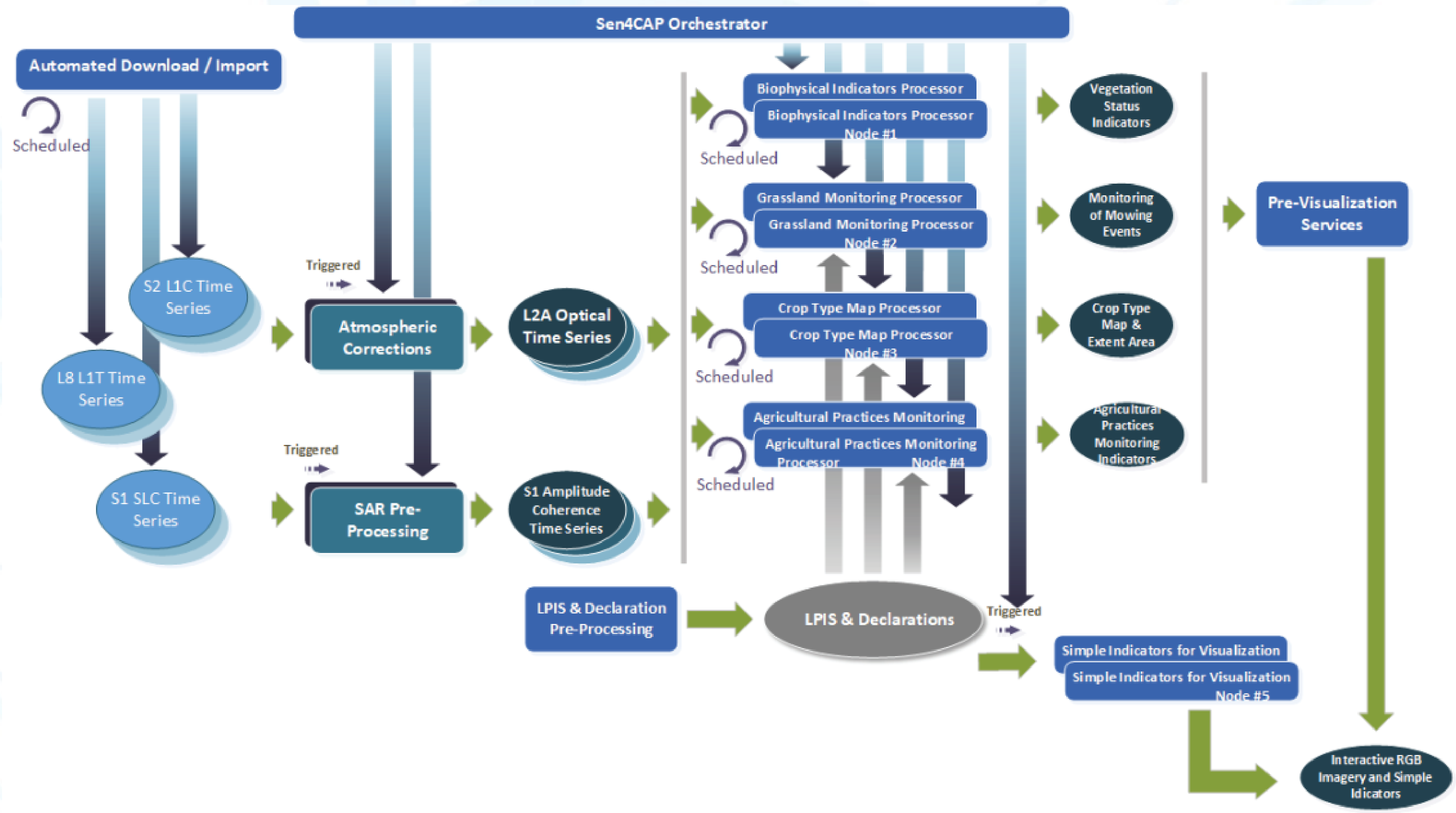
- Establishment of cartographic baselines
- Online remote sensing data services
- Improved soil and land information
- Improved access to weather forecasts and drought information
- Better administrative systems for land tenure
- Agricultural statistics for national decision making
- Water resource information to support micro-scale irrigation
- Close yield gaps in market-oriented family farming
- Development of index-based insurance products

Satellite imagery for agriculture



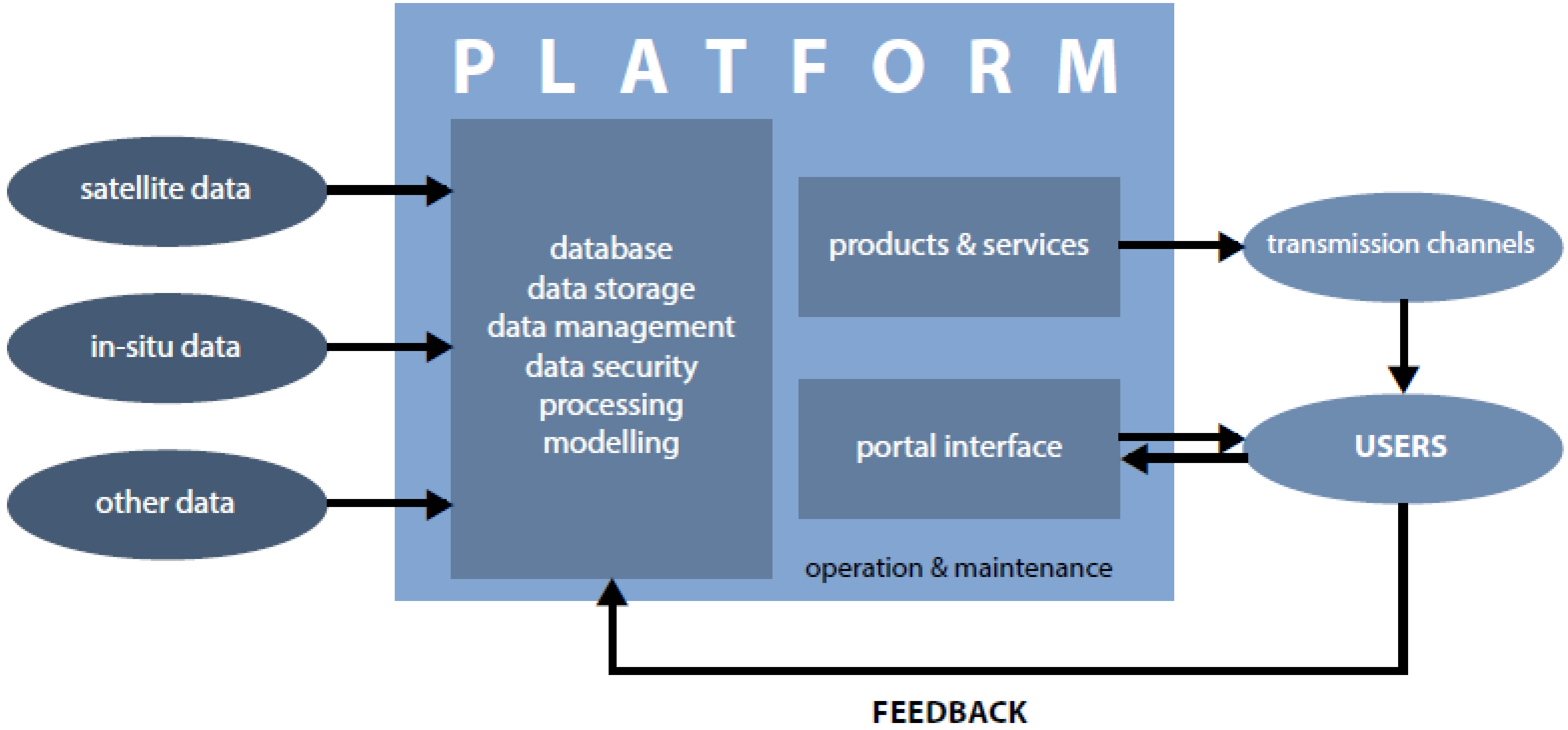
Sowing seeds of food security in Africa. (Nakalembe, C. et al. (2021). Eos Science Update.)

Data flow Sen4CAP



Logical data flow of the Sen4CAP Earth Observation processing system (Sen4CAP (2019). Sentinels for Common Agricultural Policy.)

Platform and services for smallholders



Source: NpM; 2018

Combination matrix

Clusters of geodata services contributing to inclusive finance

	Agricultural performance	Risk management	Historical records	Support financial operations
Weather-related	X	X	X	
Crop monitoring and advice	X		X	X
Location-based				X
Disaster-related		X		

Source: FAO;2018

20 Actions for transforming food & agriculture to achieve the SDGs

1. Facilitate access to productive resources, finance and services
2. Connect smallholders to markets
3. Encourage diversification of production and income
4. Build producers' knowledge and develop their capacities
5. Enhance soil health and restore land
6. Protect water and manage scarcity
7. Mainstream biodiversity conservation and protect ecosystem functions
8. Reduce losses, encourage reuse and recycle, and promote sustainable consumption
9. Empower people and fight inequalities
10. Promote secure tenure rights

next 10 actions on the next slide >>>>

Source: FAO; 2018

20 Actions for transforming food & agriculture to achieve the SDGs

11. Use social protection tools to enhance productivity and income
12. Improve nutrition and promote balanced diets
13. Prevent and protect against shocks: enhance resilience
14. Prepare for and respond to shocks
15. Address and adapt to climate change
16. Strengthen ecosystem resilience
17. Enhance policy dialogue and coordination
18. Strengthen innovation systems
19. Adapt and improve investment and finance
20. Strengthen the enabling environment and reform the institutional framework

Main benefits of the use of Earth observation for the SDGs

Improved process control

- Improved vulnerability assessment
- Earlier identification of threats and potential risks
- Reduction of damage and lives lost (estimated at 10% of total potential loss)
- Improved preparedness; reduction of incidences and loss of life
- Coverage of unsafe and/or inaccessible areas
- Increased detection rate (of illegal activities)
- Improved compliance

Main challenges for the use of Earth observation for the SDGs

Data-related

- High or sufficient resolution imagery (spatial resolution)
- High frequency imagery (temporal resolution)
- Affordable data and data processing
- In-situ validation
- Additional in-situ data
- Additional data on population, health services and education
- Time series

Main requirements for the use of Earth observation for the SDGs

Knowledge and skills-related

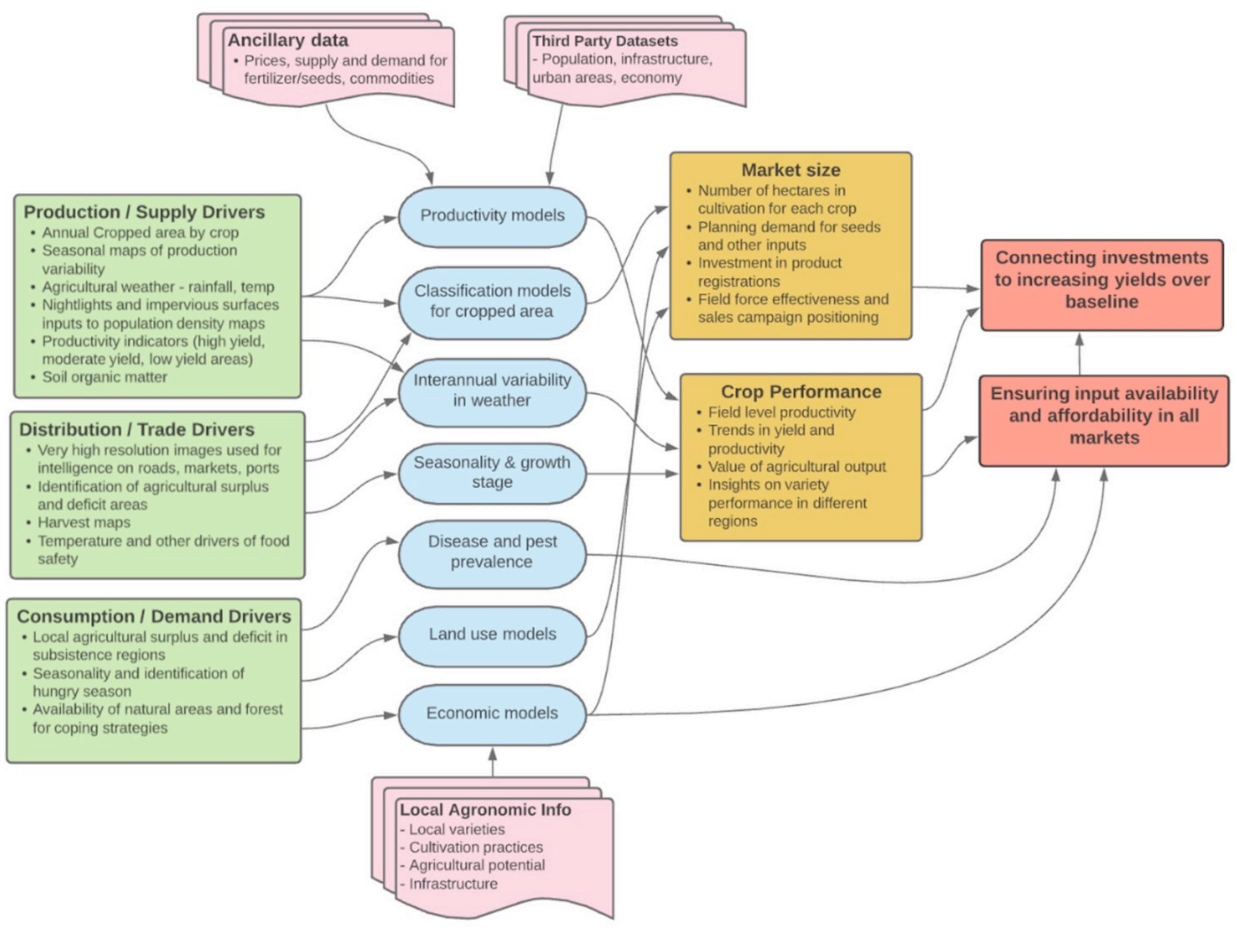
- Further development
- Expert knowledge

Marketing-related

- Increased cooperation with other actors, including aggregators
- Scaling up
- Buy-in of stakeholders
- Advocacy

Drivers, models and indicators that result in business metrics that can measure the impact of investment in SDG2 goal attainment

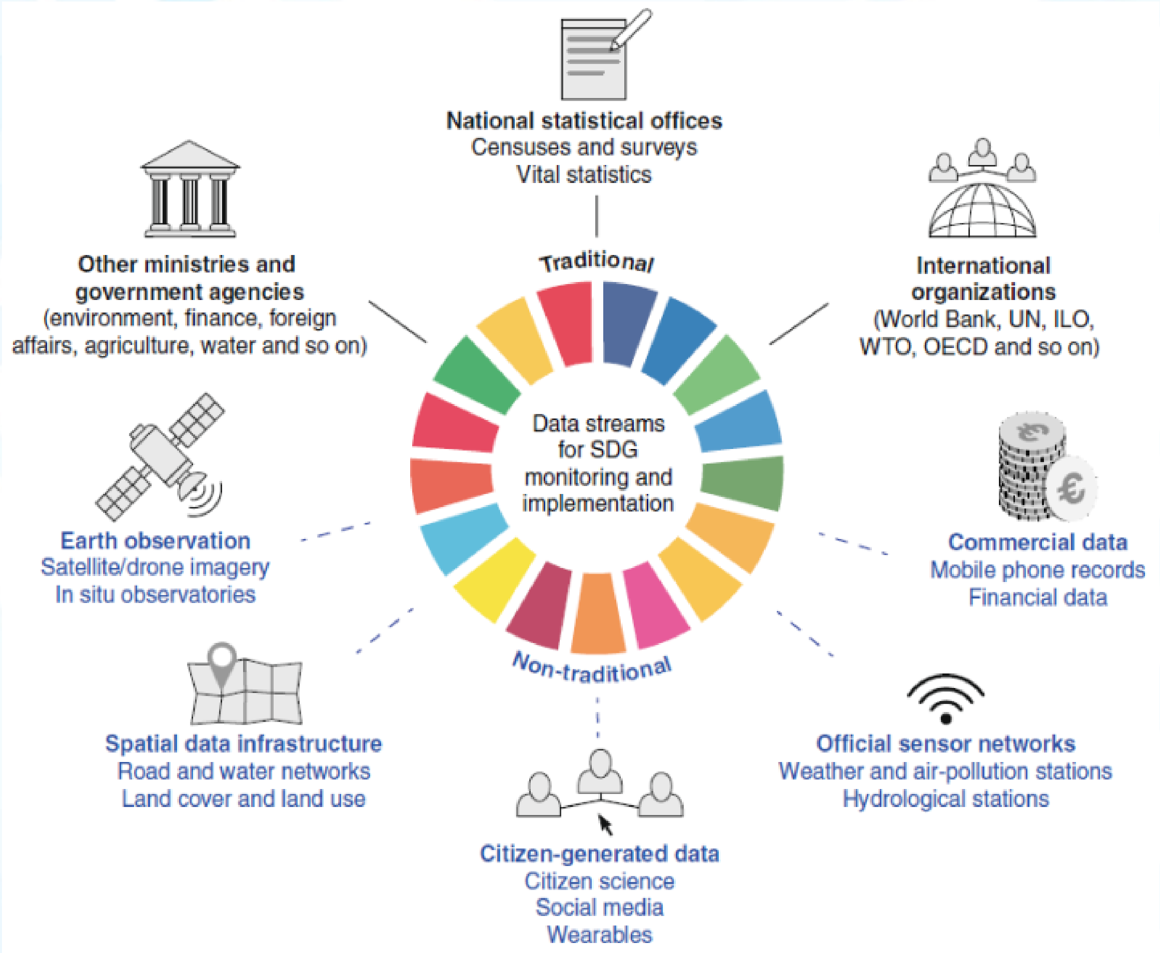
(shown in red boxes)



Brown, M.E. (2021). Metrics to accelerate private sector investment in Sustainable Development Goal 2—Zero hunger. Sustainability.

Traditional and non-traditional data available for SDG monitoring and implementation

(Traditional and non-traditional data sources are shown in black and blue, respectively)



Fritz, S. et al. (2019). Citizen science and the United Nations Sustainable Development Goals. Nature Sustainability.

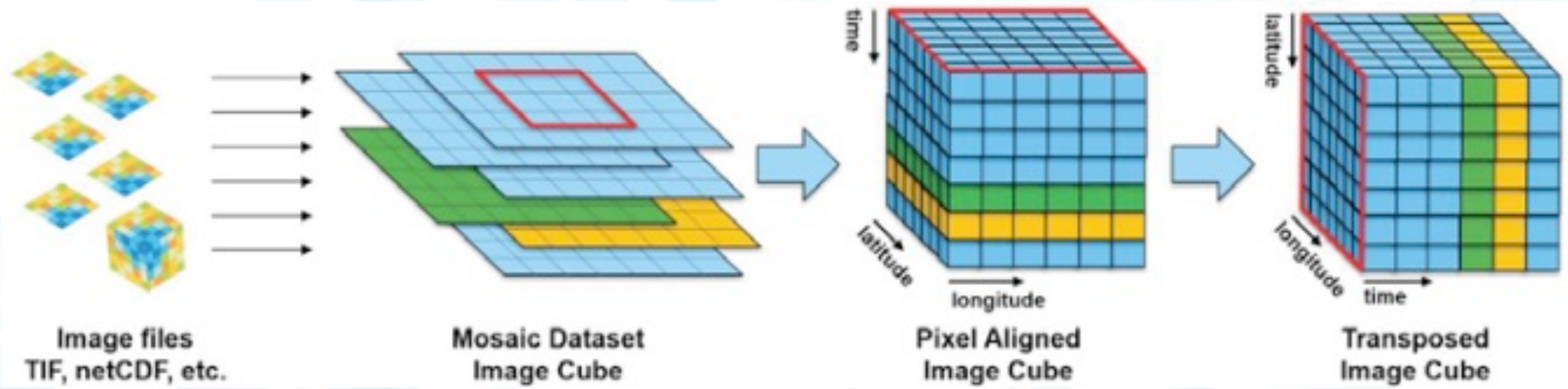
Open data cubes

Time-series multi-dimensional (space, time, data type) stack of spatially aligned pixels ready for analysis:

- Expanded use of satellite data
- Reduced data preparation burden
- Enables data interoperability
- Efficient time series analysis
- Free and open access
- Flexible deployment (local or cloud)
- Use of a common architecture
- Community development and sharing

Check out Digital Earth Africa: https://www.digitalearthafrica.org/

Killough, B. (2017). Open data cubes - A big data solution for global capacity building..

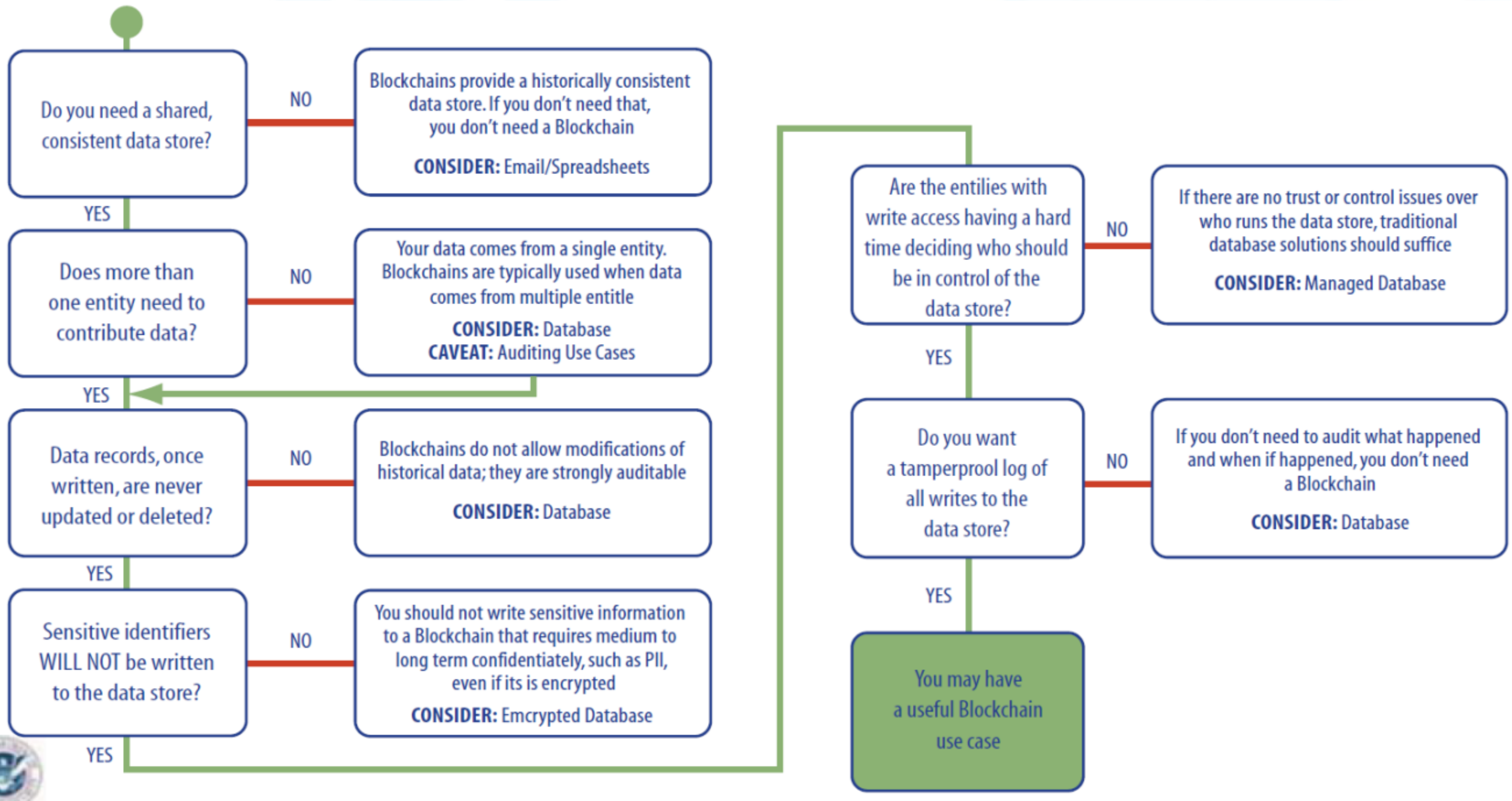


A collection of georeferenced images with time stamps can be organized for easier access as a mosaic dataset image cube. To simplify usage and improve performance the data can be processed into a pixel aligned image cube.

Optimal performance for temporal queries can be achieved by transposing the data storage along the time dimension.

Kopp, S. et al. (2020). Achieving the full vision of Earth observation data cubes (from: Giuliani, G. et al. (eds.) (2020). Earth observation data cubes.)

How to make a decision about using blockchain or a database



FAO / ITU (2019). E-agriculture in action: Blockchain for agriculture – Opportunities and challenges.

The key drivers of change in the data economy impacting the Earth observation market include:

- Rise of the platforms: leveraging cloud computing infrastructure and stimulating applications development.
- Data as a Service: user manages the application, everything else is delivered as a service.
- Open data policies: demand from users and government policies changing towards improved access to data and tools.
- New business models: people can easily gain access to and use a multitude of data analysis services quickly.
- Sensor use growing: IoT (internet of things) and sensors intelligently working at the edge of networks, the complementarity of spaceborne and terrestrial data.
- Crowdsourcing: citizen science platforms and their commercial capability.
- Disruptive innovation: introduces a new value proposition. They either create new markets or reshape existing ones.

Source: GEO data and technology workshop (2019)

Climate change: Possible negative effects for food security

A. Reduced production
B. Leads to reduced availability of food
C. Leads to increased prices
D. Leads to food insecurity

Source: FAO; 2013

Climate-smart adaptation measures that benefit from the use of geodata

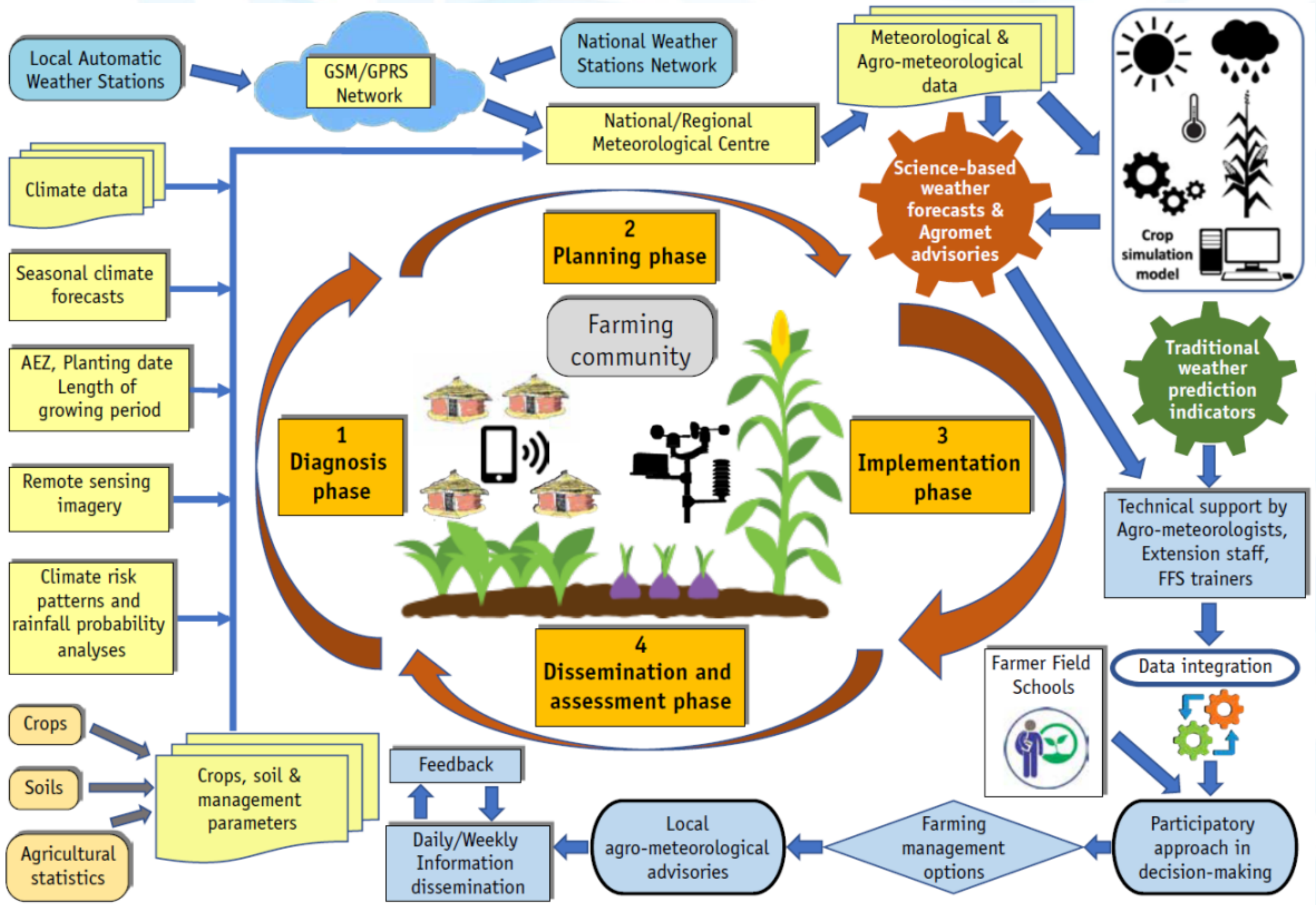
- Crop residue management: no-till/minimum tillage, cover cropping, mulching
- Nutrient management: composting, appropriate fertilizer and manure use, precision farming
- Soil management: crop rotation, fallowing (green manures), intercropping with leguminous plants, conservation tillage
- Grazing management: adjust stocking densities to feed availability; rotational grazing
- Water use efficiency & management: supplemental irrigation/water harvesting, irrigation techniques to maximize water use efficiency (amount, timing, technology), modernization of irrigation infrastructure, modification of cropping calendar
- Policy-related: crop insurances, improved weather forecasting, improved hydrological modelling, improved drought & flood forecasting & monitoring capacity

Key decision points impacted by climate information

KEY DECISION POINTS	KEY CLIMATE VARIABLE THAT INFORMS THE DECISIONS
Sowing period	Onset of monsoon
Choosing of crops/crop variety	Total rainfall forecast and its intra-seasonal distribution
Irrigation management – in terms of timing of irrigation and quantity of water to be applied	Total rainfall and its intra-seasonal distribution
Resource Use Allocation – both labour and finance	Total rainfall forecast and its intra-seasonal distribution
Fertilizer application – the quantity and type of fertilizer as well as the timing of application of fertilizers on crops	Forecast of the distribution of rainfall across the crop growth stages
Timing of pesticide application	Wind direction, wind speed and distribution of rainfall across the crop growth stages
Time of Harvest	Forecast of the distribution of rainfall during the crop maturation stages

FAO (2019). Handbook on climate information for farming communities – What farmers need and what is available.

Climate-responsive farm management



Schematic diagram of the climate-responsive farming management approach to support agrometeorological advisories at the local level. (FAO (2019). Handbook on climate information for farming communities – What farmers need and what is available.)

Source: G4AW; 2017

Gender checklist

Gender analysis questions

- What are the differences in activities of men and women?
- What resources do they have access to in order to carry out these activities? For instance, are there differences between access to mobile phones or internet between men and women?
- Focus on the user: does a male user have the same needs as a female user?
- What are the implications of the differences between men and women for the approach of your project? How is your service expected to impact women, and how is it expected to impact men?

Source: G4AW; 2017

Gender checklist

Design

- Ensure gender knowledge is present in the team
- Set up a specific approach and tools to include gender
- Make sure to provide sufficient allocation of resources in your budget to reach women and/or their organizations, as well as resources which will help enable women to participate actively

Types of intervention & results for women in agriculture

	Increase the number of women entrepreneurs in large-scale agribusinesses	Increase incomes by improving productivity and training women in core business skills	Increase access to niche markets by marketing products from women-led value chains
1. Training	✓	✓	✓
2. Increasing access to inputs	✓	✓	✓
3. Financing	✓		✓
4. Enhancing links to markets	✓		✓
5. Expanding cooperative programmes		✓	

Relation between types of intervention and results for women in agriculture. (AfDB (2015). Economic empowerment of African women through equitable participation in agricultural value chains.)

Source: G4AW; 2017

Gender checklist (cont.)

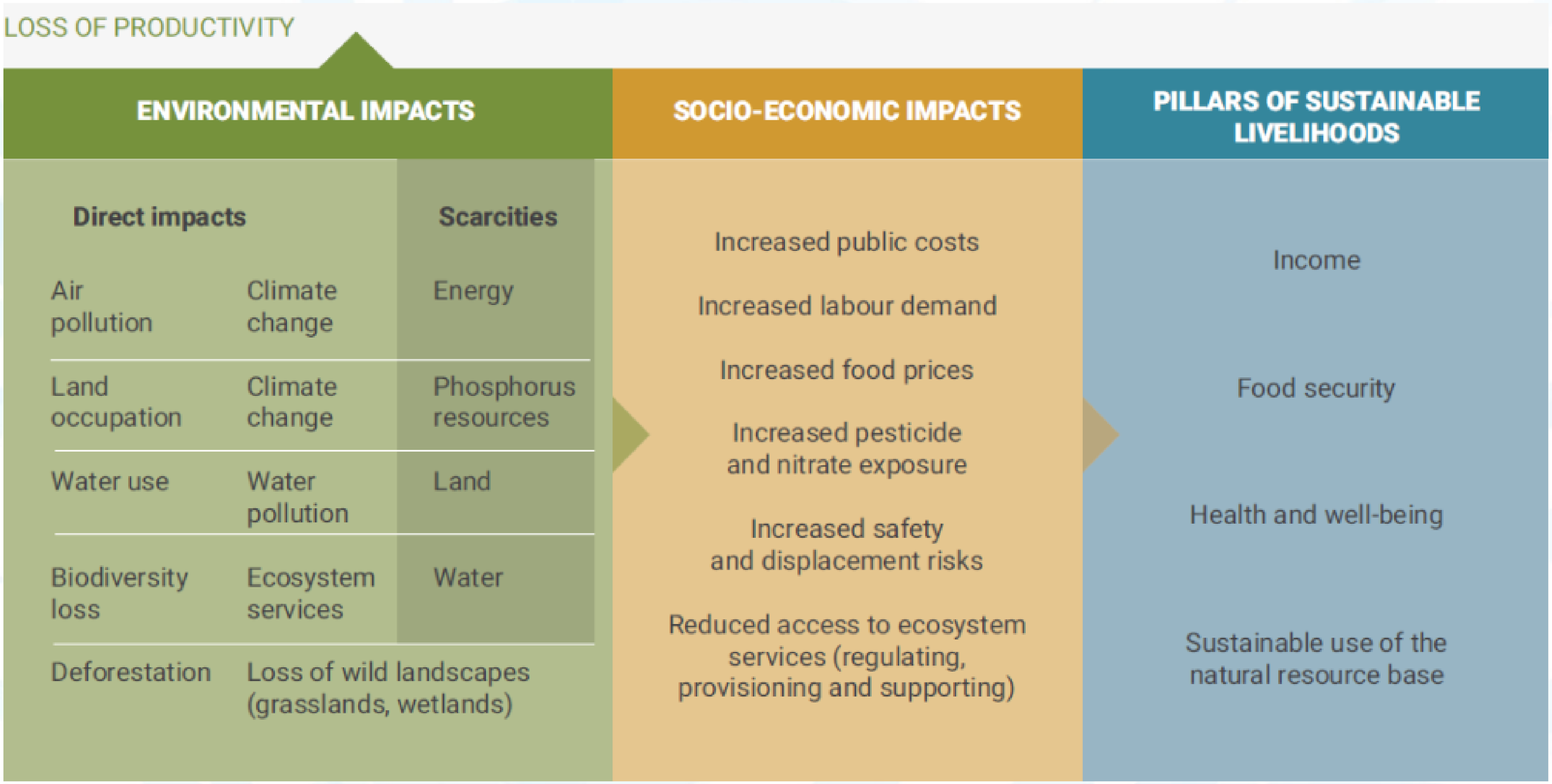
Implementation

- Adapt your tools to local needs
- Location and time: When holding (public) meetings with local stakeholders, ensure that women are invited as well, and that the training environment and timing fits the schedule of both women and men.
- Trainers and outreach: Identify how many women and men work as local trainers. Female trainers can make it easier for women smallholder farmers to participate.
- Vocational training: For instance, hold field demonstrations, role-plays, use radio shows or other methods to reach out and make information more accessible.
- Include the household: Aim to include both women and men in the trainings and demonstrations.
- Loans and insurance: Ensure that financial services provided can be accessed by women as well.

Ecosystem accounting

Translating stocks, supply and use of biomass / carbon, water and ecosystem infrastructure functional services into a sustainable use index, determining the changes over time, to arrive at a composite index of ecosystem capability.

Impacts in loss of productivity and overall welfare



Direct and indirect impacts in loss of productivity and overall welfare (TEEB (2018). Measuring what matters in agriculture and food systems: A synthesis of the results and recommendations of TEEB for agriculture and food's scientific and economic foundations report.)

Agricultural knowledge and information systems

Not only available (to work with) at national level, but also at local level, including capacity building and regular updates.

- Identification and delineation of parcels (CPU: smallest unit of land that has a contiguous, permanent boundary (fence lines, waterways, roads), common land cover & land management, common owner & producer)
- Identification of ownership
- Infrastructure mapping (as basis for market access analysis)
- Land use and land use change mapping (also as basis for erosion / land degradation monitoring)

GPS, UAV (drone), satellite images (VHR: very high resolution) or a combination (point or polygon)

Basic data

- Quality controlled, cloud-free, orthorectified, normalised, true colour composite at 1 – 2 m resolution
  (Hydrologically enforced digital elevation model at 30 m resolution)
- Online tools for consistent georeferencing of satellite, UAV and in-situ data
- Open data policy

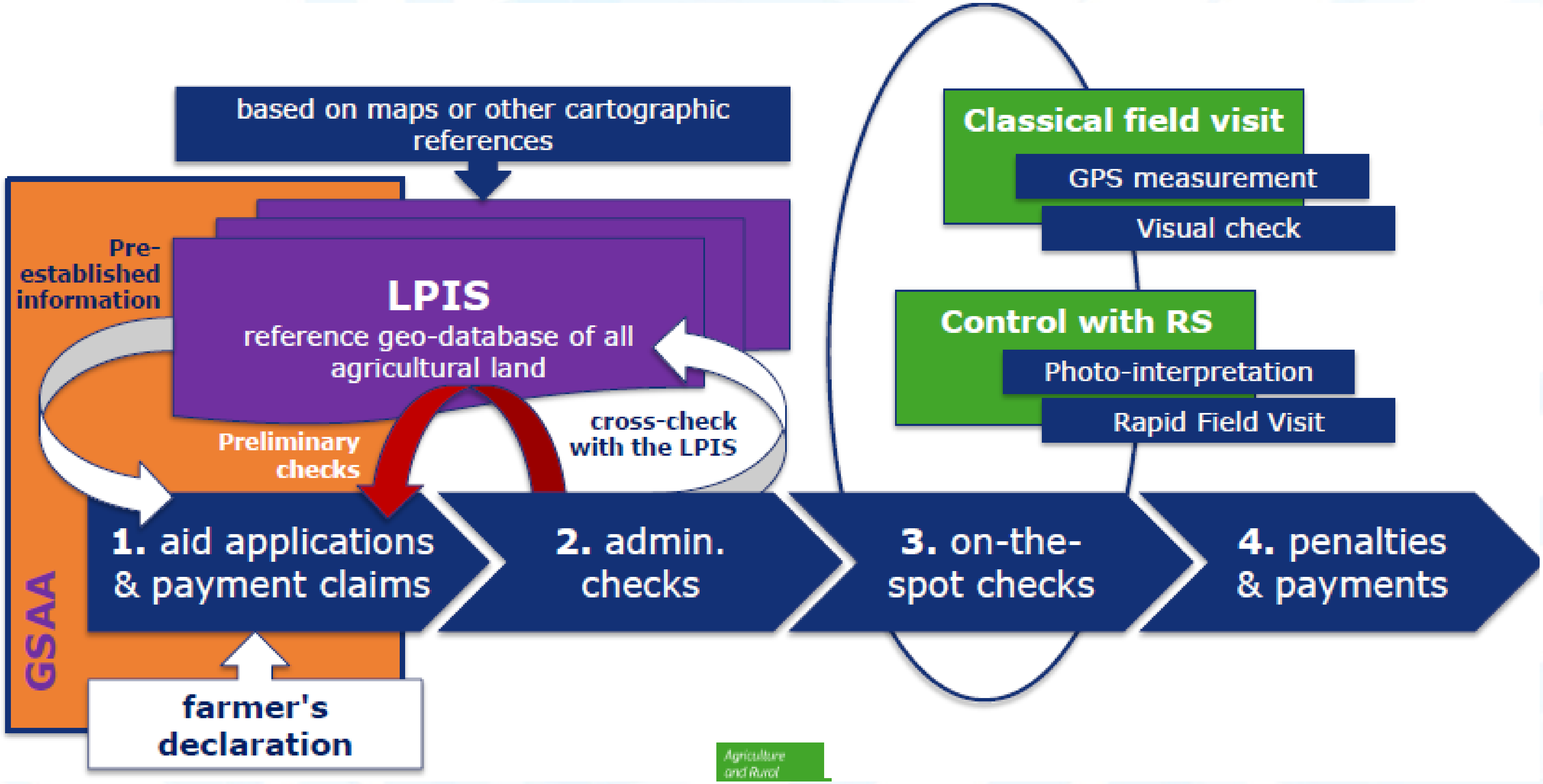
Crop monitoring

- Crop mask: distinction between agricultural and non-agricultural vegetation
- Distinction between different types of crops
- Identification of growth stages
- Distinction between fallow / cultivated & irrigated / non-irrigated
- Yield prediction

Satellite technology

- ‘Greenness’ indicators, based on optical & near-infrared
- Radar for rice & crops where there is a close relation to biomass & healthy growth: maize, wheat, soybeans, potato, sorghum
- Radar for tree-like crops: coffee, cocoa, oil palm, etc.: planted area & location, tree age and count, plantation productivity
- VOD (vegetation optical depth) based on passive microwave: observes vegetation water content at 100 x 100 m

Integrated administration & control system (EU)



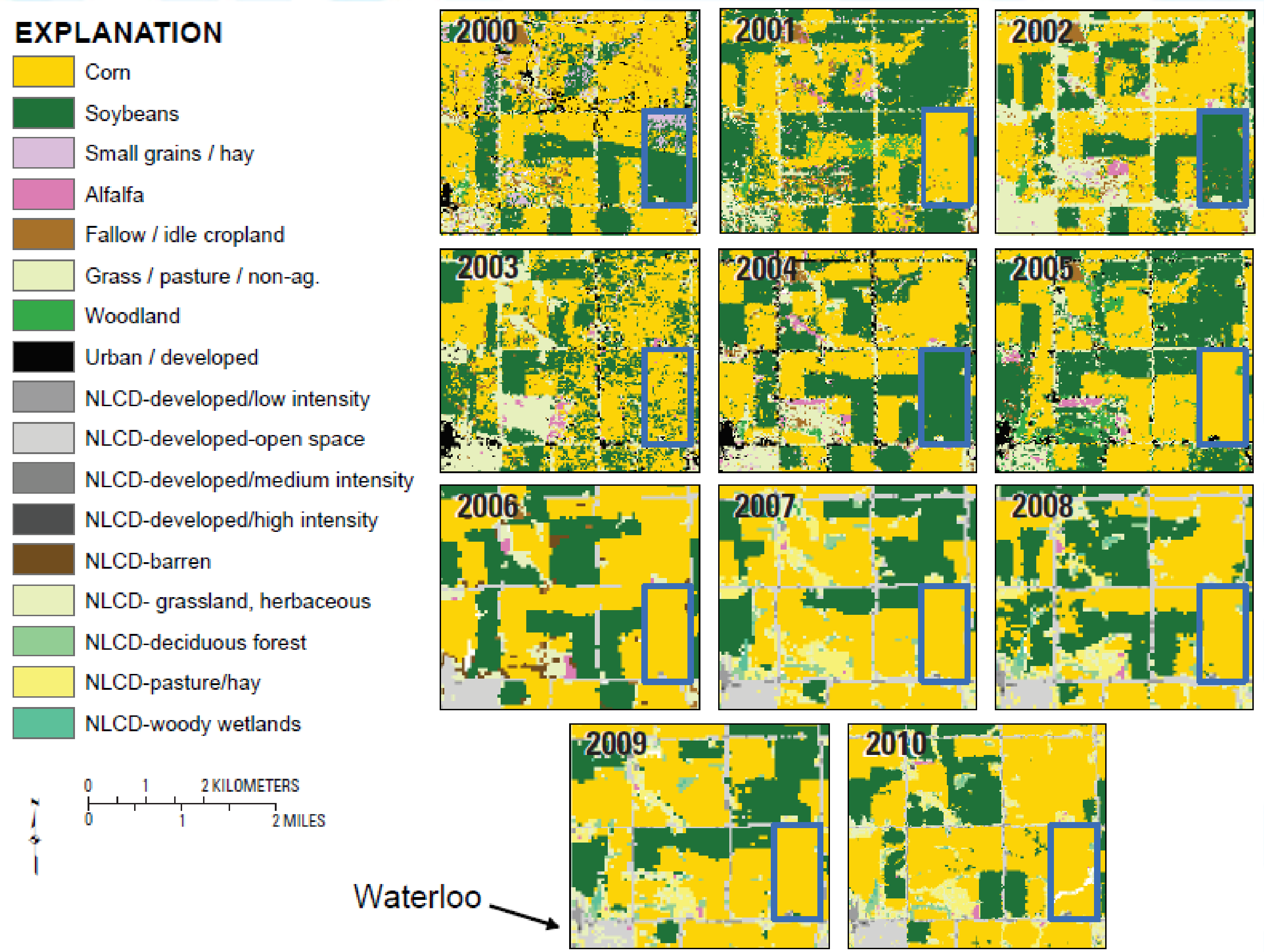
How does the Integrated Administration and Control System (IACS) work? (Greft, A. van der (2017). Remote sensing and the Common Agricultural Policy. Presentation.)

Crop monitoring

- Crop mask: distinction between agricultural and non-agricultural vegetation
- Distinction between different types of crops
- Identification of growth stages
- Distinction between fallow / cultivated & irrigated / non-irrigated
- Yield prediction

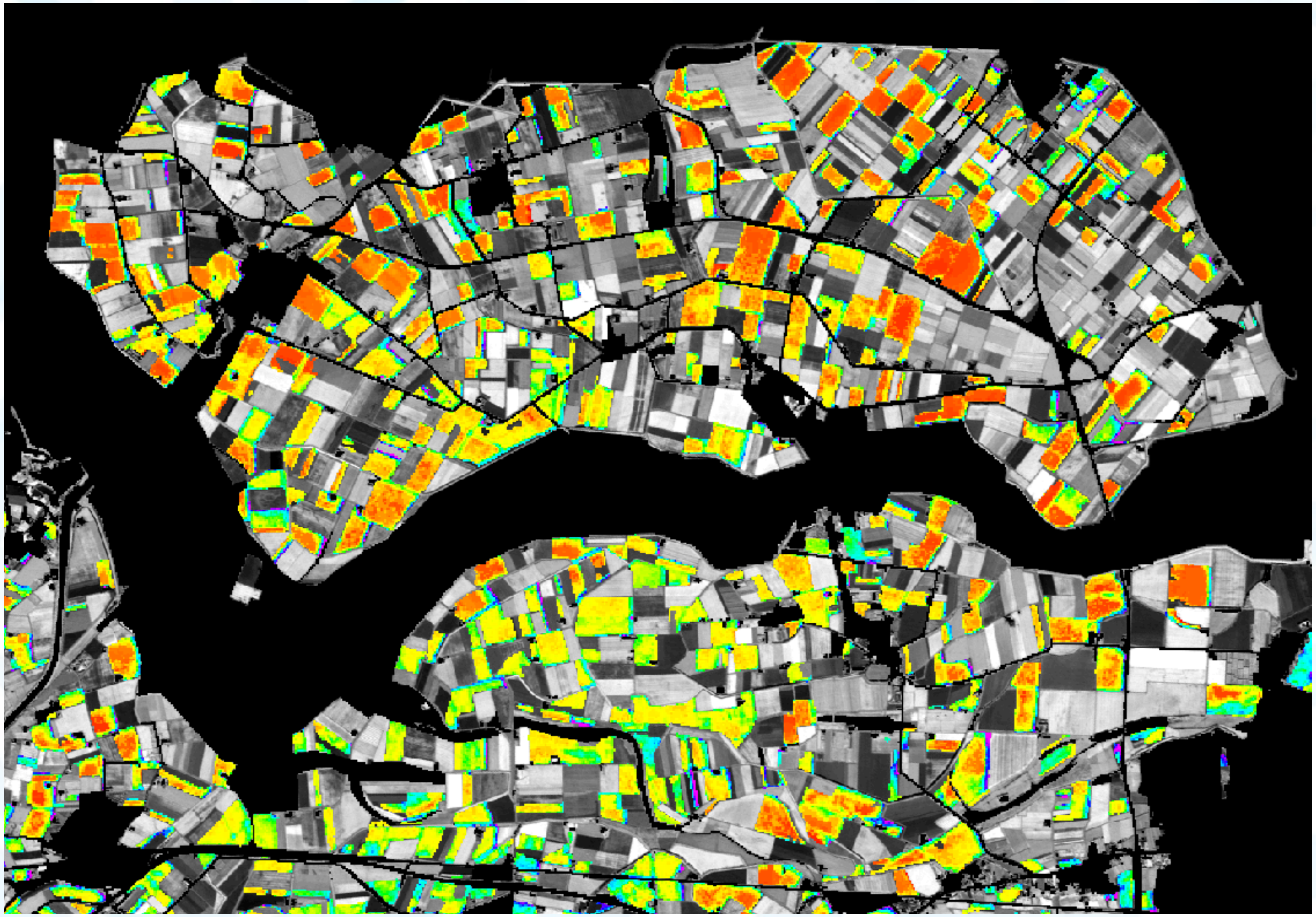
Combination with historical data (A), statistics & growth simulation models (B): identify trends (C) from data, accounting for seasonal effects (D) (& remainder)

Example crop rotation pattern identi-fication



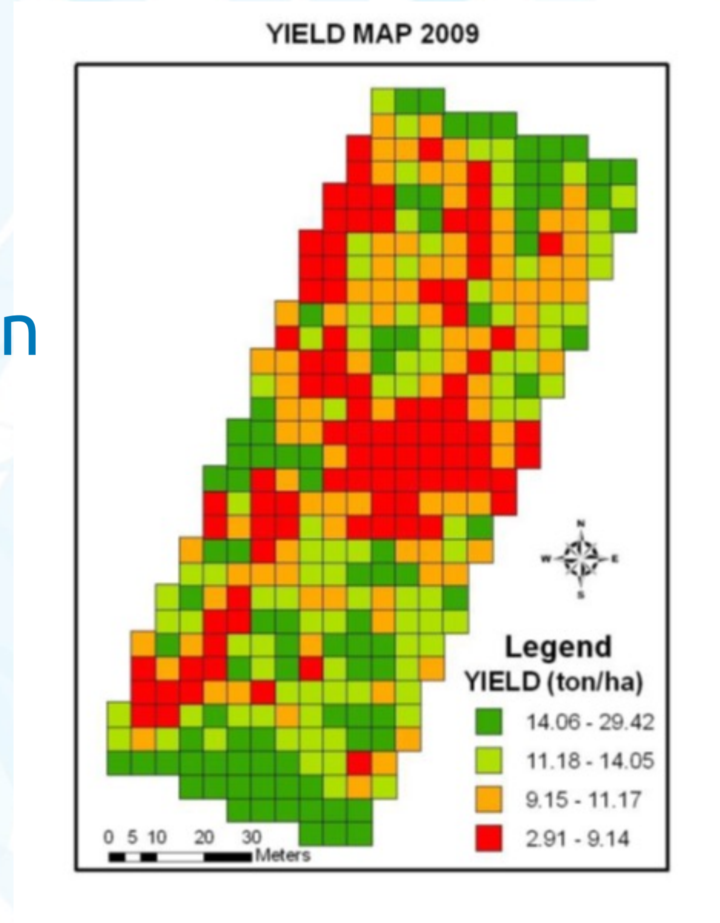
Map showing crop rotation patterns in Iowa. (Forney, W.M. et al (2012). An economic value of remote-sensing information— Application to agricultural production and maintaining groundwater quality. Professional paper 1796. USDI, USGS.)

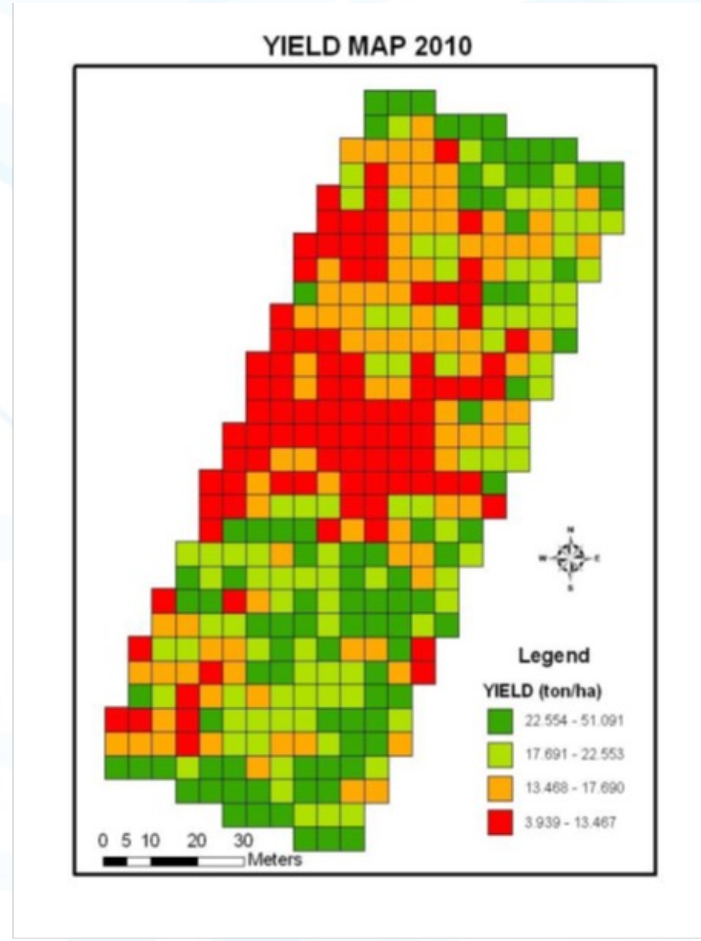
Example wheat yield estimation



Field scale wheat yield in the Netherlands (blue: 9 ton/ha, green: 8 ton/ha; yellow: 6 ton/ha, red 4 ton/ha) (eLeaf)

Example vineyard yield estimation





Vineyard yield map and comparison 2010 and 2009 (Fountas)

Satellite technology

- ‘Greenness’ indicators, based on optical & near-infrared
- Radar for rice & crops where there is a close relation to biomass & healthy growth: maize, wheat, soybeans, potato, sorghum
- Radar for tree-like crops: coffee, cocoa, oil palm, etc.: planted area & location, tree age and count, plantation productivity
- VOD (vegetation optical depth), based on passive microwave: observes vegetation water content at 100 x 100 m

Geospatial analysis and active stakeholders' field validation

1. Generating agricultural production baselines
2. Pre-season agricultural production forecasting and contextual interpretation (one-month before the start of the season)
3. Establishment of start of season/planting forecast {one-month after the start of season)
4. Crop establishment stage (two-months after the start of the season)
5. Crop maturity stage agriculture production forecast - varied with length of the growing period (three to four months after the start of the season; it is recommended this is supported by rigorous field assessments at this critical stage
6. Post-harvest assessments (evaluate and recommend new improvements in the approach of agricultural production forecasting system in the cropping zone)

FAO (2016). Crop yield forecasting – Methodological and institutional aspects.

Input parameters for site evaluation

- Vegetation ‘greenness’ (NDVI: normalised difference vegetation index)
- Soil type and nutrients (NDSI: normalised difference soil index)
- Land cover
- Digital elevation model
- Climate data (temperature, humidity, cloud cover, etc.)
- Water availability & soil salinity
- Agricultural practices

Example parcels & land cover types

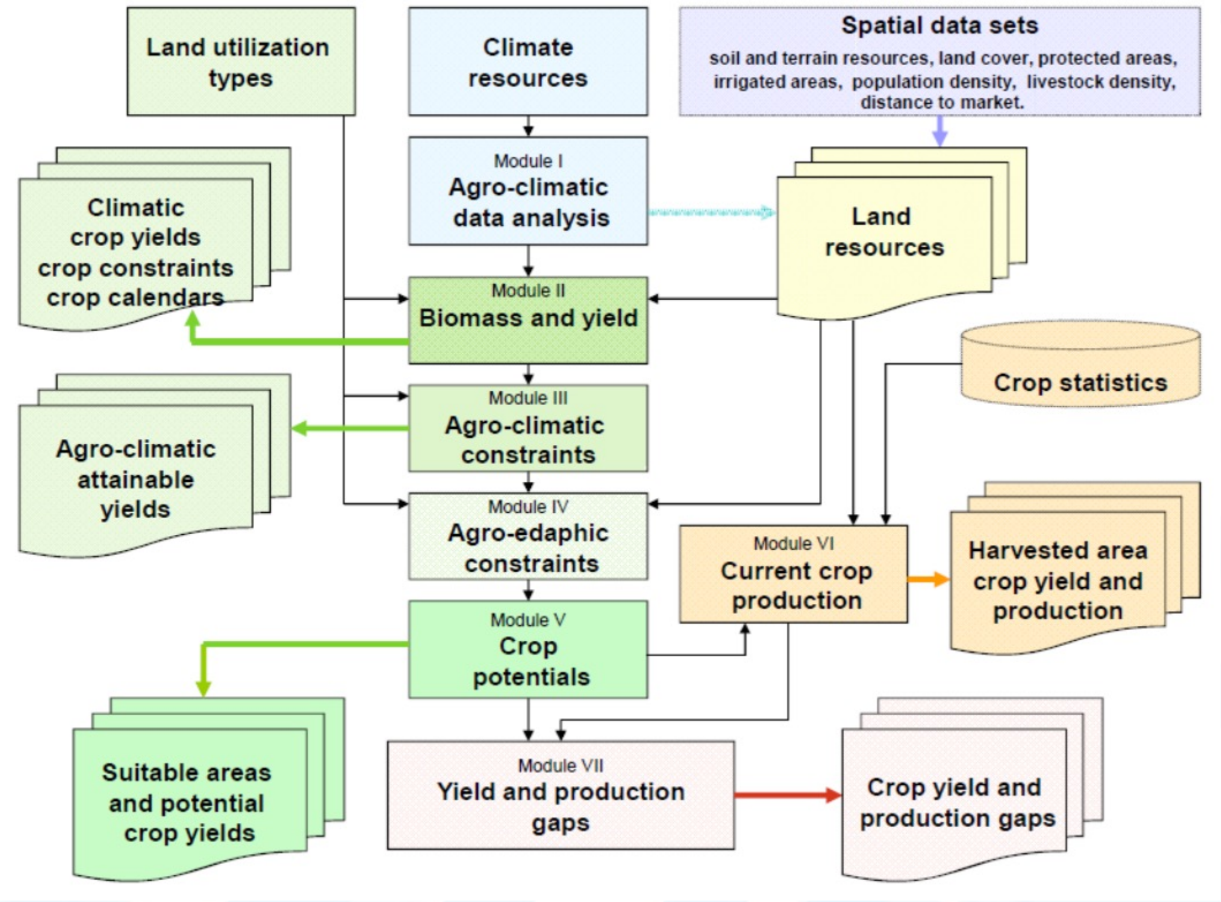
Examples of reference parcels super-imposed on aerial ortho-imagery (colours correspond to different land cover types) (GeoCAP, JRC)

Source: IIASA, FAO; 2012

Translate into Agro-Ecological Zone info

1. Climate data analysis and compilation of general agro-climatic indicators
2. Crop-specific agro-climatic assessment and potential water-limited biomass/yield calculation
3. Yield reduction due to agro-climatic constraints
4. Yield reduction due to soil and terrain limitations
5. Integration of climatic and edaphic evaluation
6. Actual yield and production
7. Yield and production gaps

Framework for determination of Global Agro-Ecological Zones

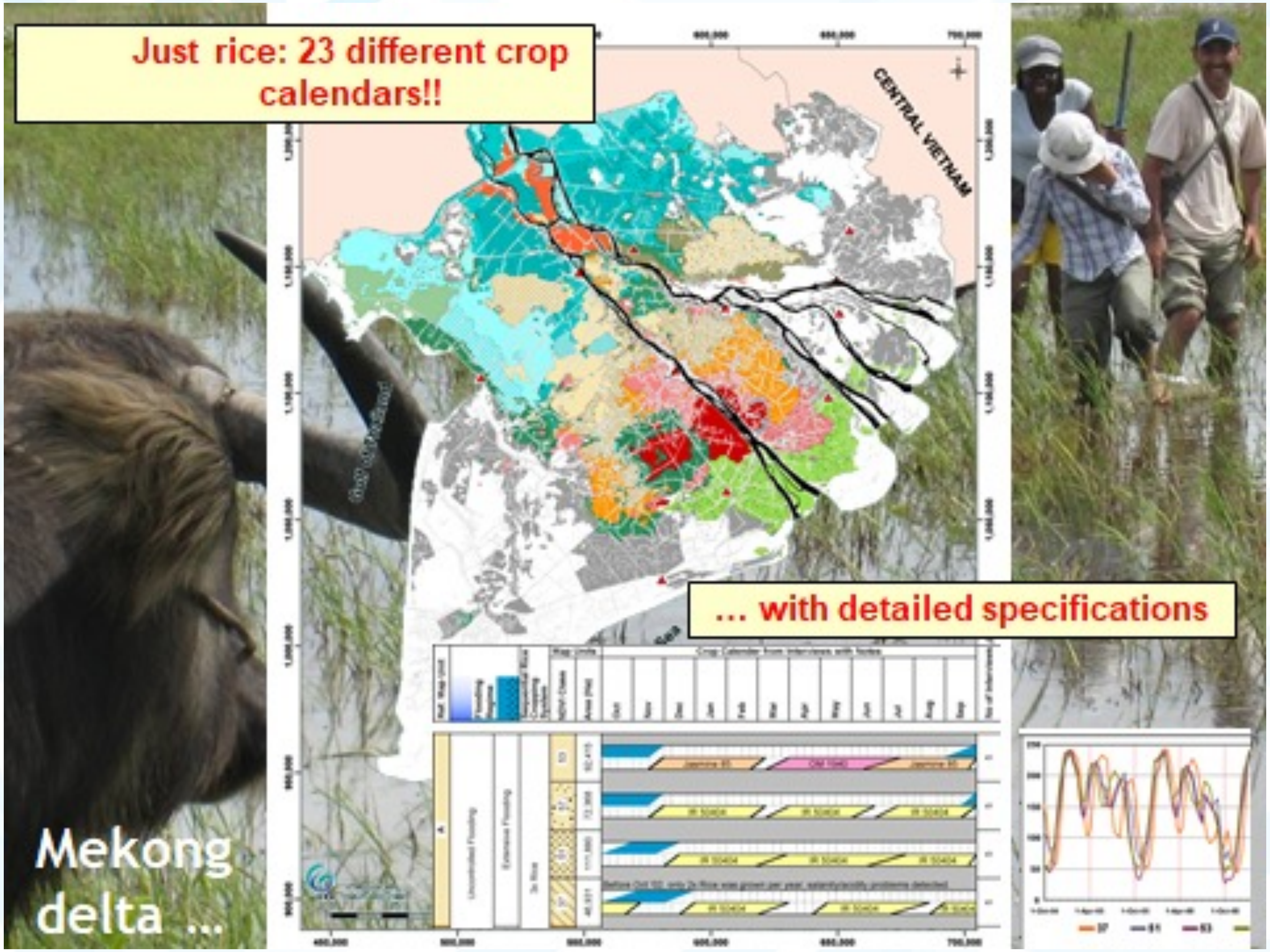


Framework for determination of Global Agro-Ecological Zones (GAEZ). (IIASA (2012). Global agro-ecological zones.)

Input parameters for crop selection & calendar

- Soil type
- Weather and climate information (phenology, temperature, humidity, expected rainfall, extreme events)
- Crop types and varieties (crop benchmarking)
- Crop statistics
- Topographical information (DEM: digital elevation model)
- Water availability
- Nutrients availability and recuperation
- Market considerations (access, price, etc.)
- Risk assessment

Different rice crop calendars in the Mekong delta

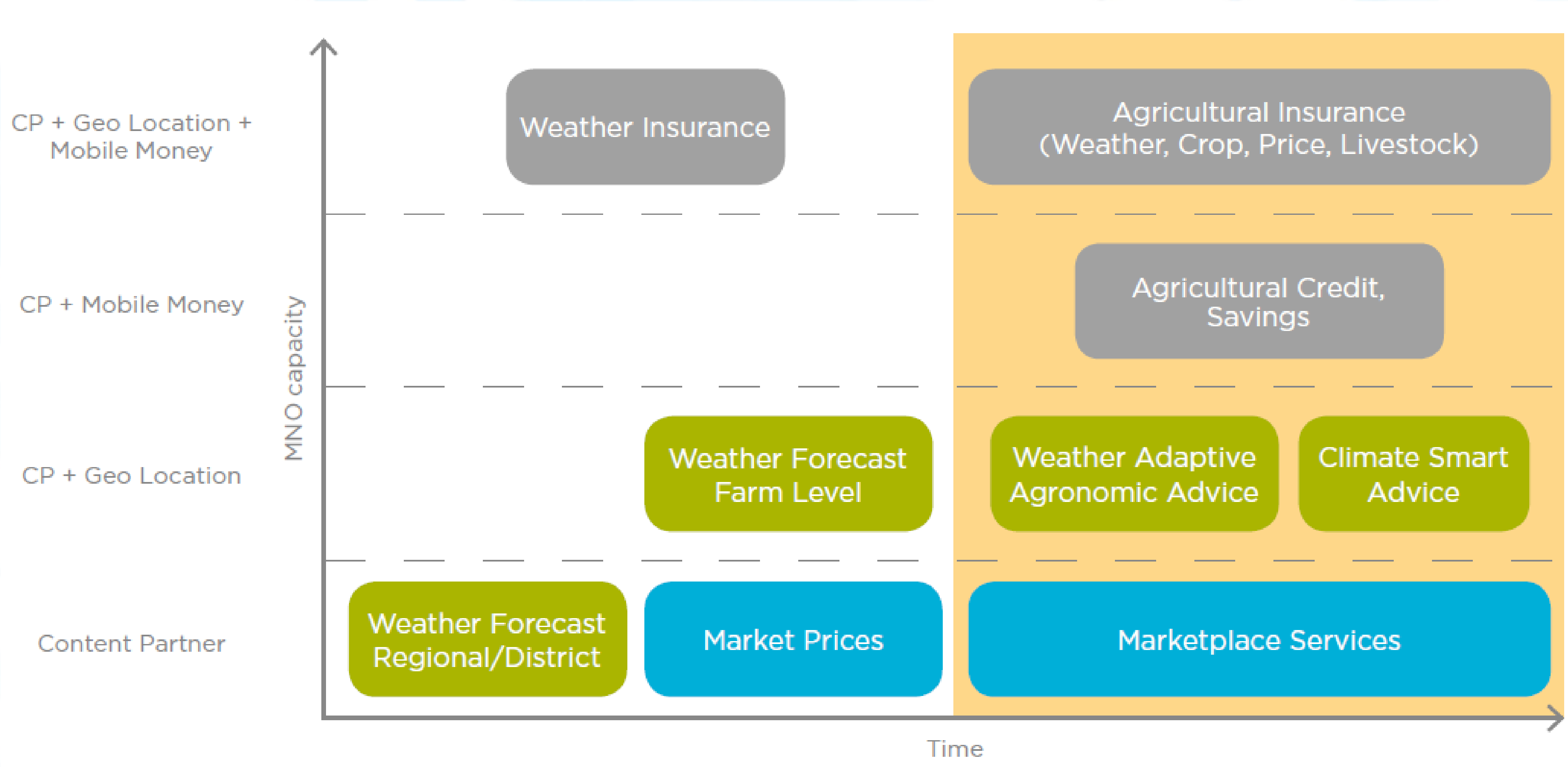


Source: de Bie, Venus; 2010

Weather forecasting should be

- Part of a holistic bundle
- Relevant at the local level (scale, timing). Local stations are important as complement to satellite data
- Communicated in a way that people understand the message

Weather advice overview

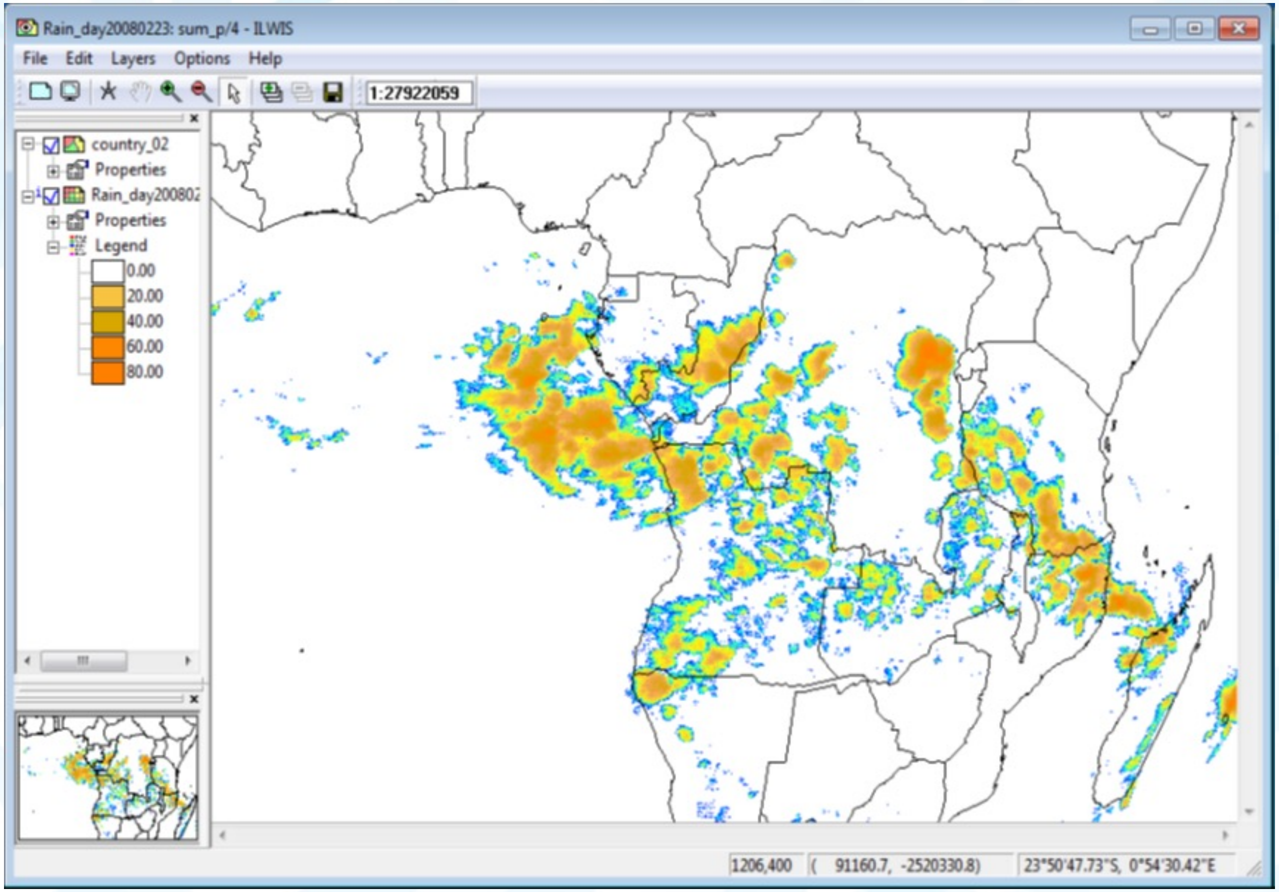


Evolution to holistic bundle making use of weather advice. (GSMA (2016). mAgri - Weather forecasting and monitoring: Mobile solutions for climate resilience. Case study.)

Weather advice inputs

- Information about temperature, humidity, wind, cloud cover, sun hours, precipitation, warning on extreme events
- Analysis of trends, based on historical data
- Long-term (seasonal) forecasts

Example calculated precipitation



Precipitation calculated over Central Africa for 23-02-2008 (ITC (2012). GEONETCast - DevCoCast application manual)

Weather data is used as input for

- Crop monitoring (weather conditions & forecast)
- Fertiliser advice (expected rainfall)
- Pest and disease management (rainfall, humidity)
- Sowing / planting advice (expected rainfall: 14-day forecast, wind, extreme events)
- Harvest advice (temperature, expected rainfall, extreme events)
- Water use and irrigation advice (expected rainfall)
- Flood risk assessment & early warning (expected rainfall)
- Drought risk assessment & monitoring
- Extreme weather risk assessment (including storm tracking)
- Locust early warning

And as input for

- Disaster monitoring & impact assessment (flooding: expected rainfall)
- Weather-based index insurance
- Market information (good or bad harvest of certain crops, based on forecasting and historical data)
- Climate change modelling, monitoring & adaptation (analysis of trends, long-term forecast)
- Pasture & water bodies identification & monitoring
- Fire early warning & monitoring (expected rainfall)

Site-specific nutrient management (SSNM)

- Based on indication of ‘greenness’ (NDVI: normalised vegetation difference index, LAI: leaf area index), combined with biomass: when (certain) deviations occur, advice is given to apply fertiliser (in certain locations) on the field
- Supported by auxiliary data on weather (expected rainfall, extreme events), irrigation and soil type & condition
- Advice is dependent on the type of crops; advice is easier to apply to large areas that are cultivated with the same crop
- Efficiency claims for nitrogen (N) -use in the range of 15%

Challenges

- Risk of false positives: for some areas that are fallow or not productive for other reasons the advice to apply fertiliser may be given
- There is a limit in accuracy for advice that is entirely based on satellite data (10 x 10 m); in ‘real’ precision agriculture the distance of the nozzles on a spraying beam is the limiting factor
- Vertical canopy position influence leaf spectral properties (and therefore determination on N-content)

Fertiliser advice

- Closely related to soil nutrients assessment
- Retail price around 8 € / ha (with a minimum order size of 100 ha)

Calculate N-uptake (kg N in crop)

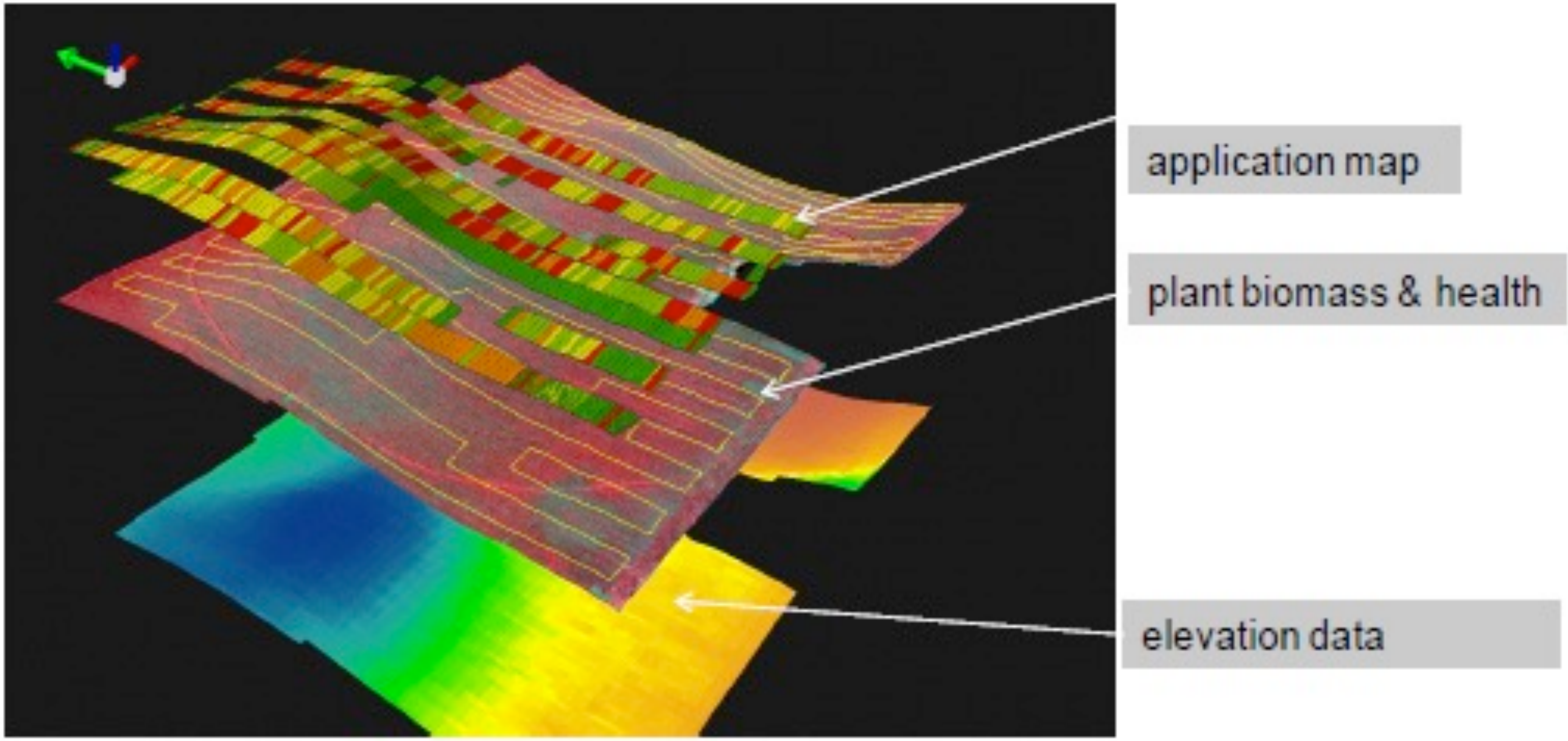
Source: Kempenaar, 2017

Calculate N-dose (based on 50 ton/ha)

Source: Kempenaar, 2017

Pest & disease management

- Historical analysis and forecast of temperature and humidity
- Assessment of ‘greenness’ of vegetation (NDVI: normalised difference vegetation index, VI: vegetation index)
- Works better when large areas are cultivated with the same crop. Examples: rice (Mekong delta), potatoes (Bangladesh)
- Cost indication 8 €/ha (with a minimum order size of 100 ha)



Source: de Vlieg, 2017

Task map potato haulm killing (2013) with Akkerweb

Source: Kempenaar, 2015

Sowing & planting advice

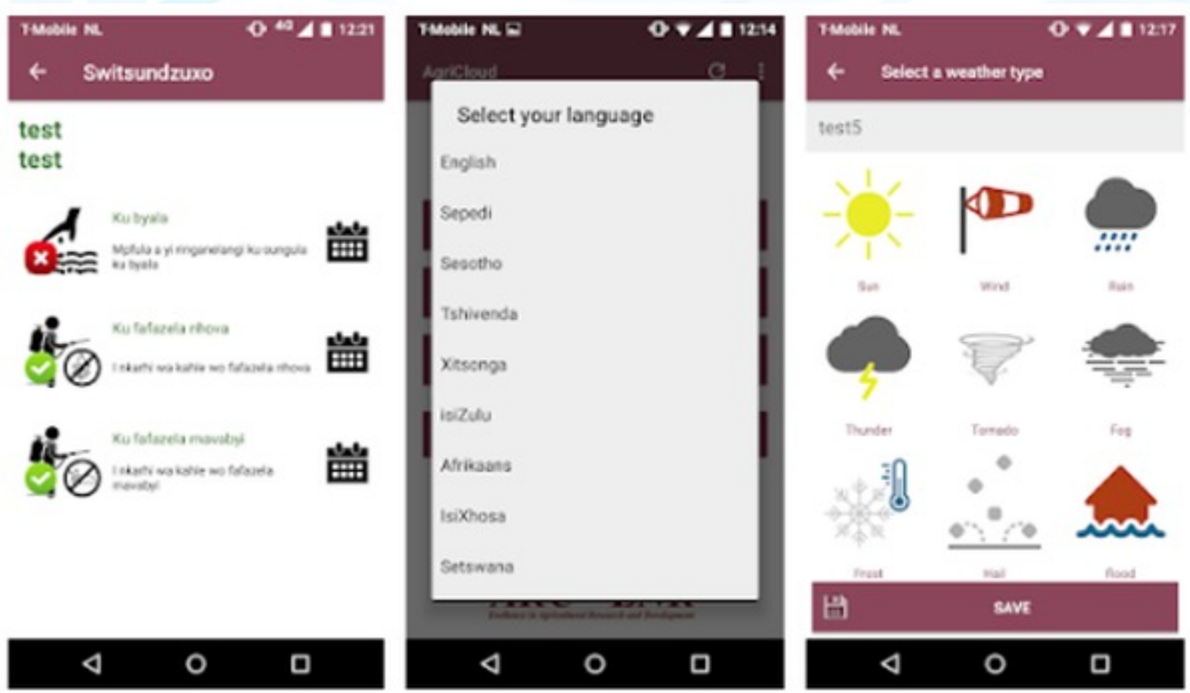
- Time series of analysis of parcel preparation (tillage or flooding), small fields pose a problem for tillage detection (especially when trees are present)
- Analysis of historical and near real-time meteorological data
- Actual and forecast of precipitation, humidity and temperature
- Forecast of soil moisture conditions (next 7 days)

Source: R4A; 2018

Agricloud

Agricloud provides farmers and extension officers in South Africa with farm specific advice.

Get forecast planting dates for next 10 days and spray conditions according to time of day.



All advisories are in your own language; Setswana. Isixhosa, Afrikaans, Isizulu, Xitsonga, Tshivenda, Sesotho, Sepedi or English.
The advisories are based on real-time weather observations and forecasts of the best quality. This app was developed in the Rain4Africa project.
It contains data and advisories from South African Agricultural Research Council and South African Weather Services.

Input for harvest advice

- Forecast of soil moisture conditions (next 7 days)
- Detection of harvested fields (based on NDVI: normalised difference vegetation index, LAI: leaf area index, (min)NDTI: normalised difference temperature index, phenology), deriving useful data for agro-industry
- Time series analysis, based on crop calendars & parcel delineation (also to distinguish harvesting from other events that affect vegetation)

Challenges

- Detecting harvesting operations on low crop canopies, such as groundnuts, is more difficult due to the limited sensitivity of the sensors used
- Appropriate timed imagery is needed to distinguish harvested areas from replanted area (for example in the case of sugar cane)
- Small fields pose a problem for harvest detection as well

Example of harvest and planting mapping on a SPOT image acquired on August 19, 2004 with 10 m resolution (Reunion):

a) False colour composition of a subset (Near IR: infrared/Red/Green), on which photosynthetic vegetation appears in red, cane residues in light blue and bare soil in dark blue.

b) Classified image of the cane cropped area, inside the block parcel limits in black (Source: DDAF).

c) Classified cane fields in a GIS layer.

(Lebourgeois, V. et al. (2010). Improving harvest and planting monitoring for smallholders with geospatial technology: the Reunion Island experience. International Sugar Journal.)

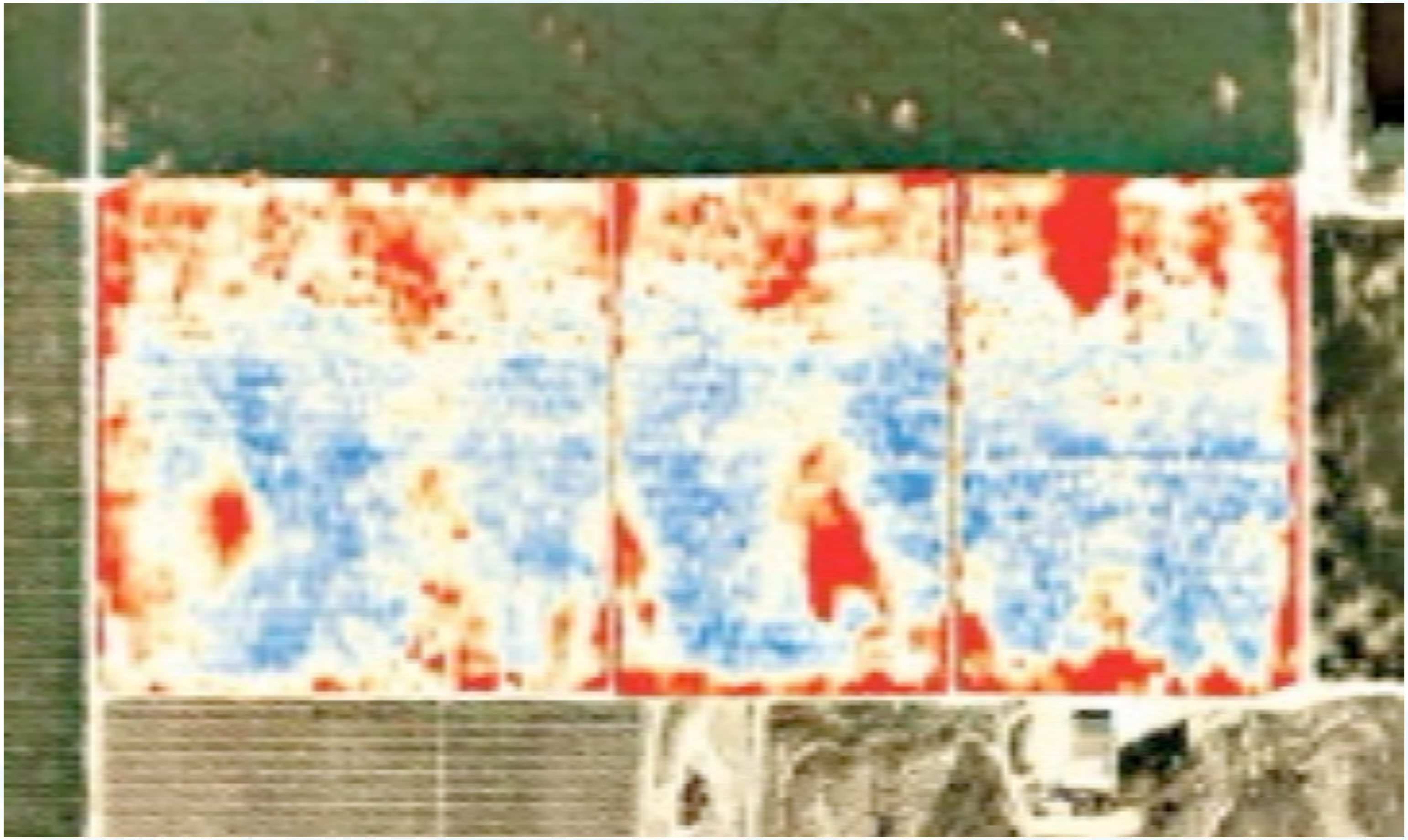
Input for water use & irrigation advice

- Data on temperature, rainfall, humidity, wind speed, evapotranspiration (historical & forecast) & past irrigation schedule
- Combination of NDVI (normalised difference vegetation index) and/or LAI (leaf area index), ET (evapotranspiration) deficit, soil moisture, soil physical properties data + weather forecast, resulting in irrigation advice
- Water availability maps

Main propositions

- Improved irrigation scheduling
- Increase of the quality & quantity of crops
- Continuous monitoring of water demand according to its determining factors (area, type of crops, weather etc.)
- Better insight into the availability of water
- Real-time monitoring of irrigation water use
- Compliance with legal & regulatory requirements

Example water stress in a vineyard



Water stress in a vineyard in Spain (AeroVision)

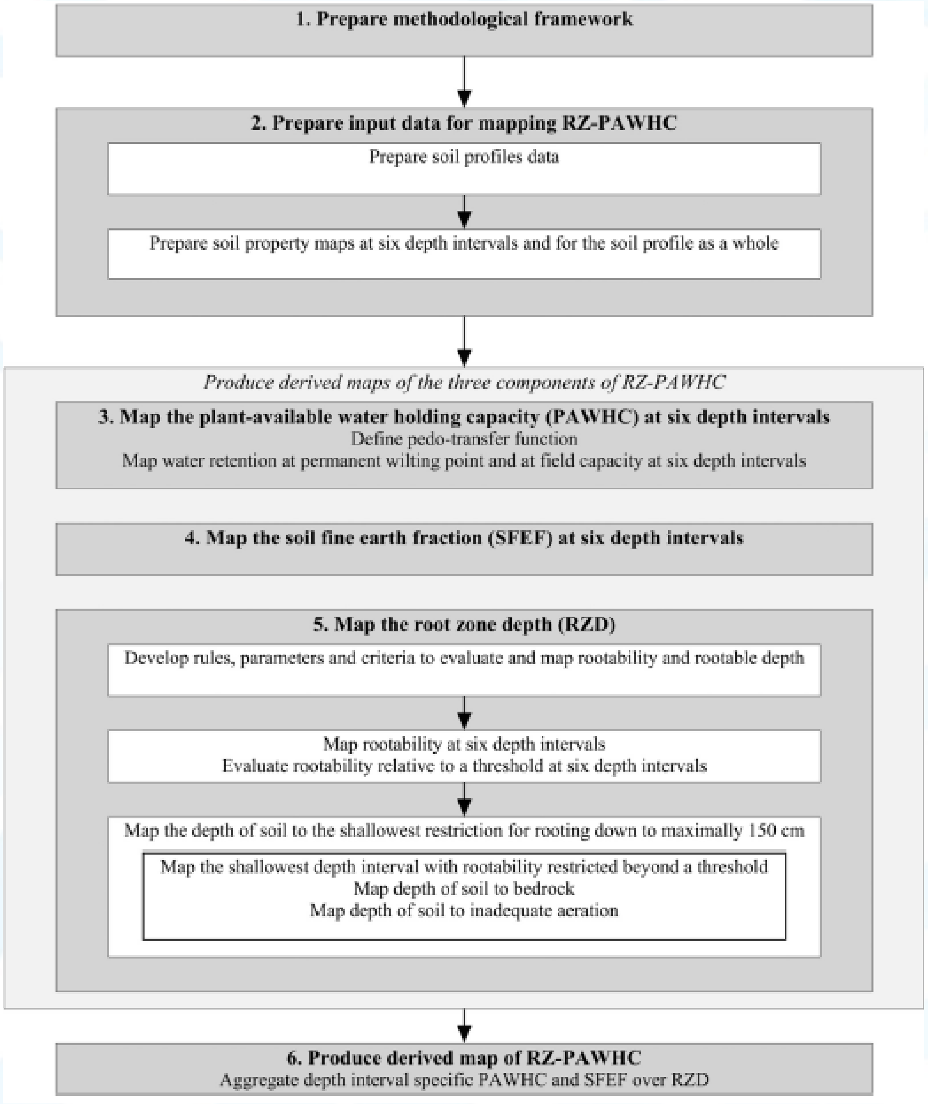
Assessment soil moisture assessment & modelling

- Soil moisture processing
- Soil water deficit processing
- Soil water deficit index process (historical database & actual)

Derived from

- SMI (soil moisture index)
- Land cover
- Land use
- Soil texture
- Hydrographic info
- DEM (digital elevation model)
- Land Parameter Retrieval Model (based on microwave)

Mapping root zone plant available water holding capacity



Overview of the methodological framework to map RZ-PAWHC (Root Zone – Plant Available Water Holding Capacity). (Leenaars, J. et al. (2018). Mapping rootable depth and root zone plant-available water holding capacity of the soil of sub-Saharan Africa. Geoderma.)

Soil moisture monitoring with Earth observation

After: Copernicus Observer (2020). Monitoring soil moisture with Copernicus

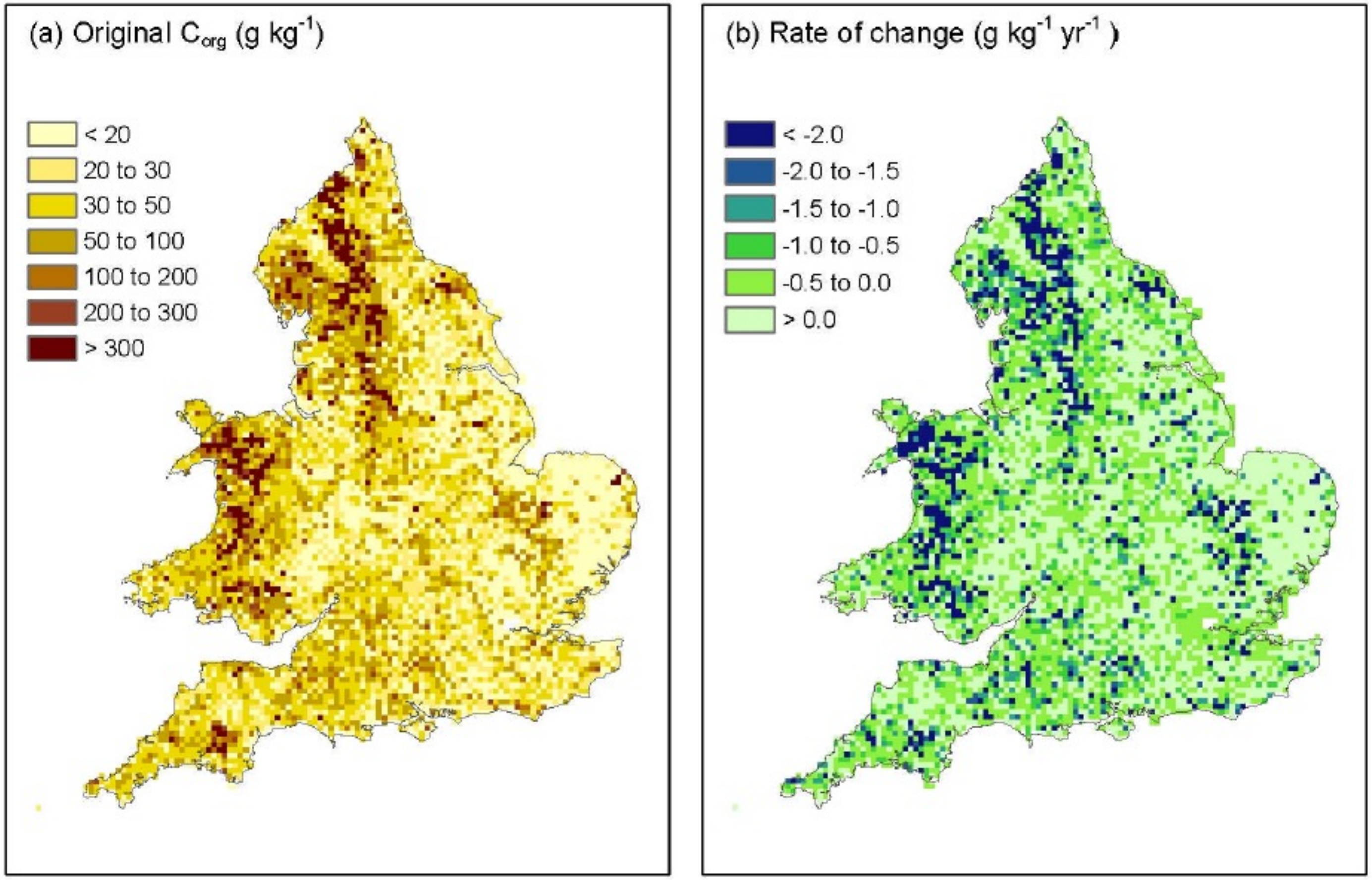
- Microwave techniques estimate the amount of water in the soil by measuring the strength of the signal naturally emitted from the surface (passive sensors), or backscattered from the land surface after transmitting a pulse of microwave energy (active sensors).
- Passive microwave instruments (also called radiometers) are used to determine surface soil moisture with high accuracy and a temporal resolution of two to three days, but they have a low spatial resolution (around 40 km).
- Active microwave sensors (such as Sentinel-1) have been very useful for estimating soil surface characteristics, in particular, soil moisture. They offer a regular temporal coverage (about 3 days), together with a spatial resolution of up to 10 m.
- By using active and passive microwave data fusion methods, it could even be possible to retrieve soil moisture at a higher spatial resolution and with higher accuracy.

Source: Univ. Zürich, INRA; 2014

Assessment of soil nutrients

- Soil texture: determined using specific absorption features to differentiate between clay-rich and quartz-rich soils; calibration of models is based on local conditions
- Soil organic carbon: analysis of reflectance patterns beyond the visible spectrum
- Iron content: RS imagery has been successfully used for determining the presence of iron over areas up to 500 km^2; quantification is difficult
- Carbonates: optical RS allows distinction between common carbonate minerals on the basis of unique spectral features found in the SWIR (short wave infrared), and especially in the TIR (thermal infrared) region.

Change in soil organic content over time



Change in soil organic content in England and Wales between 1978 and 2003. (Bellamy et al. (2005)).

Assessment of salinity

General indications of salinity can be assessed with Earth observation. Data are limited to the soil surface (A) and need to be integrated with in-situ sampling (from the whole soil profile) (B), simulation models (C) and geophysical surveys (D). Peak growth period (E) is most suitable to detect salinity via vegetation, but there may be other causes that affect vegetation growth.

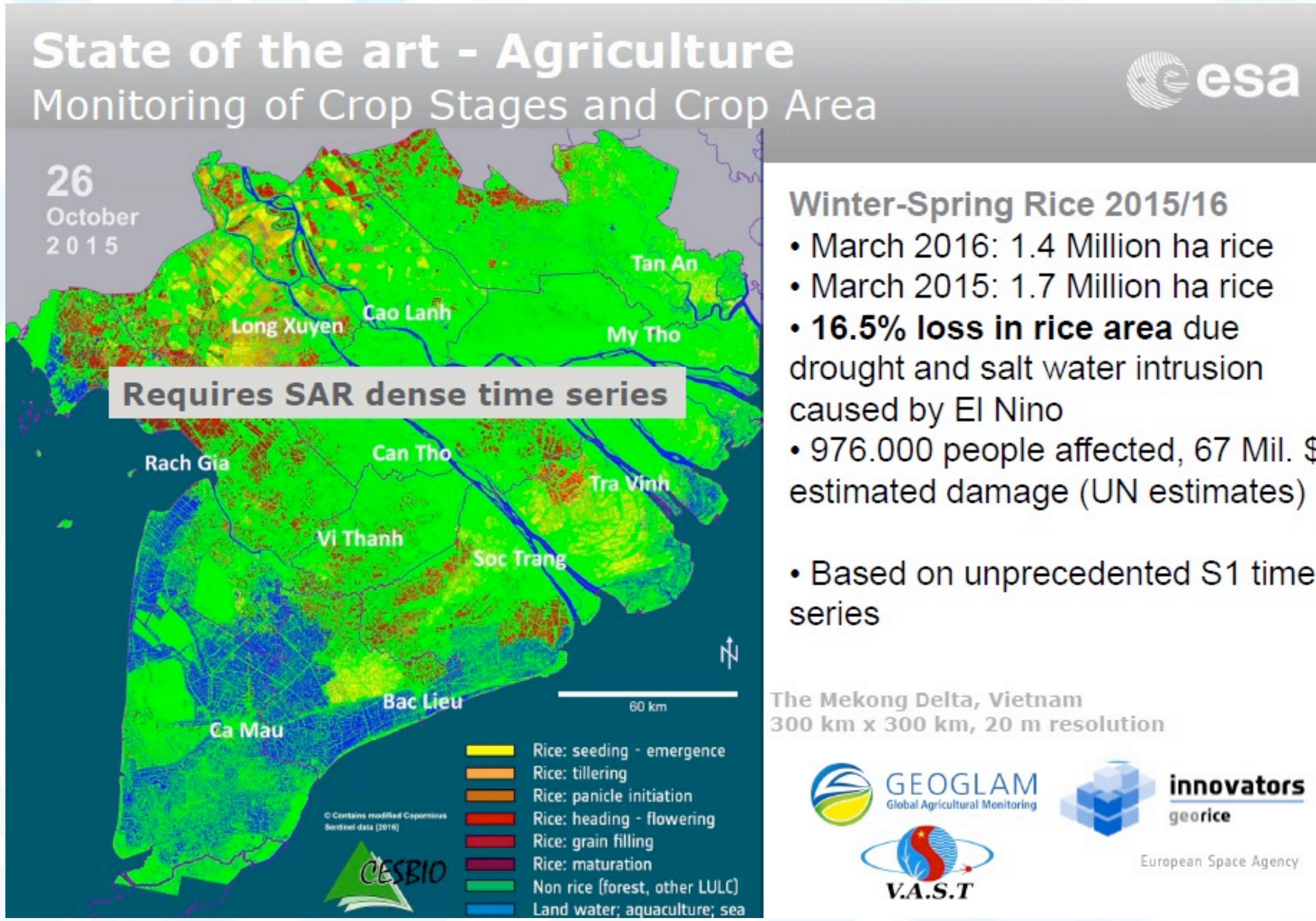
EO helps to identify and monitor problem areas

Additional measures are needed for more exact quantification, as input for reclamation measures, such as flushing and gypsum application (and cultivation of more salt-resistant crops).

The scale is not appropriate (yet) for advice to individual smallholder farmers.

LAI (leaf area index), NDSI (normalised difference salinity index), land cover and land use are important (indirect) parameters.

Loss in rice area due to salt water intrusion

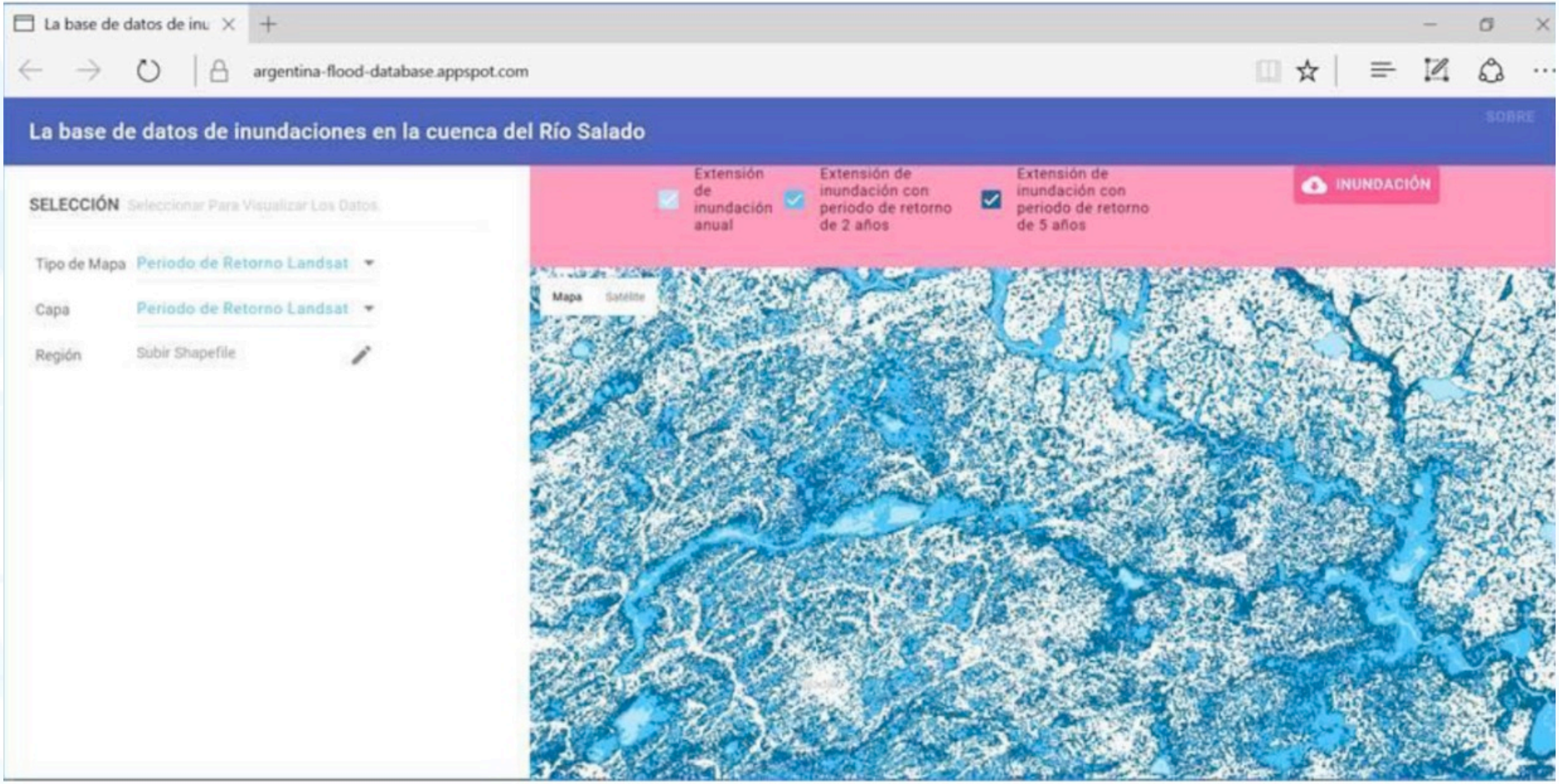


Source: ESA, 2016

Flood risk assessment: EO is used for

- Topographic base map
- Historical analysis of floods (extent, frequency)
- Population density assessment (rural areas)
- Mapping of critical infrastructure and vulnerable objects
- Indication of relatively safe areas
- Digital elevation model for hydrological modelling
- Assessment of water levels in rivers and reservoirs (large water bodies only)
- Assessment of land use and surface roughness
- Estimation of surface soil moisture (for prediction of run-off)
- Precipitation monitoring and forecasting

Example flood dashboard for different return periods

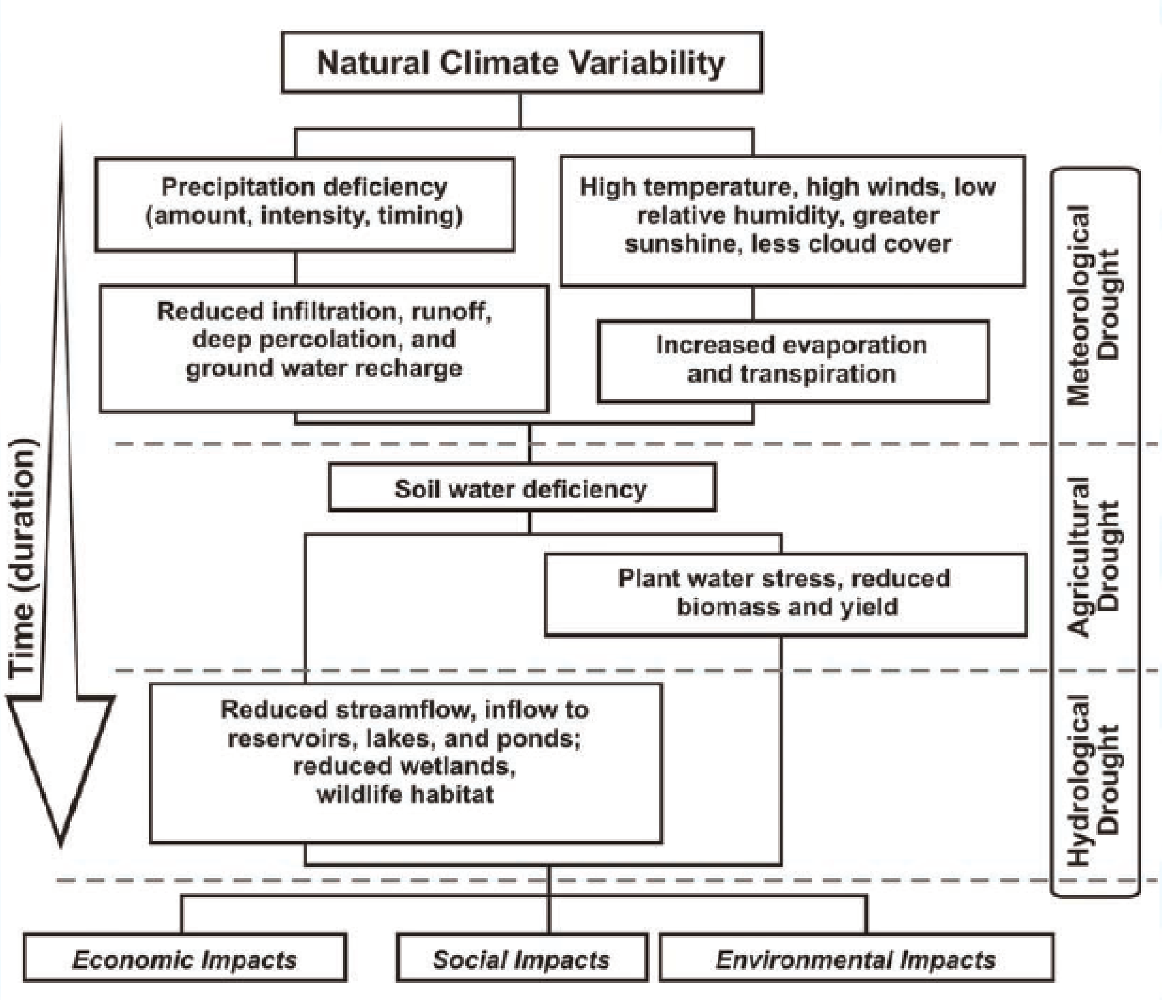


The Rio Salado Flood Dashboard displaying the flood extents for return periods for 1, 2 and 5 years, built from the Landsat archive within google earth engine: https://argentina-flood-database.appspot.com (GWSP (2019). New avenues for remote sensing applications for water management – A range of applications and lessons learned from implementation)

General consideration drought risk

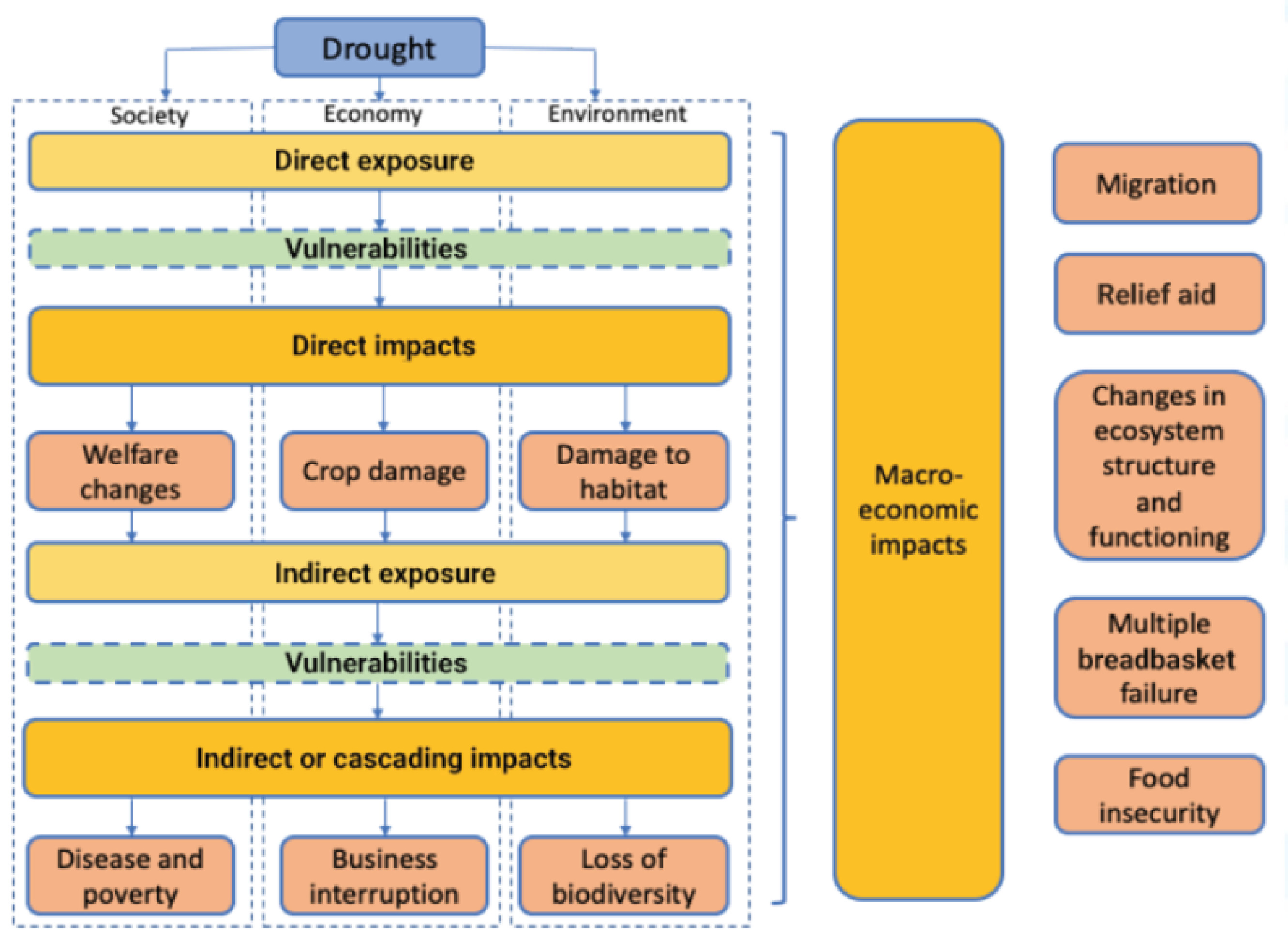
- Distinction between meteorological, agricultural & hydrological drought and economic, environmental & social impact
- Analysis of long-time weather and climate series, including recurrent patterns (El Niño, La Niña, etc.)
- Several drought-related indicators & indices (SMDI: soil moisture drought index, DHI: drought hazard index, and others) are established with the help of Earth observation, supported by other (in situ) measurements and processed in different types of models

Relationship between meteorological, agricultural, hydrological & socio-economic drought



Relationship between meteorological, agricultural, hydrological and socio-economic drought (National Drought Mitigation Center, University of Nebraska-Lincoln, USA). (ICSU, JB-GIS, UNOOSA (2013). The value of geo-information for disaster risk reduction – Benefit analysis and stakeholder assessment.)

Direct & indirect drought impacts



Schematic interpretation of direct and indirect drought impacts and their interrelation (UNDRR (2021). GAR special report on drought.)

Assessment

A Drought monitoring typically uses vegetation index anomalies and precipitation data

B However, remotely sensed total water storage, surface soil moisture, and rainfall are increasingly being incorporated into drought monitoring systems

C Forecasting drought requires landscape water balance models that can be forced (up to the forecast date) or calibrated with additional EO information on rainfall, evapotranspiration, soil moisture, groundwater, and snow and ice, where relevant

Output

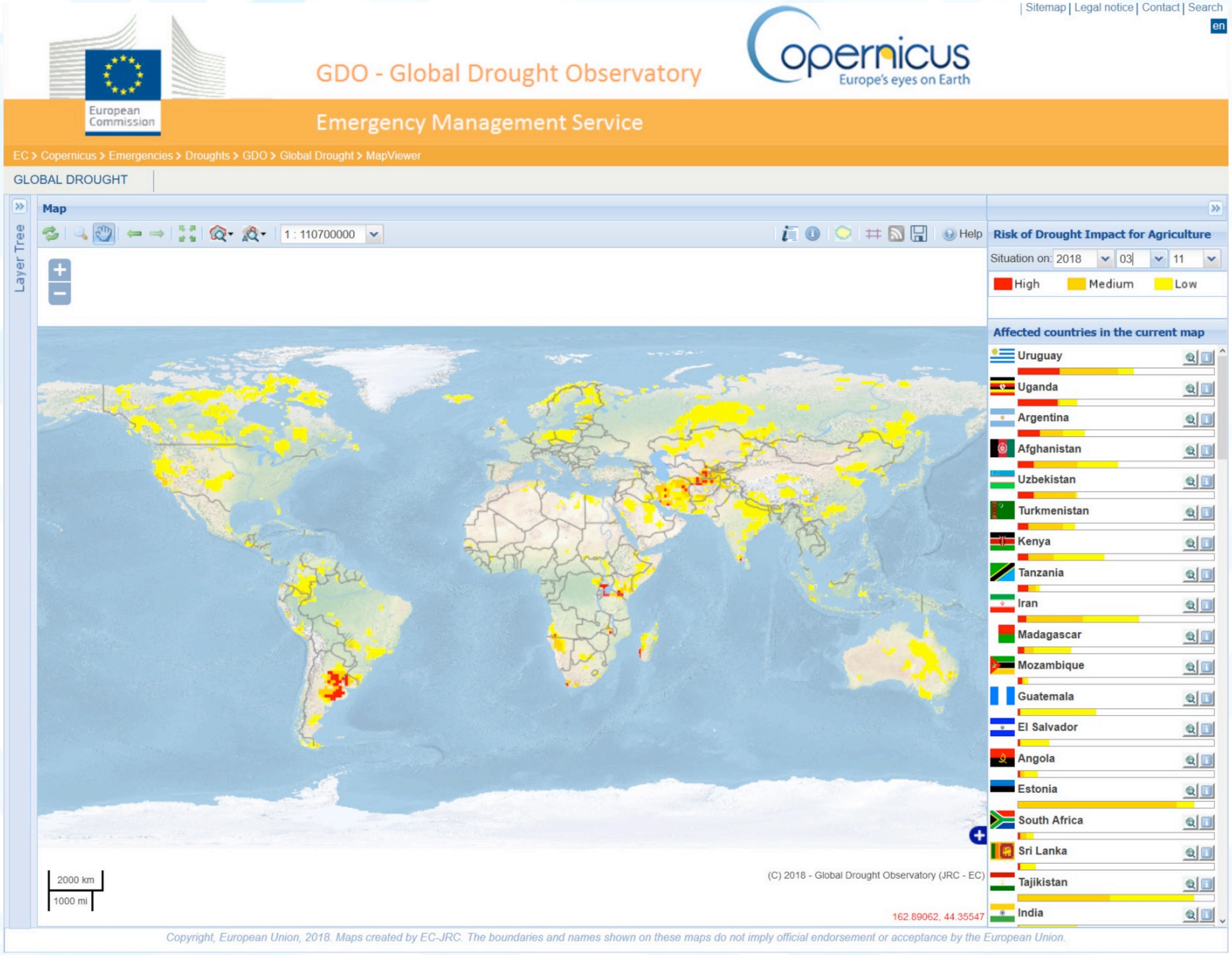
- Drought vulnerability maps should be developed well in advance of the onset of a drought
- Advice based on drought risk assessment may lead to adjustments in crop selection, cropping patterns and water use efficiency measures

Drought monitoring

Drought monitoring consists of a

- remote sensing component (SMDI: soil moisture drought index, [CDI: combined drought index = PDI: precipitation drought index & TDI: temperature drought index & VDI: vegetation drought index], DSI: drought severity index) (A),
- a climate component (precipitation index, drought severity index) (B) and
- a biophysical component (land use/land cover type, soil characteristics (including soil moisture), elevation, ecological setting) (C).

Example global drought observatory



Global drought observatory - https://edo.jrc.ec.europa.eu/gdo/php/index.php?id=2001 (JRC)

Main types of extreme weather

Main types of extreme weather events (not covered in other sections):

- Heavy rainfall
- (Thunder-) storms
- Strong winds
- Dust or sand storms
- Heat waves
- (Relative) cold spells

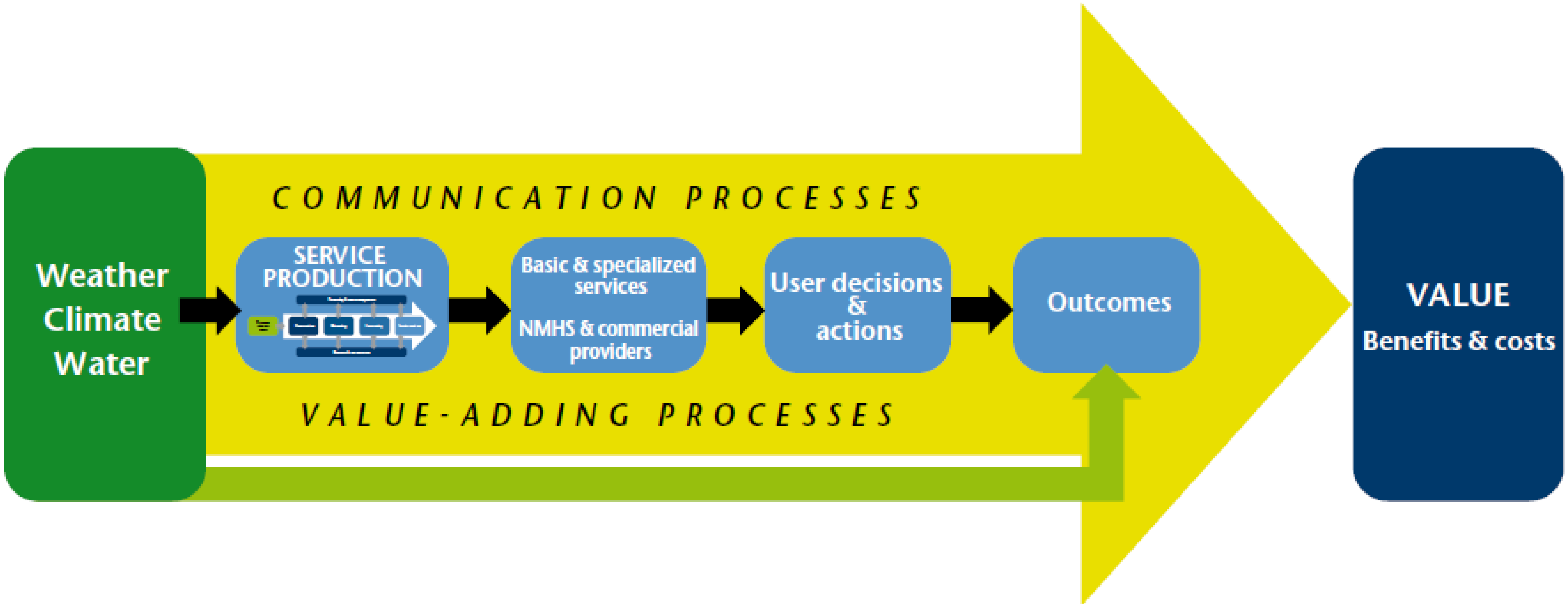
Assessment of extreme weather

Combination of historical weather analysis with actual weather forecast to assess the likelihood of extreme weather events and possible trends as a consequence of climate change.

Important data

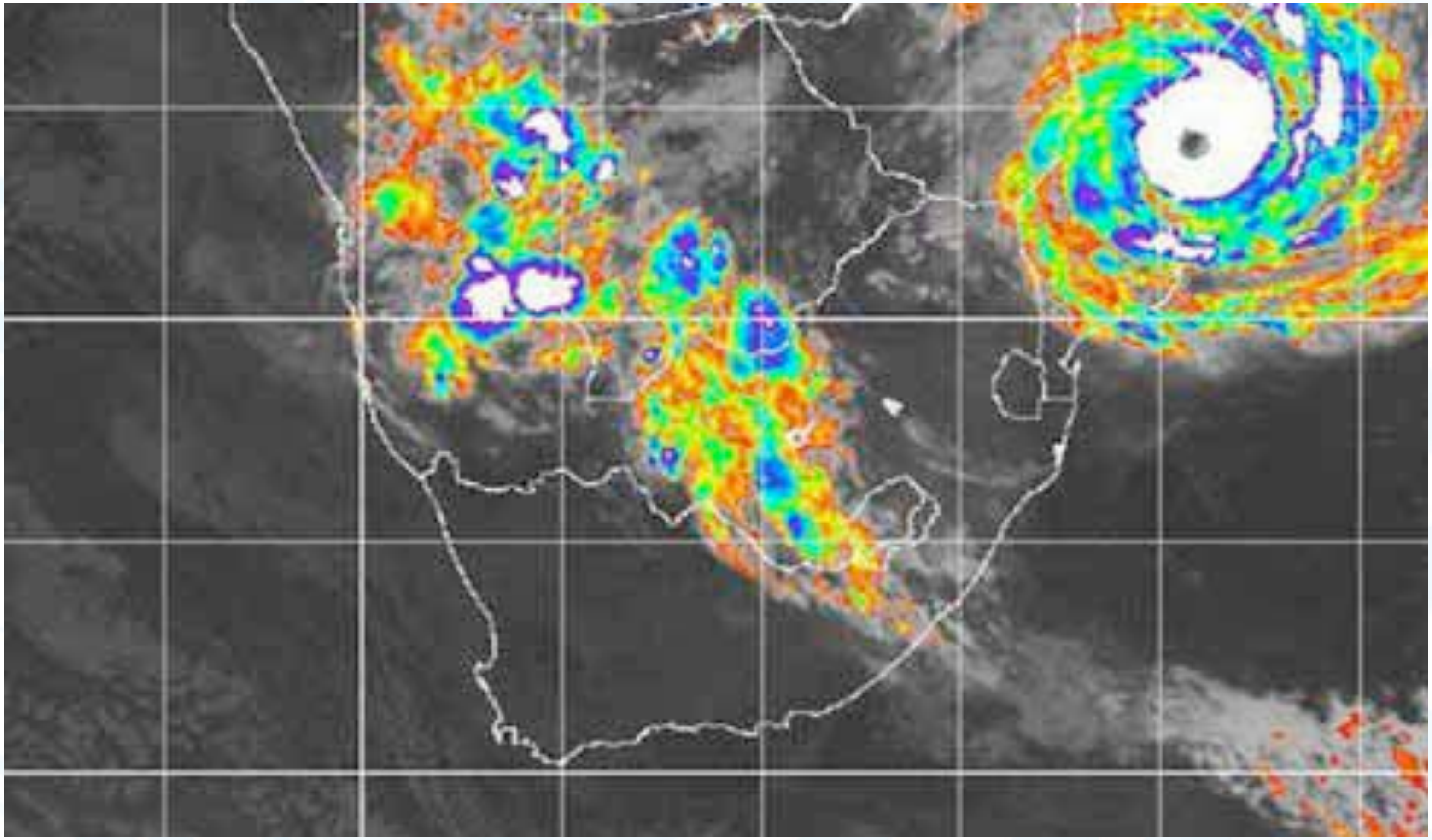
- Temperature
- Humidity
- Precipitation
- Wind
- Trend analysis

Weather, climate, water risk assessment value chain



Weather, climate, water risk assessment value chain. WMO et al. (2015). (Valuing weather and climate: Economic assessment of meteorological and hydrological services.)

Example tropical cyclone & flooding Southern Africa



Tropical cyclone Eline provoking flooding in Mozambique and Madagascar

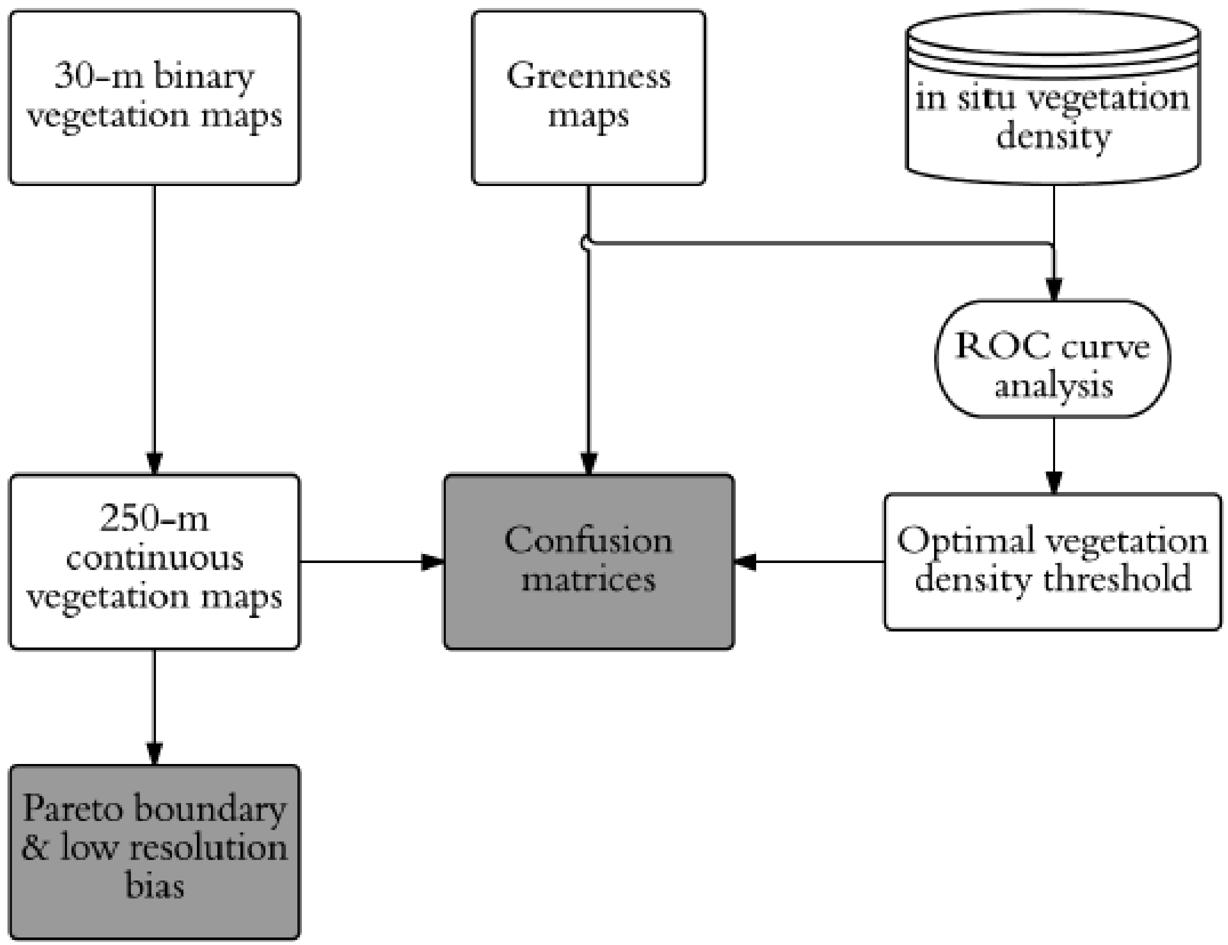
Locust early warning

Earth observation (A) combines analysis of landscape patterns (B) with monitoring of the greenness (NDVI: normalised difference vegetation index) of the vegetation (C), temperature (D), rainfall (E) and soil moisture (F) to identify good conditions for locust egg laying and hatching in arid areas.

Combination with field surveys is essential & combination with the use of drones (for spraying) is planned.

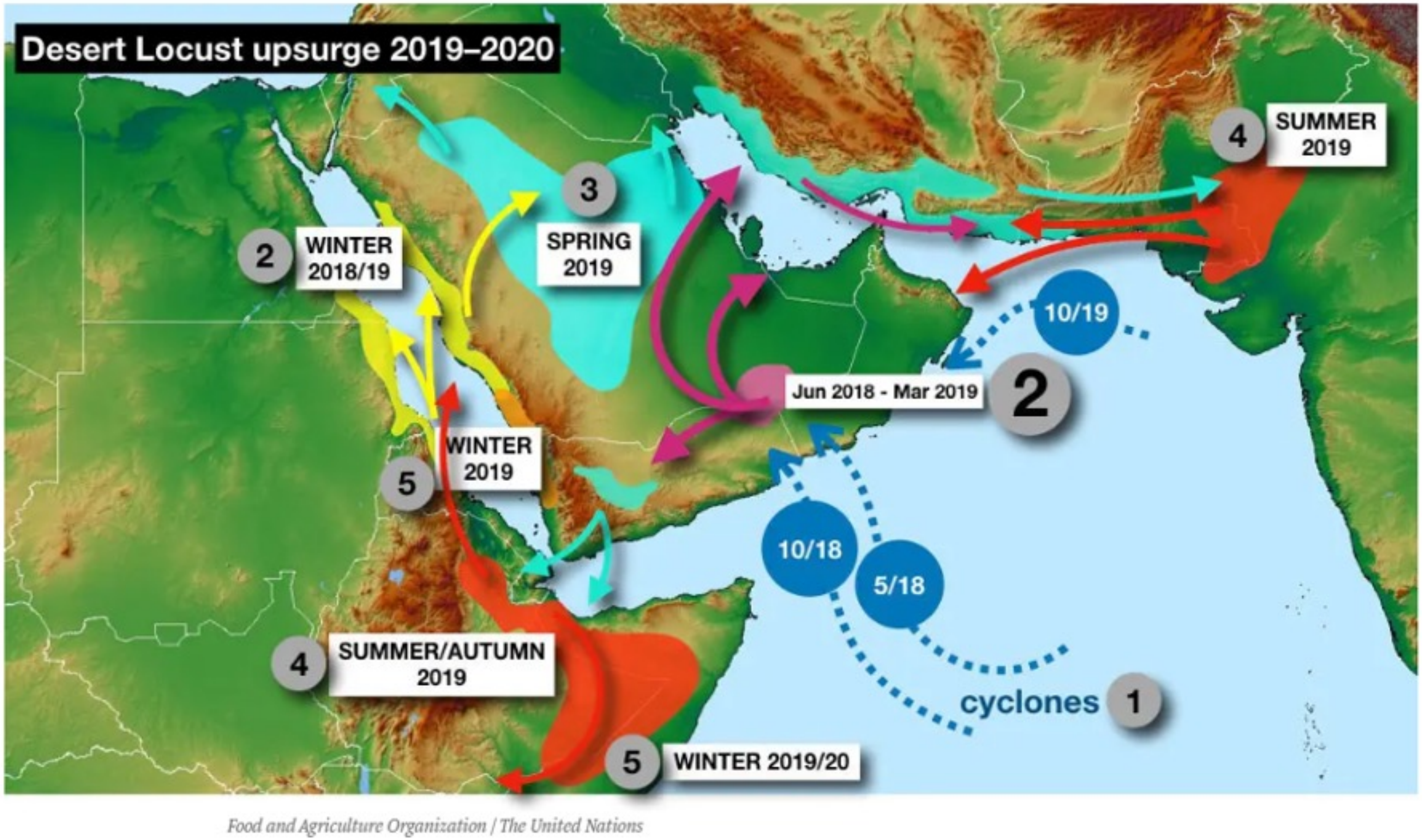
Earth observation is also important to predict the impact of climate change on locust outbreaks.

Accuracy assessment for locust warning



Flowchart of the accuracy assessment for locust warning. (Waldner, F. et al. (2015). Operational monitoring of the desert locust habitat with Earth observation: An assessment. ISPRS International Journal of Geo-Information.)

Example locust upsurge



Locust upsurge from Summer 2018 to Winter 2019/20 (FAO Locust Watch)

Earth observation for disaster monitoring & impact assessment

Earth observation provides the background information (for mapping) (A) and a synoptic overview (B) for general monitoring.

- Mapping and monitoring of flood extent, burned area, damage assessment etc.
- Support to (planning and decision-making for) rescue operations, recovery, rehabilitation and reconstruction.

Earth observation is useful as instrument for public participation (as basis for interaction on and verification of flooded areas.
Visualisation is therefore very important.

Analysis of mobile phone data helps to understand the reaction of the population to disasters (location).

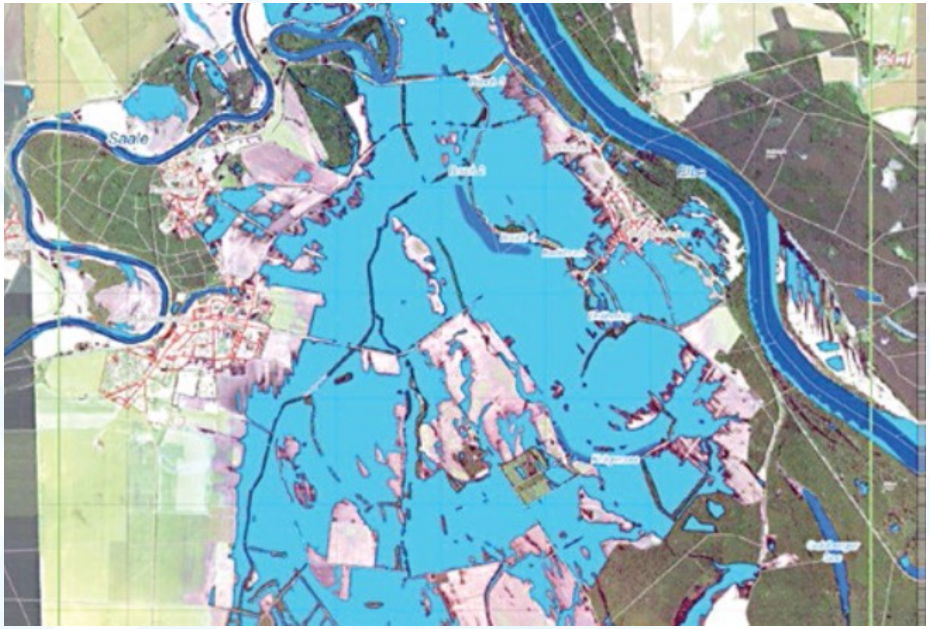
Damage assessment

Damage assessment with Earth observation reduces the need for field inspection for compensation of insurance purposes.

Apart from planning of humanitarian aid, damage assessment or inundation maps are very useful for development of preventive strategies.

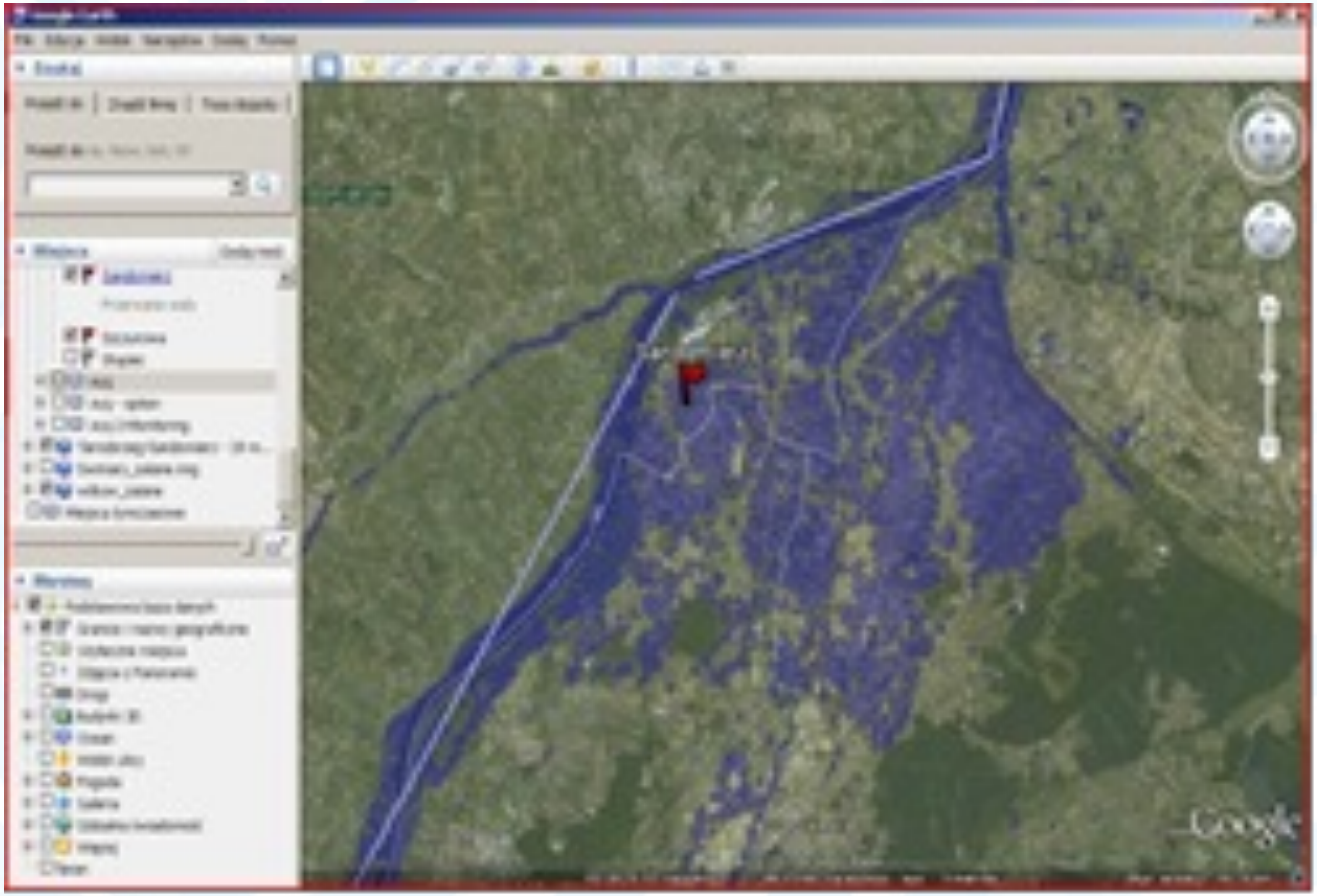
Examples flood mapping

Pre-flood situation in the agricultural area around Breitenhagen, Germany (Munich Re)



Flood on the River Elbe in the agricultural area around Breitenhagen in Germany in June 2013. The flooded area is shown in light blue, and the reference water level in dark blue. (Munich Re).

Example flood impact mapping



Flood impact maps at the Vistula River in the Sandomierz region, Poland. (SRC).

Radar

Radar is more effective for flood monitoring in case of cloud cover (an alternative is the use of optical sensors that fly beneath clouds).

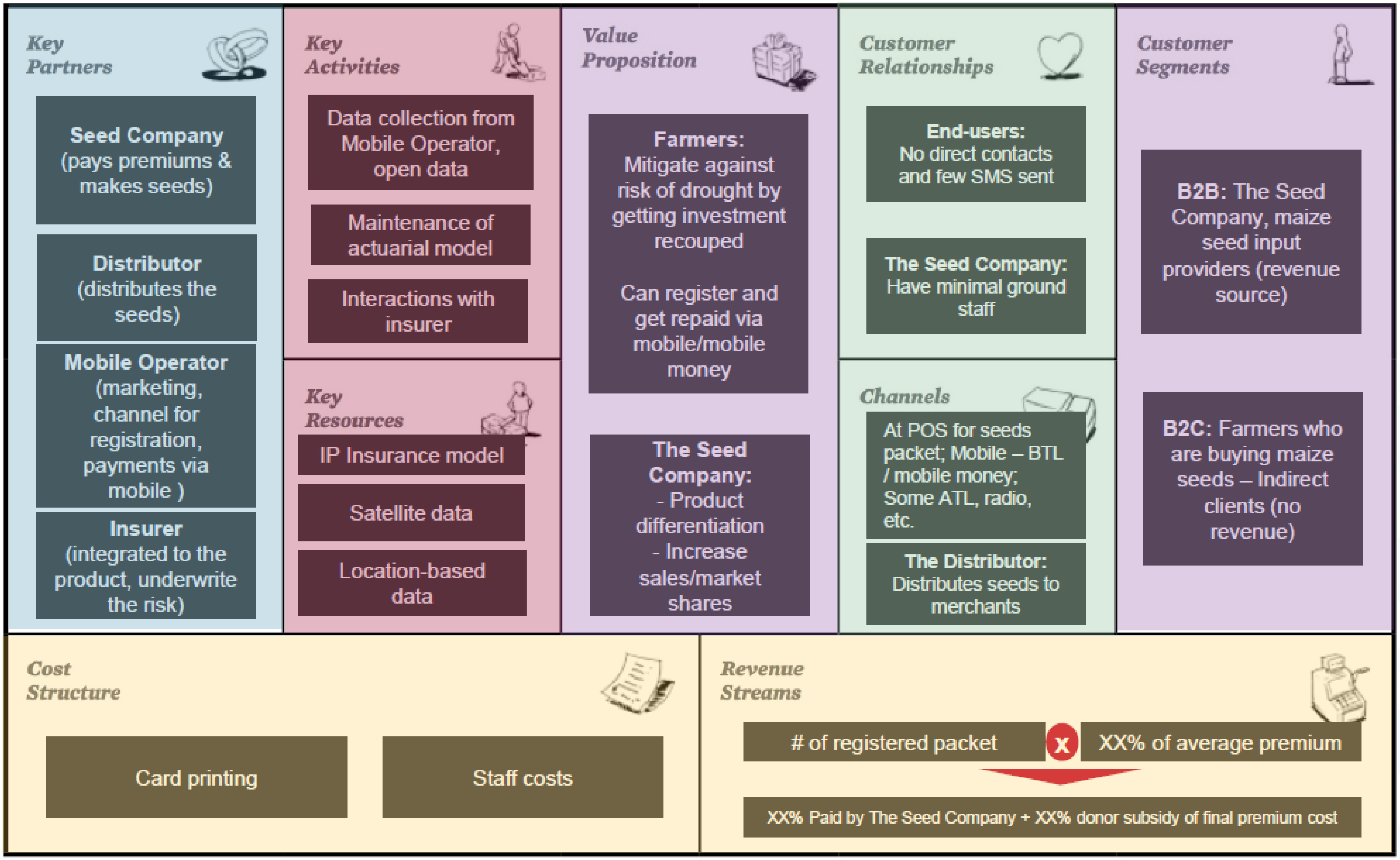
Insurance

Derisking of farming operations and provision of a safety net through insurance against extreme events and/or reduced yields.

Earth observation contributes to the following elements that are relevant to both indemnity and index-based agricultural insurance:

- Plot identification
- Crop identification
- Crop monitoring
- Yield estimation
- Loss event monitoring
- Verification
- Risk assessment
- Determination of insurance product indicators (based on various factors, such as analysis of historical risks and area and season stratification)

Example business model canvas micro-insurance



Business model canvas micro-insurance. (GSMA (2015). Micro-insurance in mobile agriculture – Case study & takeaways for the mobile industry.)

Earth observation for agricultural index insurance

Products have been developed, based on Earth observation data that relate to:

- Precipitation
- NDVI (normalised difference vegetation index)
- Evapotranspiration
- Drought
- Extreme weather
- Soil moisture

By using Earth observation and making use of the index approach, the need for (costly) field inspections is reduced considerably.

Challenges

Although there are many initiatives for Earth observation-based index insurance, most are still in the pilot or early operational stage.

Determining the right basis premium based on available data (EO time series plus in-situ data) is still a challenge.

Even in developed countries, there are no agricultural insurance schemes, which are not, directly or indirectly, supported by the government.

Bundling of (index-)insurance services with other services (that make use of satellite information) seems the most promising option.

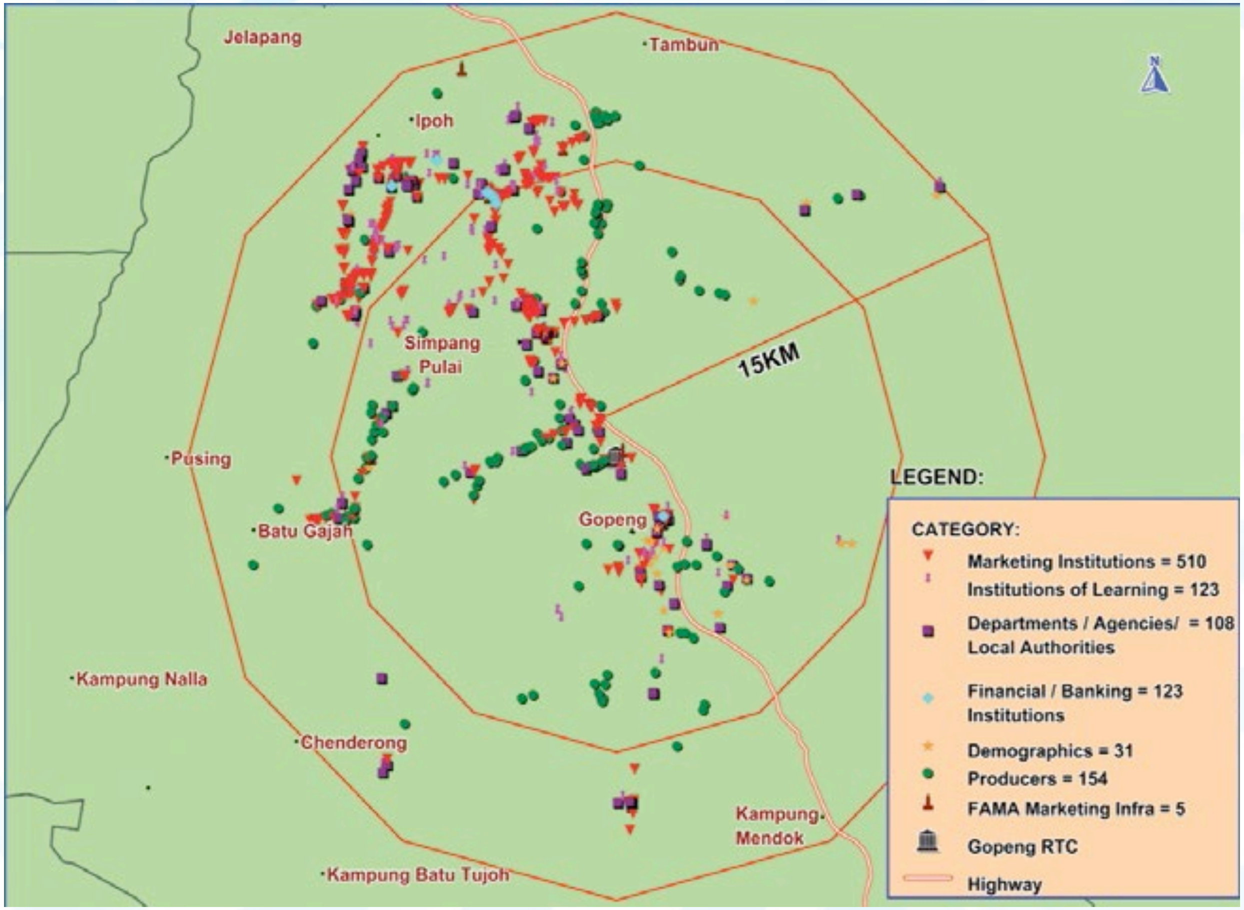
Market access

Market access deals with the availability and planning of transport infrastructure and transport to market (food chain management, including post-harvest losses).

Earth observation can be used to analyse the opportunities and constraints for optimum market access of agricultural produce, and to support decision making for planning and improvement of infrastructure, storage and market facilities.

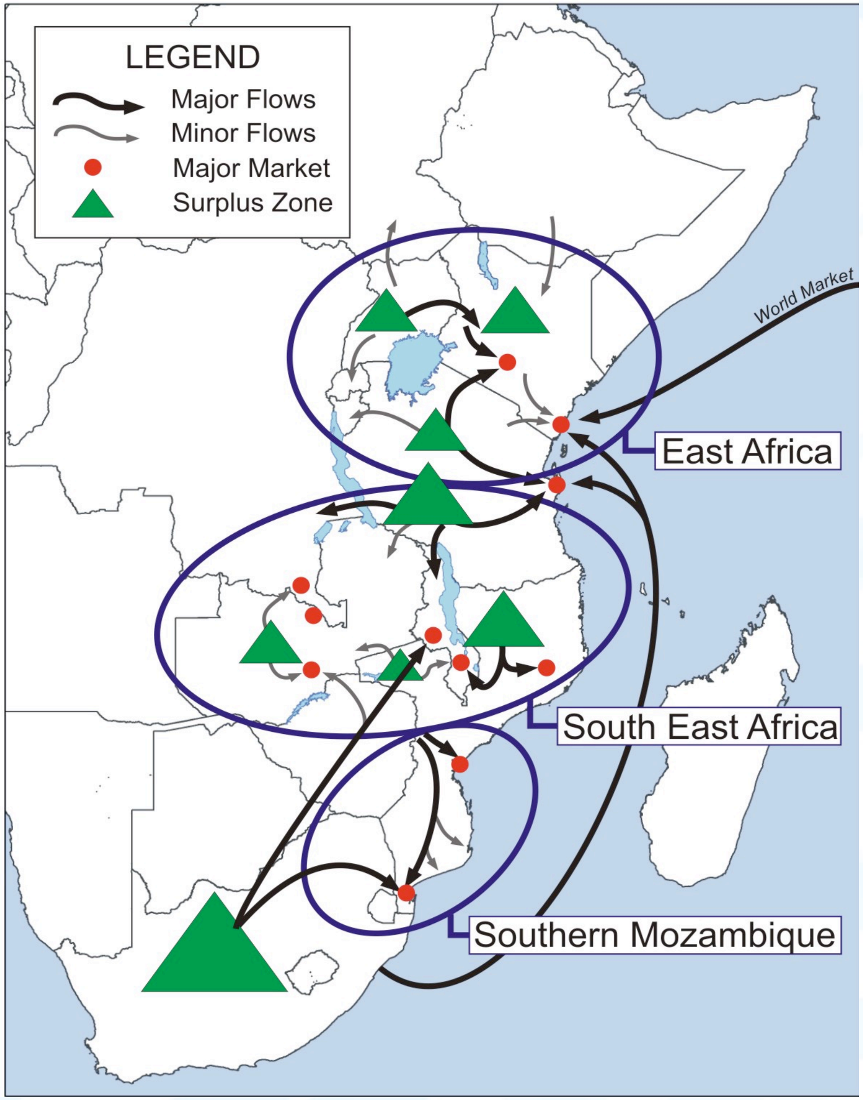
Earth observation provides the base layer for spatial information analysis (including crowd-sourcing) and monitoring of agricultural activities (crop growth and land use changes).

Example mapping agricultural plots in relation to markets



Map of plot locations in relation to markets and extension services (profiling study, Malaysia)

Example mapping maize trade flows



Maize Market Sheds in Eastern and Southern Africa. (MSU (2010). Unscrambling Africa: Regional Requirements for Achieving Food Security).

Determination of land property and land rights

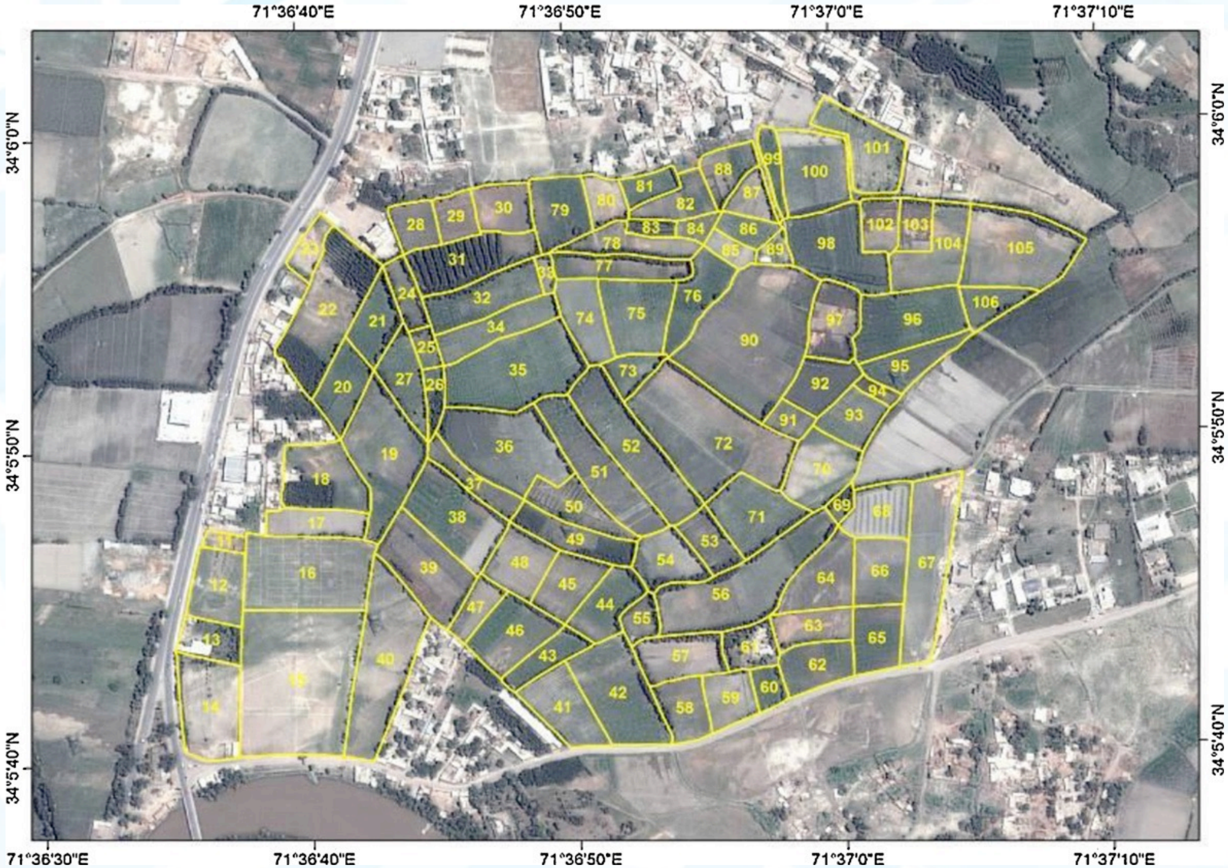
Earth observation facilitates rapid mapping and change monitoring (A).

Earth observation supports high-speed cadastral surveying (B), especially in rural areas.

Satellite images can provide the base layer for a participatory approach to land administration (C) and help increase transparency (D) of the process.

At a more informal level, identification of properties and plots (E) (through geo-location) is needed for reception of individual agricultural advice, participation in insurance schemes and eligibility for receiving credit.

Example digitised parcel boundaries



Digitised parcel boundaries on QuickBird high-resolution satellite image in Zormandi area. (WB. First experiences using high-resolution imagery-based adjudication approach in Ethiopia).

Challenges

Official cadastral surveys usually take a long time to complete, more informal approaches are often not recognised (A) by the authorities concerned.

Considerable investment (technical infrastructure and human resources) (B) is needed.

Strength of institutions (C) also plays a role.

A participatory approach, based on satellite data, fits with land administration concepts, such as those behind the Social Tenure Domain Model and affordable Cadastral Index Mapping.

Earth observation provides information

Directly on

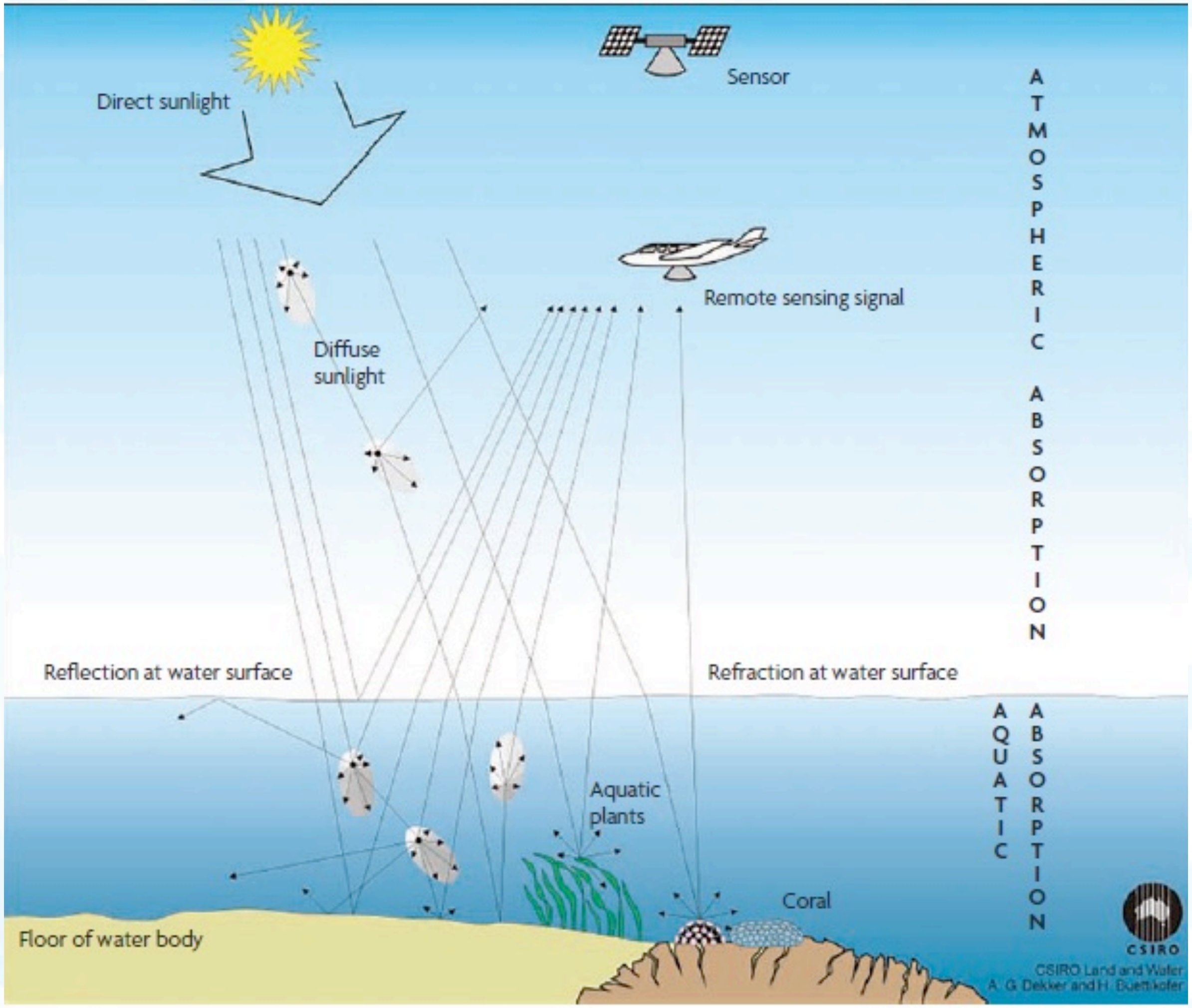
- Chlorophyll (Chl-a)
- Cyanobacterial pigments
- Coloured dissolved organic matter (CDOM)
- Total suspended matter (TSS)

Indirectly on

- Vertical attenuation of light coefficient
- Turbidity

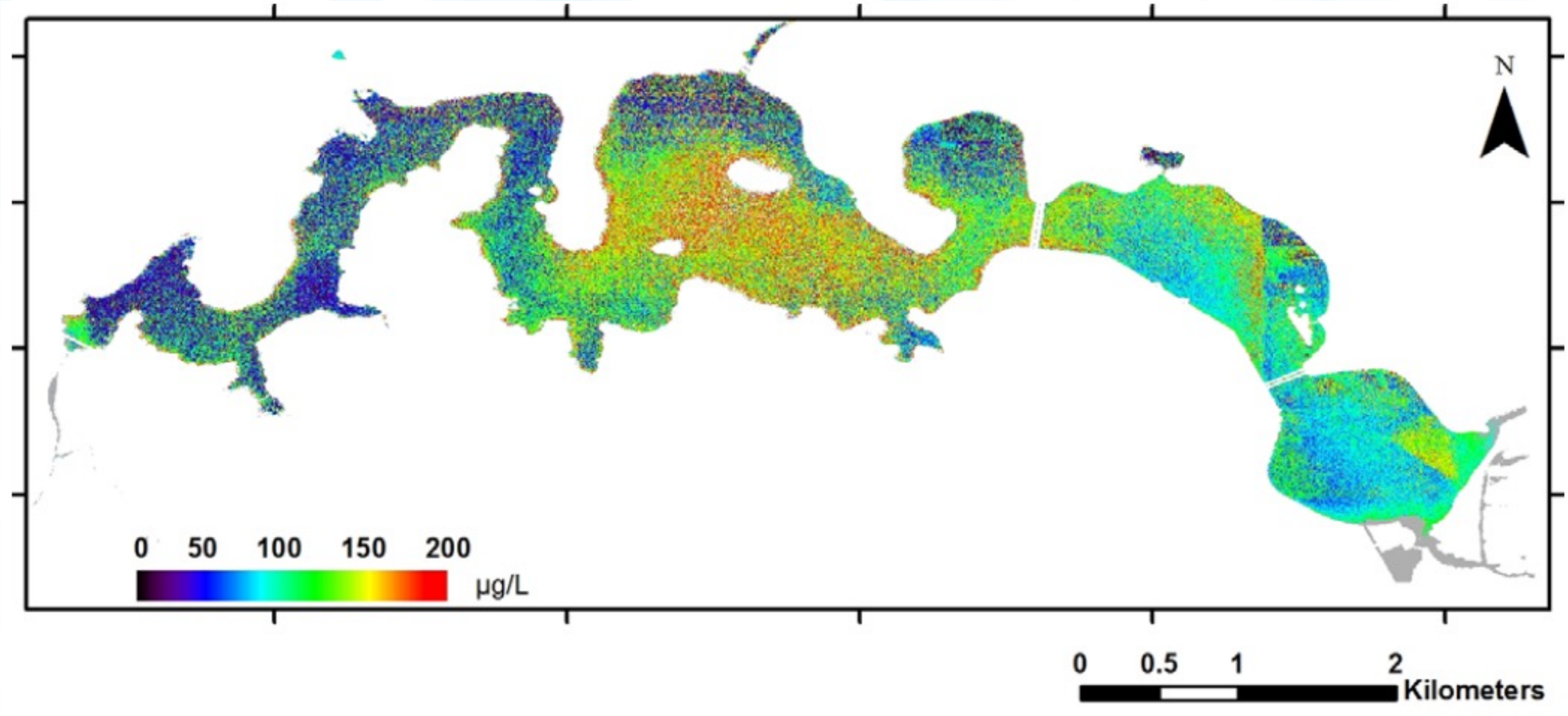
Optical imagery is used for this purpose and needs to be complemented by field measurements.

Example optical Earth observation for water quality monitoring



Schematic of the light interactions that drive optical EO involving the air, water, and substrate. (World Bank (2016). Earth observation for water resources management - Current use and future opportunities for the water sector.)

Example chlorophyll concentration in a lake



Chlorophyll concentration in Lake Burley Griffin from a Worldview-2 image, 17 March 2010. Dekker, Hestir (2012)

Long-term water resources assessment

Water resources assessment is used for long-term planning and climate change scenarios.

Earth observation facilitates the accurate and continuous observation of the long-term dynamics of the different key variables governing the energy and water cycle processes from global to local scale.

Source: WB; 2016

Earth observation is useful for

- Land use and land cover mapping and change monitoring
- Water abstraction estimation with respect to crop water demand for irrigated areas
- Refined land use / land cover mapping
- Identification of surface water bodies or pools (location, extent, dynamics)
- Digital elevation models and derived products
- Estimates of basin-wide evapotranspiration and precipitation
- Water and vegetation monitoring (entire aquifer)
- Ground subsidence monitoring and its correlation with groundwater abstraction

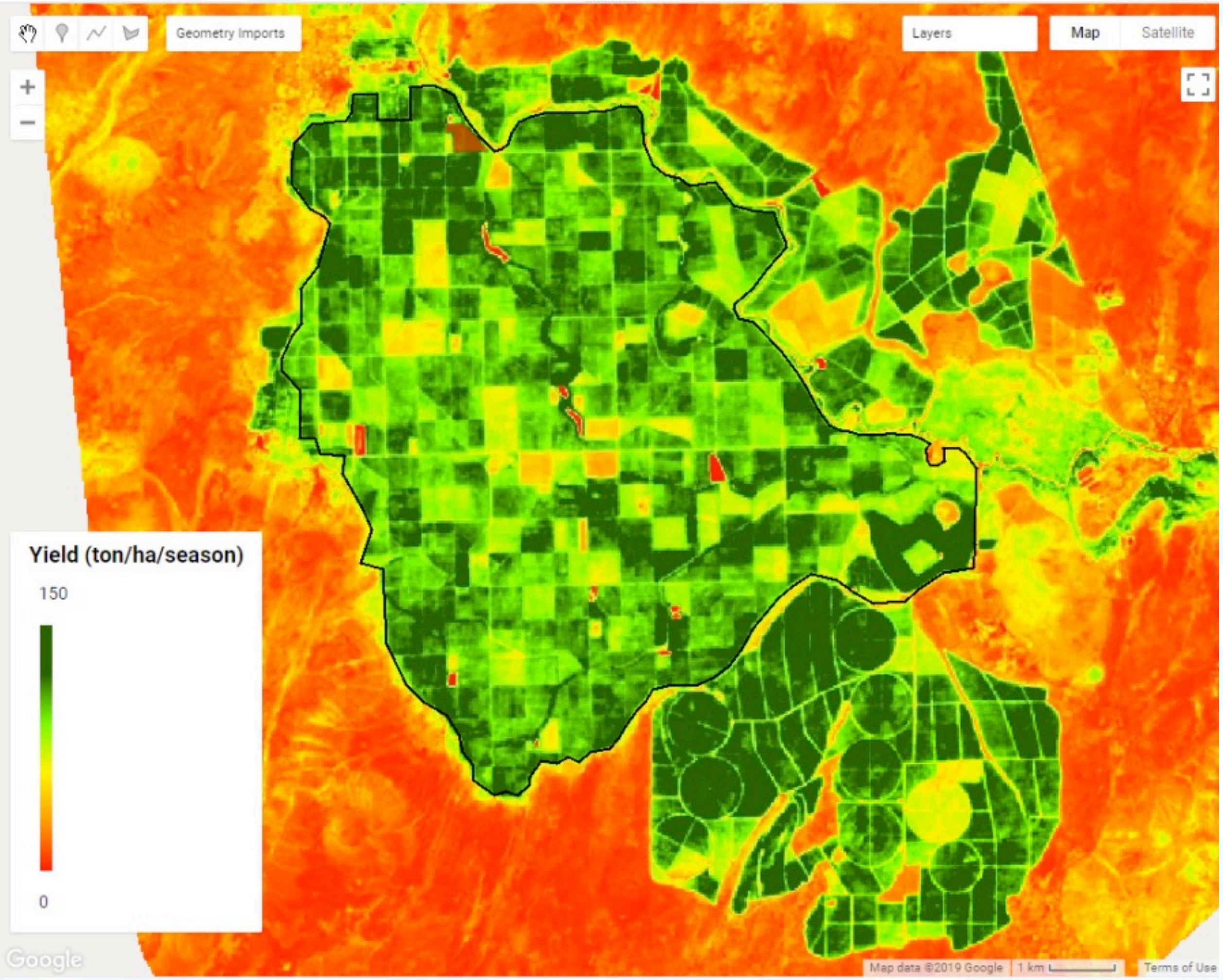
Source: WB; 2016

Water Productivity through Open access of Remotely sensed derived data (WaPOR)

- Hosted by the Food and Agricultural Organisation of the United Nations (FAO)
- Database that uses satellite data to monitor agricultural land and water productivity throughout Africa and the Near East
- Access to 10 years of continued observations over Africa and the Near East
- Open access to various spatial data layers related to land and water use for agricultural production and allows for direct data queries, time series analyses, area statistics. data download of key variables
- To estimate water and land productivity gaps in irrigated and rain fed agriculture, monitor trends of water use in irrigated areas, assess the influence of droughts on agricultural production

http://www.thewaterchannel.tv/dossiers/water-productivity/wapor

Example WaPOR derived yields sugarcane



WaPOR derived yield for sugarcane in 2015 for the Wonji irrigation scheme, Ethiopia
(Source: IHE Delft)

Challenges

Some elements, such as groundwater re- or depletion can only indirectly and not very accurately be determined with the help of Earth observation.

For hydrological modelling, a combination with in-situ measurements is needed and an ensemble approach, where different types of data are combined, works best.

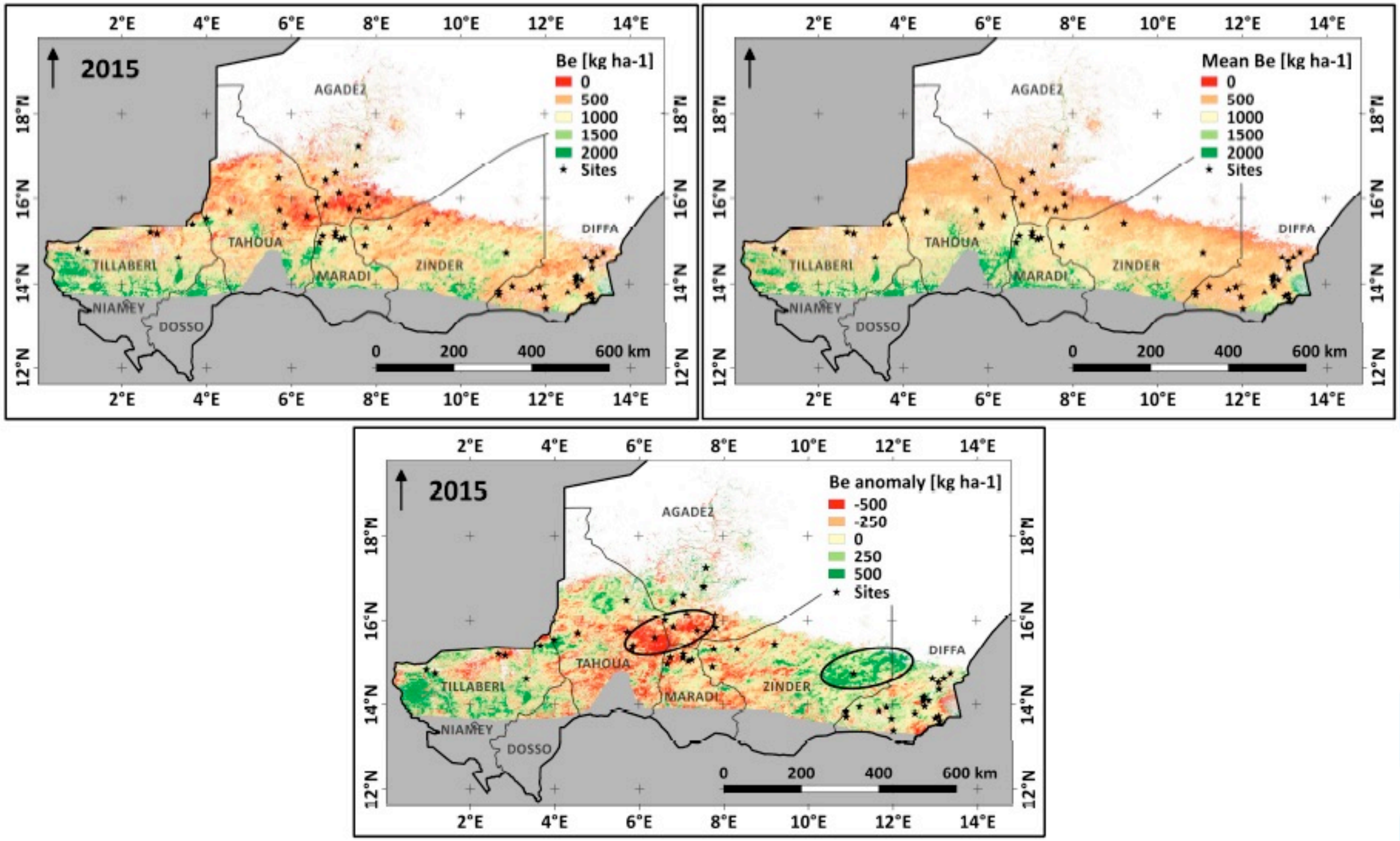
Monitoring of pastures & water bodies

- Analysis of time series
- Identification of start (and end) of season
- Quality of pasture land (assessment of ‘greenness’ of vegetation) = biomass availability, quality needs to be determined in-situ
  - Dry matter vegetation in kg/ha
  - Anomalies in biomass & early warning for deficits
  - Distinction between pasture & agricultural land
- Identification & quality of water points or water areas (surface water availability) (optical imagery)
  - Estimation of water availability
  - Distance of pasture to water point
  - Anomalies in water availability & early warning for deficits
- Rainfall information
- Early warning (analysis of historical trends & forecast), including detection of overgrazing

Other information

- Land use
- Migration model
- Climate change effects
- Market and price information
- Pastoralists surveys

Example estimated biomass



Estimated biomass (Be) for 2015 based on the biophysical model (upper left), mean Be for the years 2001–2014 (upper right), and Be anomaly for 2015 (bottom), calculated as the difference between Be for 2015 and mean Be for the years 20 30. Conflict prevention & resolution (Niger).
Source: Schucknecht et al.; 2017

Land degradation & erosion: Monitoring of large areas

Earth observation is used for the monitoring of large areas and therefore excellently suited for change detection and trends, such as

- Soil degradation
- Deforestation
- Desertification

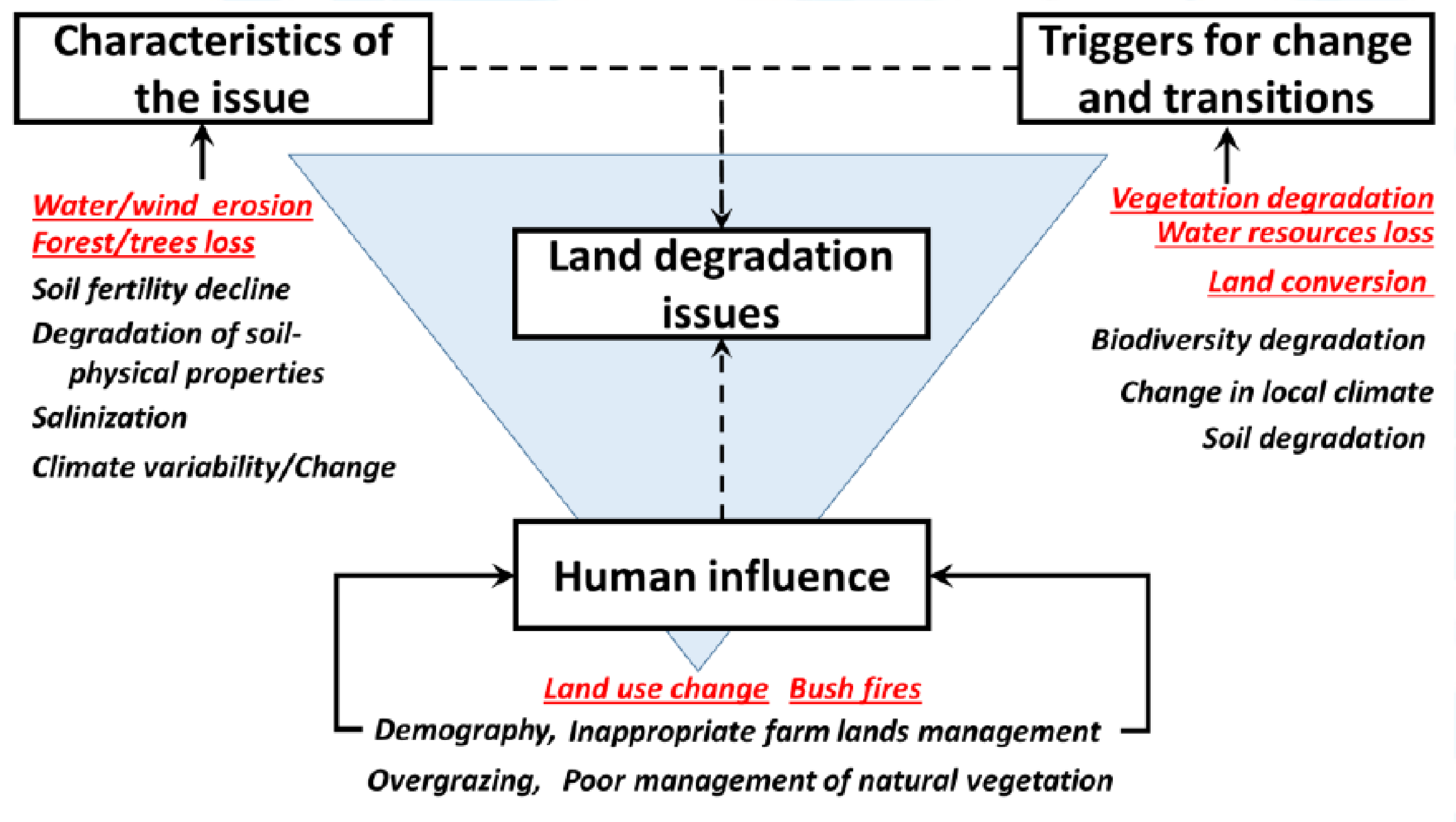
Earth observation measures vegetation parameters, such as

- Greenness
- Surface reflectance

And measures biomass hydrometeorological parameters, such as

- Evapotranspiration

Land degradation measured with remote sensing



Land degradation linkages (* red underlined text indicate the factors that can be monitored using remote sensing indicators). (Mbow, C. et al. (2015). What four decades of earth observation tell us about land degradation in the Sahel? Remote Sensing.)

Thank you

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