SIGMA

Stimulating Innovation for Global Monitoring of Agriculture

FINAL REPORT

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PROJECT FINAL REPORT

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0.2	15/07/2017		Inputs and updates	All
1.0	27/09/2017		Final update	S. Gilliams

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1. Final publishable summary report

1.1 Executive Summary

By 2050, global agricultural productivity will need to increase with at least 70%. In order to guarantee food production for future generations, agricultural production will need to be based on sustainable land management practices. At the start of SIGMA, earth observation based (global) crop monitoring systems focus mostly on short-term agricultural forecasts, thereby neglecting longer term environmental effects. However, it is well known that unsustainable cultivation practices may lead to a degradation of the (broader) environment resulting in lower agricultural productivity. As such, agricultural monitoring systems need to be complemented with methods to also assess environmental impacts of change in crop land and shifting cultivation practices. It is thereby important that this is addressed at the global level.
In 2002, the Group on Earth Observations (GEO) was formed at the Summit on Sustainable Development in South Africa. Its main vision is to build a Global Earth Observation System of Systems (GEOSS) through globally coordinated activities based on remote sensing. Sustainable agriculture is one of its core domains. In June 2011, G20 launched its 'Global Agricultural Geo-Monitoring' (GEOGLAM) and the Agricultural Market Information System (AMIS) initiatives. The main objective of GEOGLAM is to improve crop forecasts and, thereby, to increase transparency on agricultural production, through the creation of an operational global agricultural monitoring 'system of systems' based on Earth Observation and in situ observations.
SIGMA as part of Europe's contribution to GEOGLAM, actively networked with expert organizations world-wide, in a common effort to enhance current remote sensing based agricultural monitoring techniques. Its aim was to develop innovative methods and indicators to monitor and assess progress towards "sustainable agriculture", focused on the assessment of longer term impact of agricultural dynamics on the environment and vice versa.

SIGMA developed remote sensing based methods to identify, map and assess:

- Agriculture and crop land changes, globally, regionally and locally
- Changes in agricultural production levels and shifts in cultivation practices
- Environmental impacts of Agriculture

As described in this final report SIGMA achieved all its targets and goals;

- SIGMA can be considered as a major contribution to GEOGLAM, by being actively involved in the GEOGLAM and JECAM Network. Actively promoting and using this network through the cross site experiments set up in SIGMA.
- SIGMA enable sharing and integration of satellite and in situ observations according to GEOSS Data CORE principles
- Updated cropland maps at different scales were made available to the wider community, based on newly developed methodologies were tested at local, regional and global scale
- Analysis on data gaps and country needs were made and based on this information training sessions and workshops were developed
- Agricultural productivity and yield gaps (the difference between avtual and potential yields) were assessed making use of new integrated time series of EO based products and updated crop yield estimation techniques
- Global changes of Land use and impacts of land use change under different scenarios were analyses and results were published.
- Capacity building material was developed and workshops organized

All SIGMA products are available through the SIGMA Product Distribution Facility. SIGMA implemented activities in Europe, Asia, Africa and Latin America and was financed through the EC's Research Framework programme (FP7).

1.2 Concept & Objectives

1.2.1 Context

Sustainable agricultural growth is a critical component in efforts to meet the demands and challenges faced by agriculture worldwide and discover new opportunities for poverty reduction in the developing and transitional world. Agriculture's capacity to feed the world is under threat from a combination of existing- and emerging trends and challenges, whilst global hunger and malnutrition remain pervasive. As the global population is anticipated to reach more than nine billion by 2050, food production will need to grow by 70% worldwide, and up to 100% in developing countries, according to the United Nations (UN) (2015). Sustainable and well-balanced planning and management of agricultural resources are essential to achieve this. In this regard, the Earth Observation Community can contribute to some extent by improving the monitoring capacities on agricultural production.

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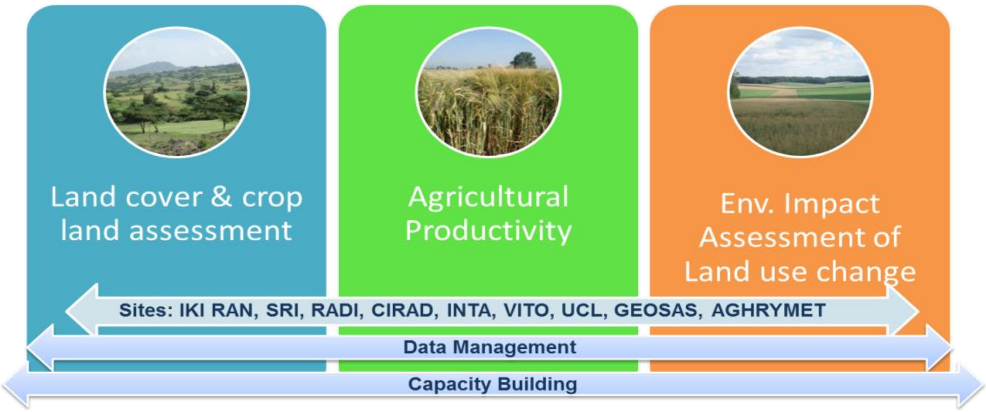
    - Environmental impacts of Agriculture

SIGMA deployed capacity building and data management activities on the above topics.



SIGMA main activities

In order to design and develop methods to assess/monitor (longer term) impacts of agricultural dynamics, as a contribution to GEOGLAM, it was important to thoroughly understand the currently used practises at a global scale. The GEO Agriculture Community of Practise describes a number of national and international agricultural monitoring systems, such as EC JRC/MARS (Monitoring Agricultural Resources), FAO/GIEWS (Global Information and Early Warning System), China's CropWatch, and the USDA FAS (Foreign Agricultural Service).

In generic terms, most of these systems have a combined approach using time series of satellite and meteorological data, a "static" crop map mask, agro-meteorological models and a statistical tool box, resulting in **within-season** crop yield estimates, area estimates and production forecasts. As a consequence, little attention is given to **pluri-annual** changes such as shifts in cultivation practises (*intensification*), expansion or abandonment of agricultural land (*expansion or shrinking*).

Both intensification and expansion of agricultural land were the primary focus of SIGMA.

In summary, SIGMA developed methods and products that enable us to answer the following sustainability questions:

How and where do changes in crop land distribution affect other ecosystems?

How and where do changes in cropping systems and cultivation practices affect environmental and sustainability options?

How can we ensure integration of developed methods in global monitoring systems?

1.2.2 Objectives

To answer the above mentioned questions the project was broken down into five main objectives:

Objective 1: Identify, map and assess agriculture and **crop land changes**, globally, regionally and locally (shifts in agriculture including expansion and shrinking of areas)

- Identification and mapping of **crop land change and extent**, to increase understanding of the relationship between crop land and other ecosystems, as well as its environmental impact. The approach envisaged relies on GAEZ-based stratification (Global Agro-Ecological Zones), automated image processing procedures and statistical procedures quite similar to the GEOLAND SATCHMO methodology, as such ensuring efficiency and complementarity, but for our purpose focussed on crop land. This entails a sampling based statistical analysis complemented by annual global full coverage mapping of crop land and crop land change.

Objective 2: Identify, map and assess changes in **agricultural production levels** and shifts in cultivation practises (agricultural intensification)

- Mapping **potential and actual shifts in productivity and cultivation practices**, to increase knowledge about agricultural system change in order to better understand its impact on the environment. *Actual* shifts will be assessed through exploring crop type mapping techniques and trend analysis of key remote sensing based environmental parameters in order to identify seasonality changes and hot spots of change. *Potential* shifts will be assessed by evaluating crop yield gaps and as such identifying areas for future agricultural intensification. Time series of advanced indicators from European satellite sensors (specifically the Sentinel series) will be analyzed and robust methods will be developed to identify and map (global) seasonality changes, characterizing agricultural systems (globally) and cropping systems (locally).

Objective 3: Identify, map and analyze **environmental impacts** of Agriculture and cultivation practices

- Assessing the various possible **environmental impacts of agriculture and cultivation practice**, focusing – depending on the study site - on issues such as water abstraction / availability, GHG emissions, biodiversity, pollution and other environmental (socio-economic) impacts. Global (EPIC, GLOBIOM) and/or local models (WOFOST, SWAP, ANIMO, SARRAH) will be calibrated and set up to assess, according to future demand for food, feed, fibre and bio fuels the impact on water requirements, (abiotic) stress conditions and nutrient leaching among others, based on the available crop and cultivation monitoring information. Results from various study sites will be compared, and an assessment of the environmental impacts of change in agriculture and cultivation practices will be done, focusing on the added value of Earth Observation for agro-environmental monitoring.

Objective 4: Ensure data interoperability and accessibility of the data to the GEOSS Data-CORE to support the development of a global system of systems for crop monitoring

- Coordinate **EO and in situ data collection and dissemination**, to facilitate data sharing and exploitation among the consortium partners, the larger agricultural monitoring community and the wider scientific community. A Web-based portal will be set up consisting of three main components: i. a data exploitation portal integrating data from various sensors and sources (based on Geonetwork and GEOSMIS technology); ii. a mechanism to integrate and explore expert knowledge and in situ observations based on Geo-Wiki technology; iii Geonetcast.

Objective 5: Increase "Agro-environmental" monitoring capacity and awareness at the global, regional and local level and identify data and knowledge gaps

- **Strengthen national and international capacity**, to enable integration of the developed systems into a global observation system for the assessment of the impact of cropland areas and crop change on the environment. Based on the methods developed, training packages will be produced and training will be conducted in selected countries and regions. The selection of the countries will be based upon the method developed by FAO, which takes into account the importance of agriculture (both national and as a contribution to global food production), share of rural population and level of statistical development.

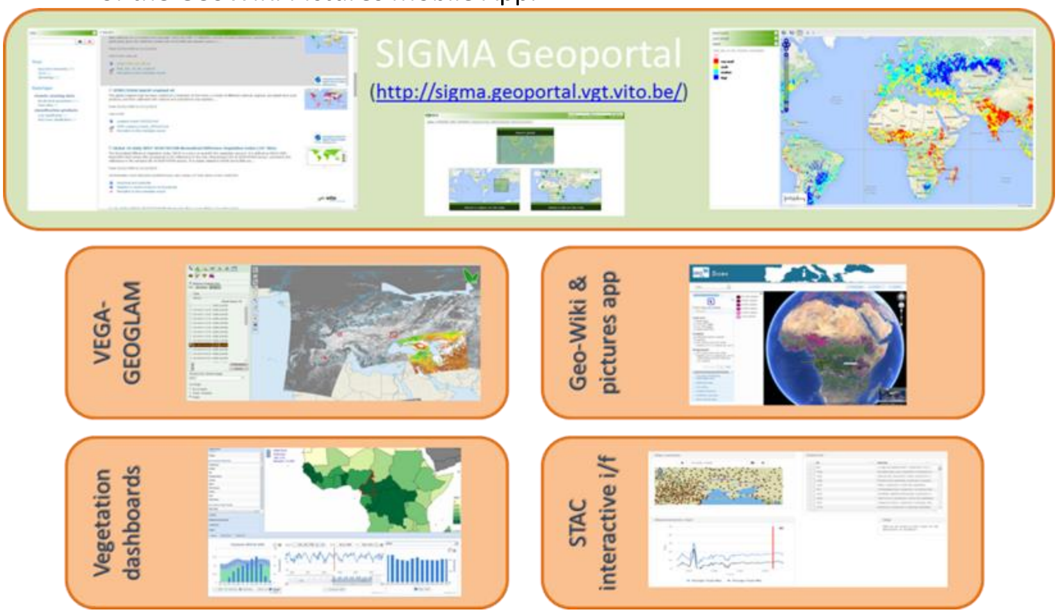
Through these 5 objectives SIGMA contributed to the establishment of a global observation system for the assessment of the impact of cropland areas and change on the environment and as such strengthen global agricultural monitoring by improving the use of Earth Observation for crop production projections.

1.3 Main Scientific and Technical Results

1.3.1 Data Coordination and Dissemination

The goal here was to coordinate the collection of Earth Observation and in situ data and their dissemination and to facilitate data sharing and exploitation among the consortium partners, the larger agricultural monitoring community and the wider scientific community. The main results, clearly indicating that the objective 4 set out at the start of SIGMA was met, are listed here;

- An operational Product Distribution Facility, as a geoportal providing access to the output products from the SIGMA project. The geoportal is accessible at sigma.geoportal.vgt.vito.be and provides also access to the other components from WP2 as listed in the next bullet points. In this task VITO also supported the project partners is documenting their output products with INSPIRE compliant metadata and appropriate publishing of the data.
- An operational VEGA-GEOGLAM system is available at http://vega.geoglam.ru/, acting as EO (HR and MR) and in-situ data analysis facility over all JECAM sites and large part of Eurasia. The VEGA-GEOGLAM is focused at facilitating agricultural lands and crops state analysis using vegetation indices time-series based on its seasonal and multi-annual dynamics at every single point or user-specified polygons.
- A Time Series viewer prototype, originating from the ESA ESE project, is improved and validated within SIGMA. Based on these results, the application is now operationally deployed and used in (1) the Proba-V Mission Exploitation Platform (https://proba-v-mep.esa.int/applications/time-series-viewer/app/app.html) and (2) the Copernicus Global Land Service (http://viewer.globalland.vgt.vito.be/tsviewer/).
- The AgroSTAC viewer is developed as a prototype to provide a GUI to users to explore the time series of in-situ crop field data as collected in the project for the JECAM sites and open data (meteo data, …).SIGMA delivered a proof of concept available at http://agrostac.vgt.vito.be/stac.html which will be further improved in the H2020 NextGEOSS project by VITO and Alterra.
- The SIGMA branch of GeoWIKI (https://geo-wiki.org/branches/sigma/) is developed and deployed, which supported the validation of EO-based products delivered by the project. The tools supports viewing of the products and experts can as well upload in-situ observations from a modified version of the GeoWIKI Pictures Mobile App.



Overview of WP2 database management linking the different aspects

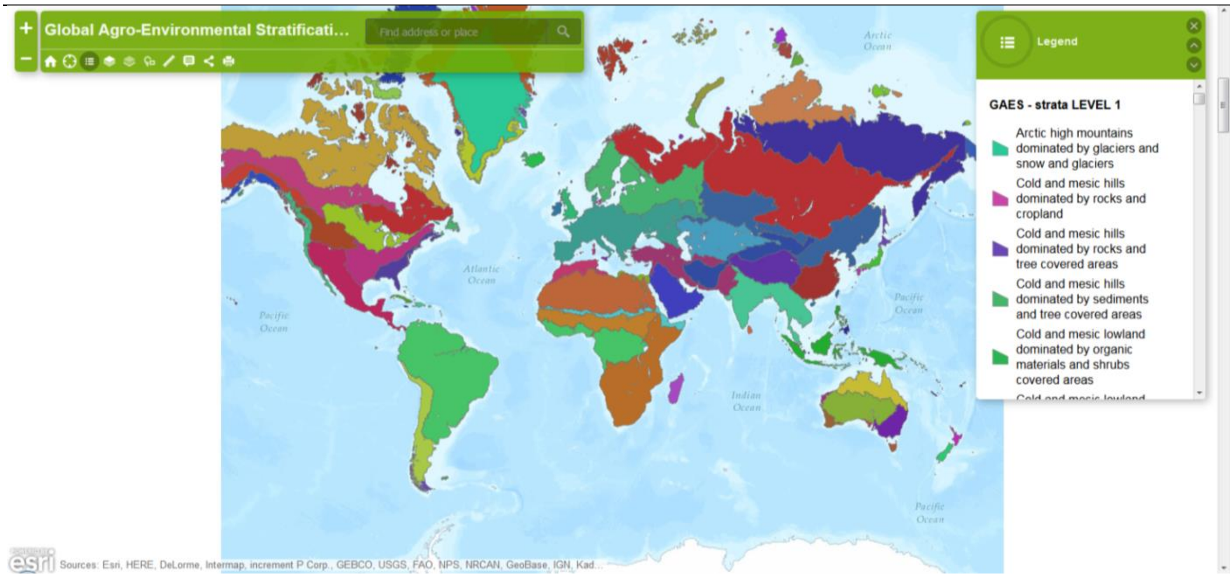
1.3.2 Land cover and cropland change assessment

The four objectives for *Land cover and cropland change assessment*, all contributed to the first objective of SIGMA which is Identify, map and assess agriculture and crop land changes, globally, regionally and locally (shifts in agriculture including expansion and shrinking of areas:

1. To capture the diversity of the agriculture at global scale by compiling all relevant existing information to describe the agricultural landscapes, the cropping systems and the growing conditions;
2. To map the global crop lands and the agricultural expansion in hot-spot areas through the development of (semi) automated methods able to regularly and timely update the information;
3. To generate crop land statistics describing quantitatively the agricultural conversion process (land use – land cover transition) at continental scale;
4. To enhance and strengthen the JECAM network by supporting their research activities as well as coordinating their field and satellite data collection. Research activities will be carried out at local (JECAM sites), national, continental and global scale in order to map the global cropland extent and assess the associated land cover changes.

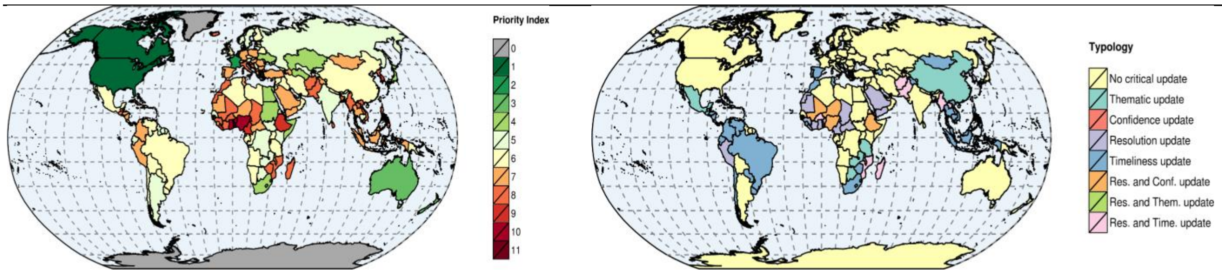
The main scientific and technical results contributing to these objectives are;

- The GAES database (version 01a) is a newly developed Global Agro-Environmental Stratification that has been designed in the first instance to support the production of a global cropland mask within the EU project SIGMA based on a strategy of exploiting a range of Earth Observation (EO) data. Nevertheless, it is anticipated that the GAES can be exploited for a wider range of applications, including others within SIGMA to make a data gap analysis to identify those strata, for which no field reference data are available on agricultural production, to assess uncertainties in existing global cropland classifications, and to assess the EO derived soil moisture products. The GAES database has four hierarchical layers with 92 attributes. A simplified legend (attribute descriptor) has been based four main characteristics:
    - Climate (16 classes: arctic, cold and mesic, cold and wet, cool temperate and dry, cool temperate and moist, cool temperate and xeric, extremely cold and mesic, extremely cold and wet, extremely hot and arid, extremely hot and moist, extremely hot and xeric, hot and arid, ,hot and dry, hot and mesic, warm temperate and mesic, warm temperate and xeric).
    - Altitude (five classes: very high mountains, high mountains, mountain, hills, lowlands).
    - Parent material (five classes: rocks, sediments, organic material, glaciers, water bodies).
    - Land cover (11 classes: artificial surfaces, cropland, grassland, tree covered areas, mangroves, herbaceous vegetation, shrubs covered areas, bare soil, sparse vegetation, snow and glaciers, water bodies).



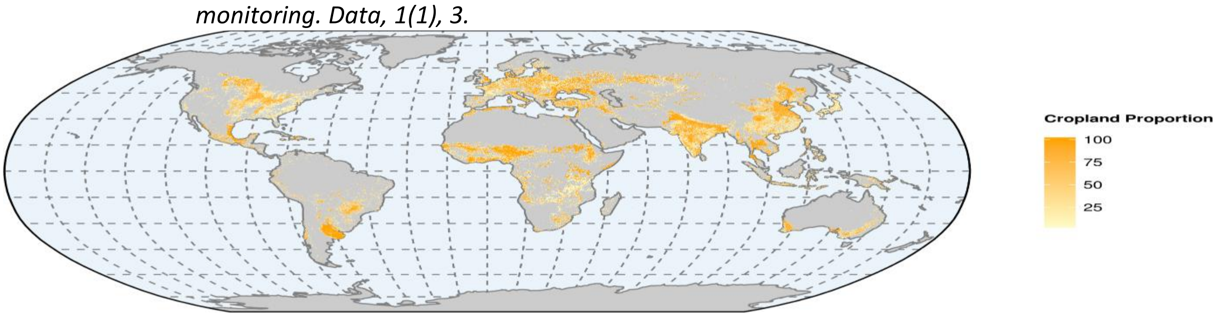
SIGMA's GAES Web app GAES strata are published as WebMapServices through FAO ArcGis Server Site and available at http://hqfao.maps.arcgis.com/apps/Viewer/index.html?appid=27f8cd872dc4488c82140636153b2adc.

- Data gap and uncertainty analysis; The results of this inventory indicated that there are large data gaps in ground-based information related to agricultural production in many African countries for the majority of sources identified, particularly for authoritative sources such as agricultural censuses. Only the validation data (from GOFC-GOLD, Geo-Wiki and other sources) have coverage across all of Africa but this varies in magnitude from country to country. However, this latter source only includes presence or absence of cropland and no other information such as yield.
- The uncertainty analysis identified the GAES strata under scenarios of low agricultural monitoring capacity and high cropland uncertainty. Using the most conservative scenario (very weak and weak agricultural monitoring capacity, high cropland uncertainty and a minimum of 10% cropland per strata), the results showed strata primarily in East Africa and the western coast of central Africa. Thus, these would be the areas to initially focus on. As the criteria were relaxed, scenario 2 resulted in an expansion to Libya, DR Congo and all of Zimbabwe, including small parts of neighbouring countries. In scenario 3, some strata appeared in west and central Africa, including almost all of Zambia, large swathes of Tanzania and DR Congo as well as small areas from neighboring countries. Finally in scenario 4, there is a small expansion of strata to the west and central-eastern part of Africa in addition to those strata identified in scenario 3. Many of these strata fall in countries prone to food security problems. These results can form the basis of guidance on where more ground-based sampling is needed in the future to improve cropland extent and estimates of production.
- Identification of priority areas for cropland mapping and construction of a unified cropland layer. Two main results need to be noted here.
    - An inventory of available cropland maps and their analysis; *Waldner, F., Fritz, S., Di Gregorio, A., and Defourny, P. 2015c. Mapping priorities to focus cropland mapping activities: Fitness assessment of existing global, regional and national cropland maps. Remote Sensing, 7(6):7959–7986.*



Priority map and its update typology. Areas with high priority index (reddish shades) characterize priority areas for cropland mapping, whereas areas with low scores correspond to an accurate and precise current mapping (greenish shades). West Africa, Ethiopia and South East Asia (Indonesia) clearly appear as priority area for cropland mapping

- The generation of a new unified cropland map that combines different input products based on their fitness. *Waldner, F., Fritz, S., Di Gregorio, A., Plotnikov, D., Bartalev, S., Kussul, N., ... & Löw, F. (2016). A unified cropland layer at 250 m for global agriculture monitoring. Data, 1(1), 3.*



Cropland proportion from the Unified Cropland Layer at 250 m for the year 2014. The Unified Cropland Layer combines the best forming products with regards to the multi-criteria analysis. It should be noted that cropland proportions are likely to be overestimated in areas where the spatial resolution of the original product is not higher than 250-m.

- Annual global cropland mapping with PROBA-V 300 m time series. The map has an accuracy of 94.7%, which is more than what similar existing maps achieve. Annual cropland masks derived from PROBA-V or equivalent can be used to identify hotspots of crop cover changes were site-specific workflows would provide more precise information. While most existing cropland maps were produced from multi-annual data, SIGMA extracted the annual cropland at global scale.
- land cover change detection in hot-spot areas. Results in Costa Rica show: a) expansion of the sugar cane agro-industry in irrigated zone at the expense of food production (rice) driven by the dynamic of private agroindustry and privileged access to public investment in irrigation infrastructure; b) renewal of a diversified agriculture supported by rural development programs and local community organizations and c) abandonment of agriculture in coastal areas in favor of tourism development boosted by foreign investment. These results go beyond the duality intensification/abandonment of agriculture. They highlight the spatial diversity of agricultural dynamics associated with forest recovery.
- Report on country needs, capabilities and actions”. A country assessment, based on the methodology proposed by the Global Strategy on Agricultural Statistics. The model encompasses an evaluation of: Importance of Agriculture for the national economy, share of rural population and level of statistical development (particularly level of use of remote sensing and time series in crop condition monitoring and reporting). A general needs and capabilities assessment was made for some countries willing to migrate towards statistical methods that encompass geospatial data. The state of the data they currently produce and disseminate, the methodology they use, and their readiness to begin implementing planned activities has been evaluated.

- Data collection and validation protocol. Field data is an important input into geospatial modelling or mapping products for different purposes. Field information plays a crucial role to calibrate and train but also verify and validate such geospatial information products. The deliverable explores the different approaches and provides an orientation for practitioners on basis of recent science and today's applications and methods. The provided field data collection and validation protocol is aimed to collate the current state of science and technology and to formulate main principles to be considered for planning and executing field data collection and geospatial products validation.
- A two-tier strategy for validation global binary cropland maps In a first part of this section, we proposed a new sampling approach for the validation of binary products. We then applied the sampling scheme to global cropland validation. All the samples were interpreted twice, once by experts and once by crowdsourcing, with the goal of enlarging a core reference data set interpreted by experts with samples collected by the crowd.
- Development of the QuantumGIS plugin tool for the area frame sampling. The tool is intended to support the (1) process of decision making related to building of an area frame sample for land cover and crop area estimates, (2) optimization of sample allocation into strata and (3) distribution of samples according to a systematic or stratified random sampling design. In order to address the requirement of simplicity of handling and distribution the tool is being developed as a plugin into QuantumGIS, which is nowadays the most advanced open-source GIS application.
- SIGMA Sampling Tool – open source tool distributed as plugin for QuantumGIS under GNU General Public Licence integrates once scattered statistical routines, libraries and procedures into one tool. The tool supports the (1) process of analysis of sampling design and decision making related to building of an area frame sample for land cover and crop area estimates, (2) optimization of sample allocation into strata and (3) distribution of samples according to a systematic or stratified random sampling design.

1.3.3 Global, regional and Local Agricultural Productivity Assessment

The main objectives of the SIGMA work on Agricultural Productivity Assessment, are:

- To develop concepts and methods to monitor and map current and future trends in agricultural productivity to increase knowledge about cropping system change in order to better understand its impact on the environment on the long term.
- To contribute to an improved monitoring capacity for a more accurate crop yield forecast data as an input to Early Warning Systems on Food Security and the Agricultural Market Information System (AMIS) to foster stabilization of markets and increase transparency on agricultural production

And both contributed to achieve Objective 2 of the SIGMA project
Here we focused on the exploration of the potentials to extend and improve the currently available time series for agro-environmental monitoring.

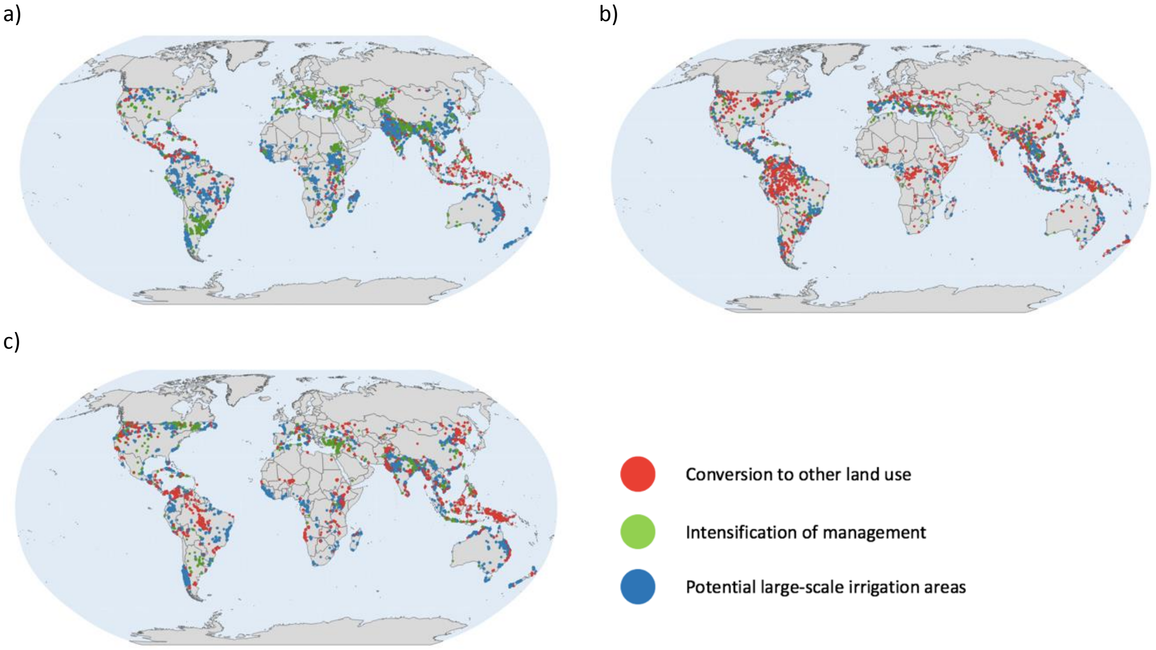
- Generation and publication of global soil moisture product.
- Development of a global Evapotranspiration datase

In particular the fusion of optical and synthetic aperture radar (SAR) imagery has gained interest due to the day and night SAR acquisition and the ability of SAR signals to penetrate through clouds and mist.

- Development of an operational data fusion method (Kalman filter, Kempeneers et al. 2014)
- Exploration of the joint use of Sentinel 1 and high resolution optical data for field level crop monitoring.

In addition the improvement of analysis methodologies was targeted to enable a better capturing of vegetation dynamics, phenologies, anomalies and agricultural productivity in terms of actual yields. An extensive study was performed to provide insight into the complex inter-relationships between vegetation growth and climatic as well as non-climatic factors on a global scale based on phenology and productivity parameters of the vegetation.

- Research and publication on a global analysis on detecting hot spots of changes in vegetation dynamics. In addition an original classification scheme was developed that enables better specification of the relative role of the main drivers of NDVI trends. In the Sahelian region, it was found:
    - strong evidence that rainfall is not the only important driver of Sahel re-greening (16% of the area) over the 2000-2015 period. Browning hot-spots (5% of the Sahel) can be chiefly attributed to factors other than rainfall.
    - At local scale ("Degré Carré de Niamey"), the significant role of land cover (mainly tiger bush on lateritic plateaus, particularly prone to pressures from overgrazing and overlogging) and accessibility factors in biomass production trends was observed.



Observed anthropogenic caused changes that lead to increasing and decreasing vegetation trends across the globe, for a) the cyclic fraction, b) the dry (or cold) seasons and c) the vegetation year

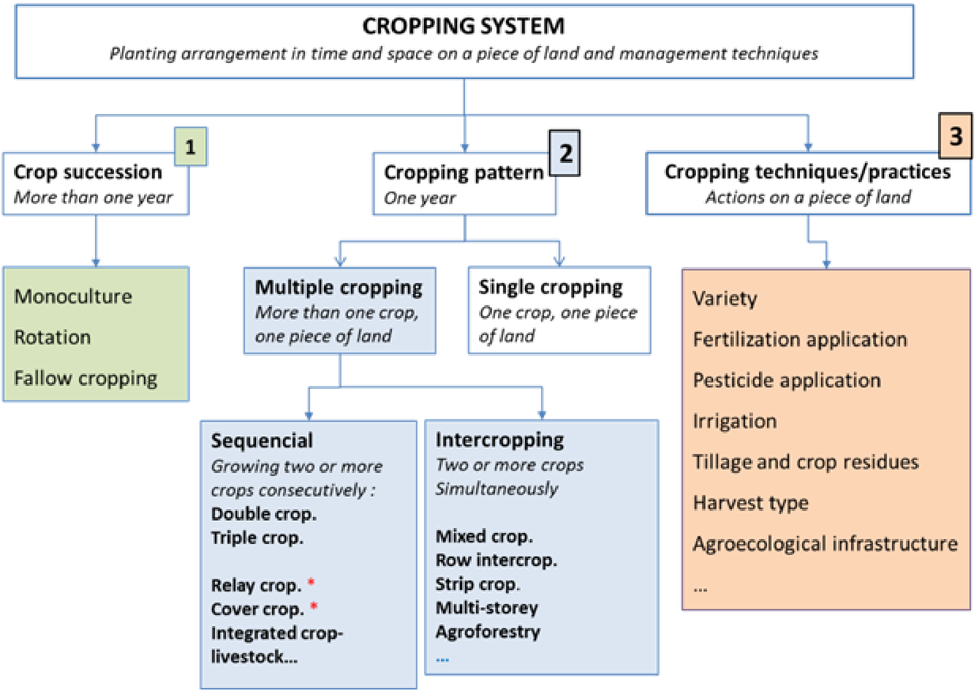
Besides this work was done to improve methods for monitoring and yield forecasting within the current season. A study was conducted to assess how indicators, taken from commonly available global data sets, perform in regional crop yield forecasting under different agro-climatic landscapes.

- Research and publication on the performance of indicators & methods for crop yield forecasting under different agro-environmental landscapes. The study shows that the available global data sets are useful to do crop yield forecasting in a relatively fast and easy way especially when using existing tools like SPIRITS and CST (http://spirits.jrc.ec.europa.eu). Still a large fraction of the use cases show limited performance of indicator models though it still outperformed the benchmark. One avenue to explore better performing models is to work on improving indicator data.

Further analysis was done of the occurrence and nature of long term changes of cropping and agro systems and to study how methods at the local scale can be transferred to a regional scale.

- Sentinel-2 data processing over Burkina Faso and Madagascar sites for land cover mapping
- An up-dated JECAM nomenclature that better accounts for the tropical cropping systems (especially the woody crops)

- Since 2015, large annual ground campaigns to get land cover/use GPS points in Argentina, Brazil (2 JECAM sites), Burkina Faso, China, Kenya, Madagascar, Pakistan, Ukraine and Vietnam
- The use of a VHSR image (Pléiades or SPOT6/7) in complement to HSR satellite time series (Landsat, SPOT5, Sentinel2) improves significantly the cropland and main crop types maps accuracy;
- The development of a new method of land stratification at country scale based on optical time series only (test on Brazil-Tocantins state and Burkina Faso country), the "radiometric landscape" approach
- Land cover changes and biomass modelling at local scale (Koumbia, Burkina Faso) using Ocelet spatial modelling platform and SARRA-H crop model.
- A typology of the main components of a cropping system



Typology of the main components of a cropping system (sources : adapted from J. Wery (personal communication) and De Bie, 2002)

- Crop type classification utilizing long time series of high resolution addressed a need to evaluate historic development and changes of cropping practices and patterns implied by socio-economic drivers at national level in Czech Republic. Variability of crop distribution was assessed annually as well as distribution and evolution of field size classes in time at regional level which both were compared to national trends.

Future increase of agricultural productivity was researched by assessing and mapping potential yield levels either under rain fed or irrigated conditions for different cropping and agro systems. Potential shifts were assessed by calculating crop yield gaps and as such identifying areas for future agricultural intensification. Actual yields do exist but only at national and, at the most, at sub-regional levels. To support spatial explicit analysis of actual productivity a spatial disaggregation approach was sought which attempts to generate allocations of crop yields, at finer scales, possibly down to the scale of individual grid units through Area-To-Point kriging.

- Potential yield levels and yield gaps were calculated and analyzed for China, Shandong (grain maize and winter wheat), Burkina Faso (sorghum and grain maize) and Argentina (soy beans). The yield levels in China Shandong are relatively high especially in the western and central areas. In case of winter wheat the south-eastern part has room for intensification. The room to increase productivity

[2] de Bie C.A.J.M. , 2000 : Comparative Performance Analysis of Agro-Ecosystems. Doctoral Thesis, Wageningen University and Research Centre, The Netherlands., October 2000. http://www.itc.nl/education/larus/landuse/

for rain fed soy beans in the pampas of Argentina is limited. According the calculations a yield increase of 1-2 ton.ha-1 seems realistic to achieve an 80% yield gap closure, especially in the central-western part. Out of the three regions, Burkina Faso shows the largest room for increasing productivity of sorghum (3-6 ton.ha-1) in the south and south-west assuming an 80% yield gap closure.

- Next yield levels were compared to other data sets (EPIC-GLOBIOM and GYGA). EPIC's yield levels for some regions in China Shandong and Burkina Faso deviate from what was calculated in this study and published by GYGA. For Burkina Faso one reason is the use of one fixed crop calendar for the whole country.
- The modelling work contributed to improve certain aspects around the use of crop simulation models in a regional context in support crop monitoring and crop yield forecasting. For example a new generic CalibrationManager, within PCSE, was developed to estimate any set of model parameters for a specific zone (e.g. a zone from the SIGMA GAES zonation) provided observations are available. Furthermore SARRA-O was developed to test farmer strategies and evaluate the effect of land use changes.
- Wheat and grain maize parameterizations, as being used in the EU-co-ordinated MARS project, were evaluated leading to a number recommendations on adjusting parameters related to LAI dynamics. This will help to improve simulated crop indicators used in NRT crop monitoring and crop yield forecasting.
- A new method area-to-point kriging (ATP kriging), a novel and versatile method for disaggregation of spatially averaged crop yields, was develop and tested on two use cases. The method explicitly takes into account spatial variation of crop yields within regions where yield statistics are available. ATP kriging is founded on statistical theory, and consequently also provides estimates of the precision of the disaggregated yields. Covariates derived from numerical weather models (e.g. ECMWF), satellites (e.g. SPOT-VGT) or soil databases can easily be accommodated as covariates in ATP kriging, increasing the detail of the map with disaggregated crop yields.

1.3.4 Environmental Impact Assessment of Agricultural Land Use Change

The main research questions underpinning the work were related to advancing state-of-the-art modelling tools on the evolution of future cropland extent and intensification, and their environmental impacts, at various scales. More precisely, the work tackled three main research questions:

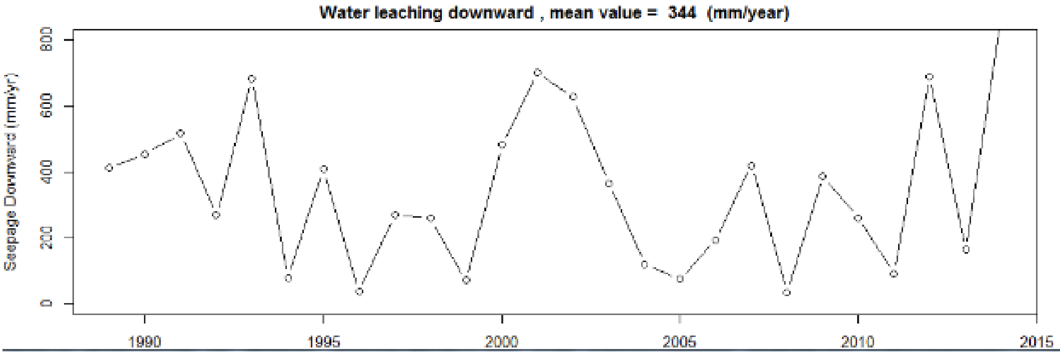
- Can we improve and apply local environmental models to study concrete case studies on the local effects of cropland use changes on the environment for specific sites of the Joint Experiment of Crop Assessment and Monitoring (JECAM) network?
- Can we improve and apply global land use models to project the future changes in cropland extent and intensity and their environmental impacts at global to local scales?
- Can we develop methodologies to compare and cross-fertilize these various approaches (and that of other work packages) at specific scales in specific regions?

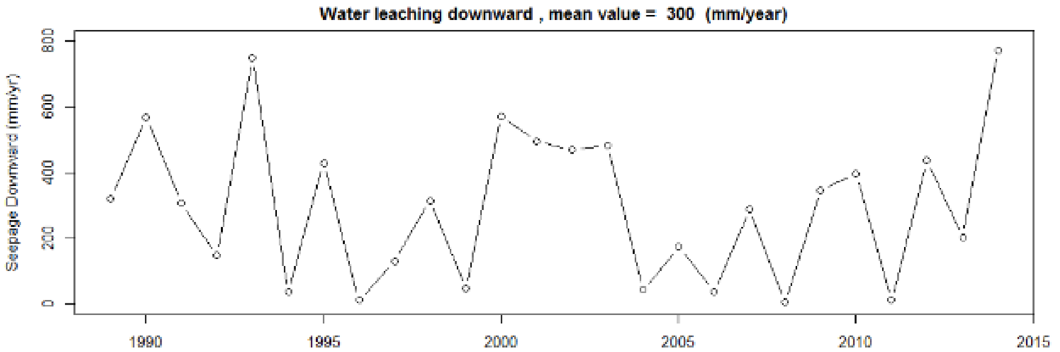
All contributing to Objective 4 of SIGMA.

A structured analysis of local environmental issues at each JECAM site proved to be instrumental in defining a logical and workable work sequence for each site. In addition, the definition and use of a protocol increases transparency and reproducibility of the work process. As such, this contributes to the quality assurance (transparency, reproducibility) of the results obtained. By following this approach for each JECAM site it was revealed which data were available and which data were still missing and, therefore, should have been collected. Following the same protocol for each JECAM site had the clear advantage that sites became inter-comparable and enabled the highlighting of similarities as well as differences between sites.

- protocols for Environmental Impact Analyses developed for each site
  - EiA for JECAM sites in Argentina

- Dynamics of land management with respect to planting and fertilizer time have environmental impacts. This may result in changes in soil hydrology, rising groundwater tables, and changes in nitrogen concentrations of groundwater.
- Rising groundwater tables in regions with vulnerable aquifers that contain salts may hamper future agricultural production.
- The downward leaching of nitrate increased when comparing soybean with a crop rotation, because the crop rotation contains fertilized crops and fertilizer losses cannot always be avoided.
- The downward leaching of water from soybean is higher than from crop rotations.
- Improved management of fertilizer applications, e.g. smaller doses and more precise timing, can reduce environmental impacts.





Simulated downward leaching of water (mm/year) for the continuous soybean cultivation (top) and the recommended crop rotation (bottom) at the JECAM site San Antonio

- EiA for JECAM sites in Russia
  - Moderate resolution remote sensing data are proven to be helpful in environmental problems assessment in the Stavropol region.
  - Major land use changes occur in the eastern part of Stavropol SRIA JECAM site, while crop rotation intensification is seen in central parts.
  - Regression models linking EO-based indicators related to yield and crop acreage are shown to be significant enough to explain most of the yield decrease by ineffective management, such as crop area increases with no significant support through fertilizers and herbicides.

- SIGMA clearly demonstrated that the dynamics of land use changes and their environmental effects can be monitored using a combination of remote sensing and modelling.

An econometrical modelling approach to land use change determinants was developed. We used a global land-use change dataset based on satellite imagery, which was harmonized with FAO data. Through a novel Bayesian multinomial logit framework we can assess the posterior inclusion probability of determinants and can provide evidence of regionally important factors for land use changes.

The methodology developed within the SIGMA project allows for providing estimates of future changes to the cropland extent and management intensity consistently across spatial scales (from a global level to high spatial resolution information). By implementing this methodology for a range of scenarios encompassing major drivers of future land use changes (Share Socioeconomic Pathways SSPs and Representative Concentration Pathways RCPs), we investigated such future trends between 2010 and 2030 and 2050 time horizons at various scales.

Overview of the methodology used to project future cropland extent and intensity consistently from global to local scale

- A novel time series method was developed based on vector auto-regressions as a means of estimating crop and region-specific price elasticities of area, quantity, and yield with a global coverage.
- A novel dataset of estimates of crop harvested yield, input requirements (nitrogen as mineral fertilizer application and water as irrigation) and components of field scale water and nitrogen balance was generated using the EPIC crop model at 5 arcminutes resolution and for 18 crops and 4 crop management systems.
- Using the above inputs, a novel method was developed to improve the dynamics of cropland expansion and intensification dynamics of the GLOBIOM global land use model.
- A novel method was developed to downscale land cover and use change projections of the GLOBIOM model to a resolution of 5 arcminutes. The method incorporates the latest remote sensing based estimates of recent land cover change (ESA-CCI) and is capable of taking into account the uncertainty of land use maps, and, in addition, provides valuable inference over the drivers of high-resolution land use change.
- Based on the above-mentioned developments, the work package provides 5 arcminute resolution cropland extent and intensity projections for 2030 and 2050 along different socio- economic (SSP) and representative concentration pathway (RCP) scenarios.
- At a regional scale, Sub-Saharan Africa stands out as a region with major increases to global cropland extent and intensity in almost all scenarios, while Latin and Central America, and South East Asia can significantly contribute to global cropland extent increase.
- However, some regions display very little change in total cropland extent, but relatively high and sometimes robust changes in cropland management intensity (Community of Independent States, Southern Asia, Oceania).
- As a final step, the work package aims to have a set of experts assess the plausibility of the cropland projections in 2030 and 2050 across multiple scenarios. Based on the geo-wiki SIGMA branch (https://geo-wiki.org/Application/index.php)

During the SIGMA project, large efforts were dedicated to improve future LULCC projections from the GLOBIOM model, in the direction required for better accounting of LULCC impact on biodiversity. Yet, our modelling framework was not able to translate the biodiversity outcomes of such improved projections of future LULCC. We thus further developed the model within the SIGMA project to be able to translate future LULCC projections changes in terrestrial biodiversity, and, more particularly, changes in local species richness at various spatial resolutions, as well as species extinction risks.

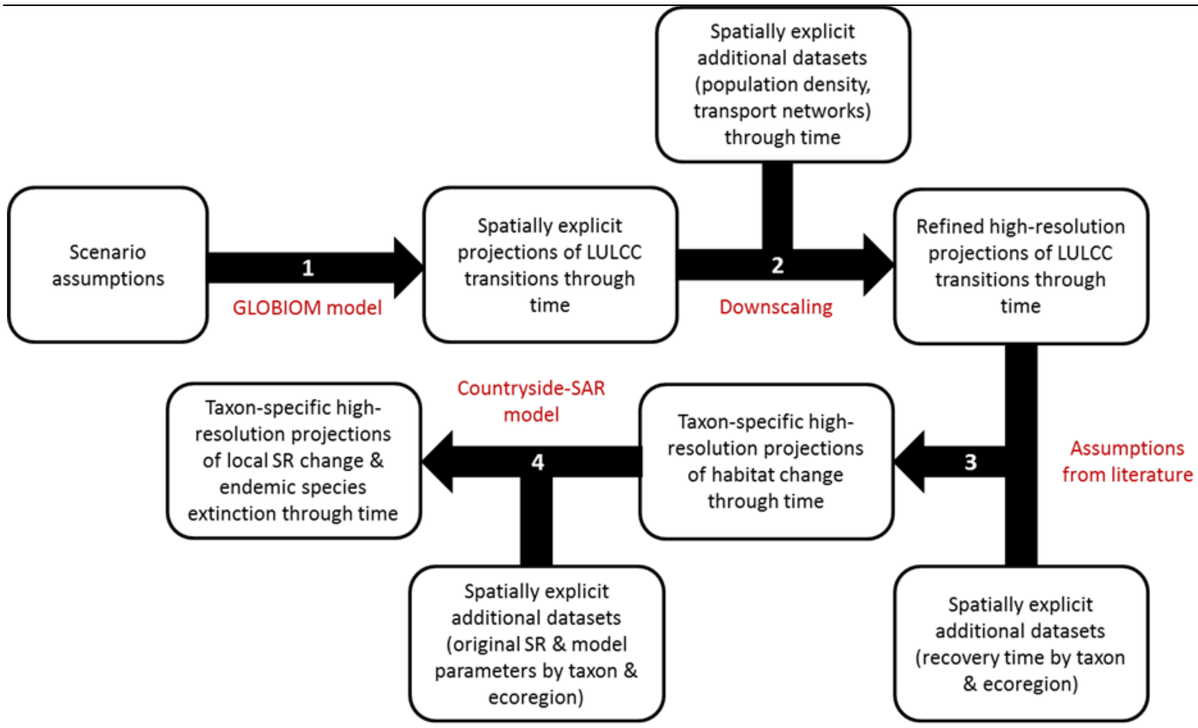


Illustration of the methodology to generate projections of taxon-specific and high spatial resolution projections of future changes to local species richness (SR) and threatened endemic species loss through time due to changes in land use and land cover change (LULCC)

The methodological developments and the impacts of the LULCC projections developed within the SIGMA are;

- A novel method was developed to estimates the habitat degradation related to future cropland extent and intensity projections, and implications in terms of changes in local species richness and global loss of threatened endemic species.
- A novel method was developed to provide estimates of the various components of the cropland nitrogen and water balance, using the novel EPIC dataset (see Results of WP5.2), the GLOBIOM assumptions about future technological progress, and the downscaled GLOBIOM projections of the acreage of crops and crop management systems.
- The existing GLOBIOM methodology to estimate greenhouse gas emissions from the Agriculture , Forestry and Land uses (AFOLU) sector was used to estimate future GHG emissions related to cropland expansion and intensification.
    - The above methods were used to estimate the environmental impacts on terrestrial biodiversity, freshwater resources and ecosystems, greenhouse gas emissions, and cropland nitrogen flows of the projections of future cropland extent and intensity by 2030 and 2050. The significant intensification of cropland will increase by more than 50% the amplitude of nitrogen flows within cropland. This translates, in particular, to increased emissions of nitrous oxide emissions (up to more than +50%), which can be softened but not cancelled under strong mitigation efforts. In addition, despite a more efficient use of irrigated water, the irrigation water will, at best, stabilize and could increase by up to 10%. Without mitigation efforts, the future expansion of cropland will generate additional GHG emissions. In addition, future cropland extent could amplify the effect of projected increase in cropland intensity in some scenarios. However, increased mitigation reduces cropland expansion and could lead to co-benefits for biodiversity. We find, however, that without mitigation the average local species richness decreases at a global scale under the projected LULCC, implying local biodiversity losses (potentially reversible) and irreversible losses of species that are endemic and already under threat. These impacts are differentiated across spatial scales, regions, metrics, taxa and scenarios. At a global scale, the decline in both average

species richness and threatened endemic species is steady and moderate for all taxa, but of higher amplitude for amphibians and reptiles (up to 2% and 3% decrease, respectively, in species richness and threatened endemic species richness), and lowest for mammals (less than 1% decrease).

In general, cropland expansion and intensification is expected to be highest and generate high and robust detrimental environmental impacts in Sub-Saharan Africa. For some regions (Latin and Central America, South and Eastern Asia, Community of Independent States), the environmental impacts can be high but are more uncertain across scenarios. Higher resolution details on these impacts allow for identifying the hotspots of environmental impacts. Similar to cropland extent and intensity, the environmental impacts at high resolution can display patches of either potentially large but highly scenario specific impacts, or large and highly robust impacts of opposite direction compared to the regional trends.

1.3.5 Technology Transfer and Capacity Development

This work is dedicated to reach Objective 5: Increase "Agro-environmental" monitoring capacity and awareness at the global, regional and local level and identify data and knowledge gaps of SIGMA.

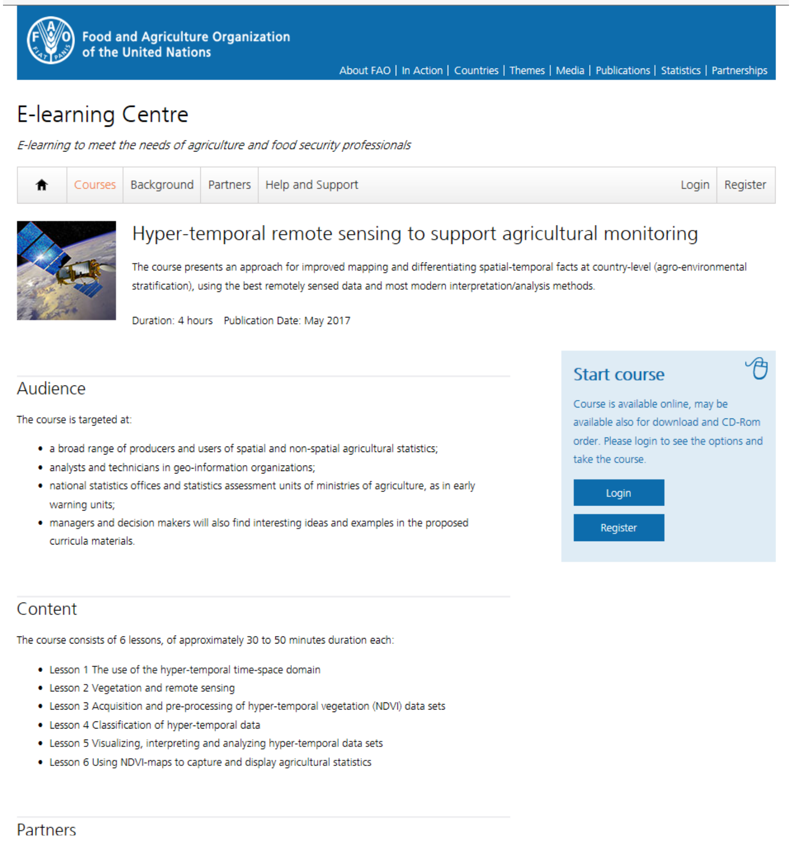
The goal is to strengthen national and international capacity, to enable integration of the within SIGMA developed methods.

As a first step in this work we developed a methodology to identify gaps for agricultural monitoring at national scale. As such a document on capacity needs assessment was developed.

- Production of deliverable "Capacity needs assessment report on the use of geospatial data for agricultural statistics generation with the use of other spatial/non-spatial data and curriculum design". The deliverable is a detailed assessment of the main needs for the generation of the agriculture statistics based on use of EO technology. The work consisted on a cross-cut assessment of the: results and questionnaires of the GSAS project related to agriculture statistics capacity for Asian and African countries; SIGMA country needs assessment on agriculture statistics generated by use of geospatial data Report; additional research reports delivered under AGRICAB project related to the African countries assessment on use of EO for agriculture monitoring.

Next to this work the main task was to develop learning material for the SIGMA training session.

- Development of the following three e- learning modules:
  - Methodological aspects of the use of geospatial technology for agriculture statistics (module 1)
  - Hyper-temporal remote sensing to support agricultural monitoring (module 2)
  - Geodata and tools for global monitoring of agricultural trends, changes and environmental impacts (module 3).
  - FAO prepared the Module 1 outlines identifying the contents and lessons related to the use of geospatial technology for agriculture statistics. The module is divided into 2 main sessions including 6 lessons. The materials for the module 2 consisting of 5 lessons have been produced (by ITC). For module 3, three e-learning lessons have been produced by ITC and IIASA: change detection (ITC), global trends and hotspot analysis (based on Sigma WP4 outputs – ITC with contribution of Geoville), and global impacts (based on Sigma WP5 - IIASA). All three courses will be made publically available through the FAO E-learning Centre at the following url http://www.fao.org/elearning/#/elc/en/courses/GDLM


Food and Agriculture Organization of the United Nations

About FAO | In Action | Countries | Themes | Media | Publications | Statistics | Partnerships

E-learning Centre

E-learning to meet the needs of agriculture and food security professionals

Courses | Background | Partners | Help and Support | Login | Register

Hyper-temporal remote sensing to support agricultural monitoring

The course presents an approach for improved mapping and differentiating spatial-temporal facts at country-level (agro-environmental stratification), using the best remotely sensed data and most modern interpretation/analysis methods.

Duration: 4 hours Publication Date: May 2017

Start course

Course is available online, may be available also for download and CD-Rom order. Please login to see the options and take the course.

Login

Register

Audience

The course is targeted at:

- a broad range of producers and users of spatial and non-spatial agricultural statistics;
- analysts and technicians in geo-information organizations;
- national statistics offices and statistics assessment units of ministries of agriculture, as in early warning units;
- managers and decision makers will also find interesting ideas and examples in the proposed curricula materials.

Content

The course consists of 6 lessons, of approximately 30 to 50 minutes duration each:

- Lesson 1 The use of the hyper-temporal time-space domain
- Lesson 2 Vegetation and remote sensing
- Lesson 3 Acquisition and pre-processing of hyper-temporal vegetation (NDVI) data sets
- Lesson 4 Classification of hyper-temporal data
- Lesson 5 Visualizing, interpreting and analyzing hyper-temporal data sets
- Lesson 6 Using NDVI-maps to capture and display agricultural statistics

Partners

Disseminating the knowledge of SIGMA was not only done through the learning modules but also through workshops and Seminars. At regional and global scale;

- SIGMA Organized two regional workshops in Kenya in March 2016 and March 2017. Particularly the second regional workshop focused on Geospatial Workshop "SIGMA Regional Training Workshop on Geospatial Technologies for Agricultural Statistics & Monitoring" and was conducted using inputs from six SIGMA partners, sharing their SIGMA progress and tools developed to 30 participants from across Africa.

Participants of SIGMA regional workshop

- Organization of a global workshops as side event of the GEO plenary meetings in Mexico and Russia. The side-event during the Saint Petersburg meeting gathered key players and stakeholders for setting out capacity development actions in innovative uses of EO and in-situ technologies for global monitoring of agriculture, agric. changes and its environmental impacts. Current progress on translation of research into operational monitoring actions, incl.

use of capacity development actions, dissemination and rapid uptake, in the framework of SIGMA (Stimulating Innovation for Global Agricultural Monitoring), a global EU support action to GEOGLAM, was shown, together with other int'l efforts. The side event also discussed the ways forward to integrate capacity development and new modes of learning into GEO initiatives and flagships. Public, private sector and project partners from Asia (China), Russia, Africa, Europe, America and UN presented experiences.

overview of training activities in SIGMA

Date/location	Event	Training Session organizer(s)	Topic/content
18-19 Sep 2014, Wageningen, NL	WP5 training workshop	ALTERRA	EIA agriculture
15-24 Sep 2014 / Wageningen, NL	WP4 related training workshop	ALTERRA	Agric.production monitoring
Oct, 2014	SIGMA Annual meeting	CAS/RADI and NMSC	Fengyun data
6-15 July, 2015 / Wageningen, NL	WP 4 related training	ALTERRA	Crop Yield Monitoring
09-13 Nov, 2015 Mexico city	GEO Plenary Side event on CapDev4EO	ITC (and RCMRD)	Execution Capdev under GEOSS
16-20 Nov, 2015 Brussels / Belgium & UCL	SIGMA Annual and SEN2AGRI training workshop	UCL	Back-2-back SEN2AGRI training
4-6 July, 2016, Wageningen, NL	WP4 training workshop	ALTERRA	Crop yield forecasting
10-14 Oct 2016 Kiev, Ukraine	SIGMA Annual and training event	SRI with FAO, ALTERRA	Agri-statistics; Crop yld mon
8-10 Nov, 2016 Sint-Petersburg, Russian Federation	GEO Plenary SIGMA GEOGLAM side event	ITC and IKI	Streamlining Int'l capdev GEOGLAM
15-17 March, 2016 Nairobi/Kenya	Regional Workshop on agricultural statistics, land cover analysis (	FAO, RCMRD	ECO-NET) organised in East Africa
20 Feb – 06 June 2017 FAO Rome	Webinar series on Agri-statitistics (for Pakistan)	FAO (with UNIBO)	Methodology aspects of Agric. Statistics
20-Feb - 06 May 2017 FAO Rome	Webinar series on Agri-statistics (for Iran and Afghanistan)	FAO (with UNiBO)	Methodology aspects of Agric. Statistics
21-24 March, 2017 Nairobi/Kenya	SIGMA Regional Training workshop	ITC with RCMRD, VITO	Geospatial tools for GAM
April, 2017 Webinar	Webinar on Sampling tools	EFTAS	Geospatial Tools for GAM
28-29-Jun, Rome, Italy	workshop pursued further newest technology transfer and capacity building for EO and agricultural monitoring.	UCL	S2AGRI
July 2017 Moscou, Russian Fed.	Regional workshop (WP4) & VEGA GEOGLAM	IKI with VITO, ALTERRA	Crop Yld Forec, …

1.3.6 Outreach and Information Dissemination:

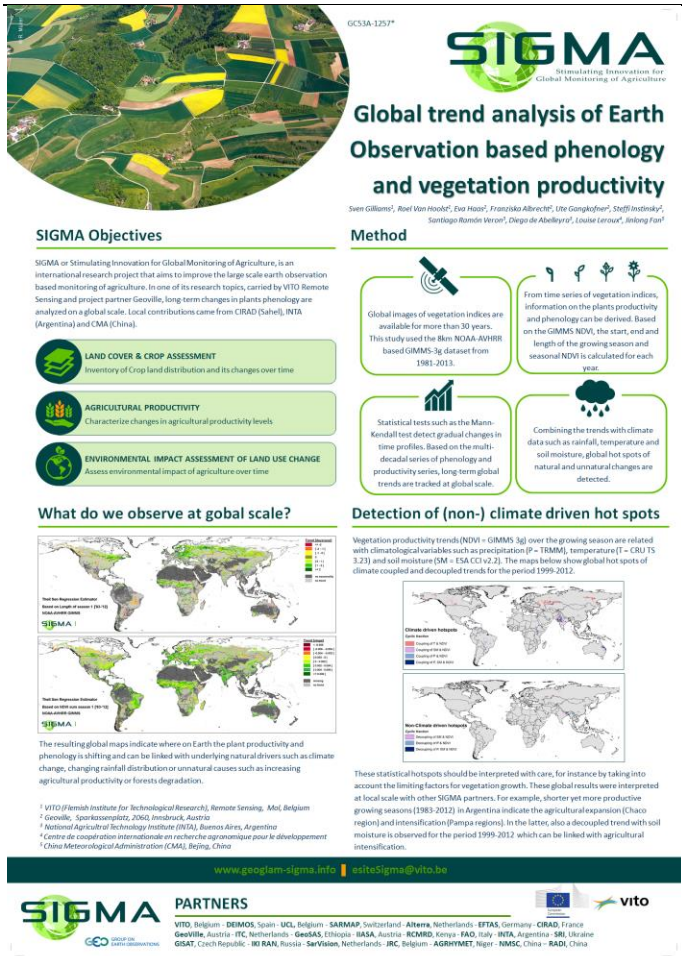
- Through out the life time of the project The SIGMA website was online and up to date (http://www.geoglam-sigma.info). On this site people can also download the outreach material of SIGMA

screen shot of sigma site

- Next to this the SIGMA twitter account and SIGMA linked in page were maintained a screenshot of the Linked in page can be found below.

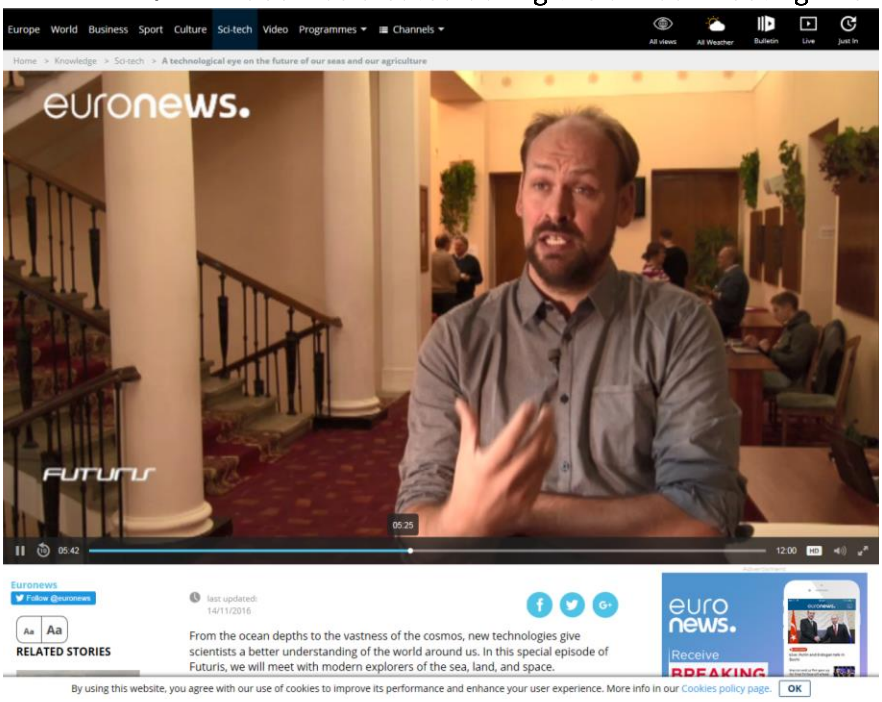
screen shot of SIGMA linked-in page

- Production of informative outreach materials:
  - project leaflet,
  - project presentation project poster
  - leaflet on GAES
- Throughout the project lifetime:
  - 90 presentation on SIGMA results were made in international scientific conferences
  - 10 poster presentation were made



Example of SIGMA poster; SIGMA poster on global trend analysis

- 20 workshops were organised
- A video was created during the annual meeting in Ukraine



http://www.euronews.com/2016/11/14/a-technological-eye-on-the-future-of-our-seas-and-our-agriculture

- 2 PhD were achieved on the SIGMA research
- The photographic observatory was established

www.photo-obs.webmodele.com

1.4 The potential impact

The expected impacts of the SIGMA project as set out at the start were to have :

- A significant contribution to the G20 GEOGLAM initiative, reinforcing the awareness of decision and policy makers about the impact of agriculture on the global environment
- An active network of agricultural and environmental monitoring and research organizations
- Capacity building activities, directed at a sustainable agricultural environment and enabling the prediction of the impact of crop production on natural resources and ecosystems
- Improved transparency of agricultural crop production and international coordination for risk-management capacity
- European leadership for an initial global agricultural land monitoring system based on both satellite and in-situ observations

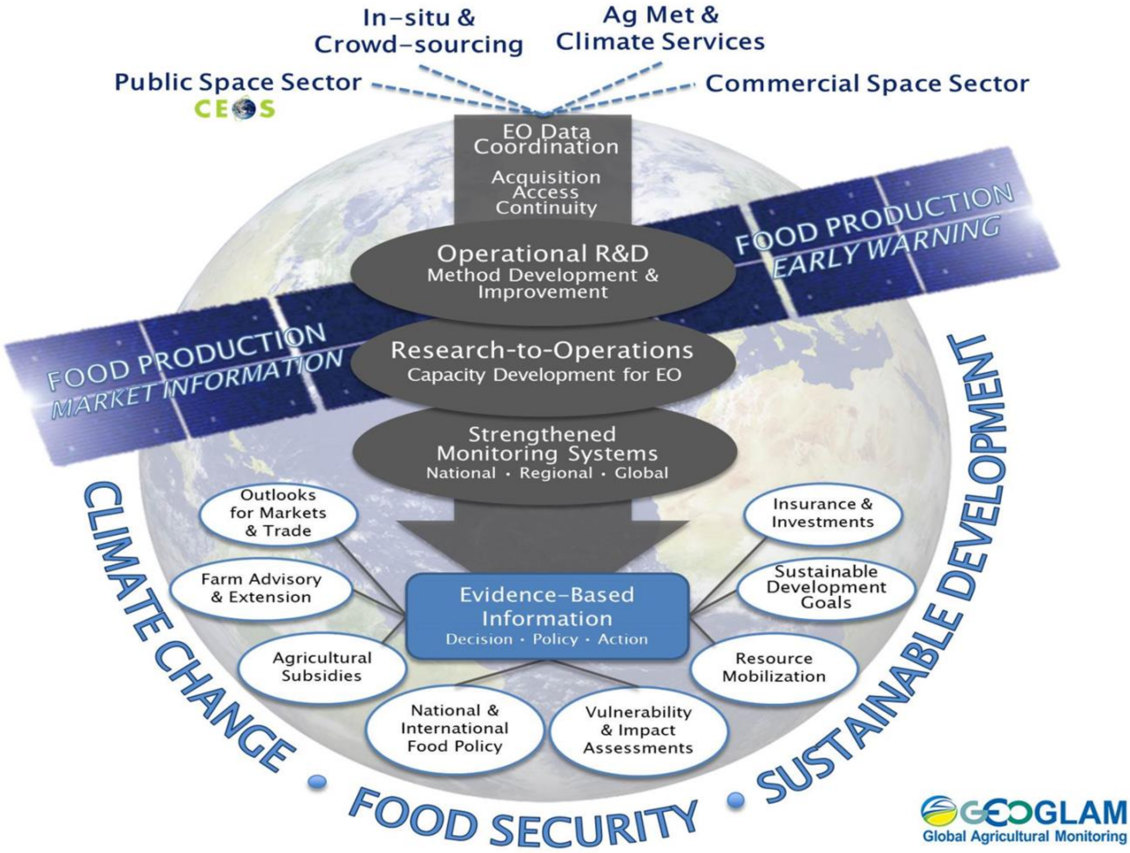
SIGMA activities were designed to address these requirements through:

- The establishment of an international partnership, with active members of the GEO Agricultural Community of Practice and stakeholders of the **G20 GEO-GLAM initiative**
- Establishing a network of globally distributed ***research*** and ***monitoring*** organizations in Europe, Asia, Africa, South America and North America with a particular and well-known expertise in Environment and Agriculture
- Implementation of specific **capacity building and awareness activities** for the agricultural monitoring community at large
- Research activities, designed to strengthen international risk-management capacity and improve transparency on agricultural crop production; research activities are designed for:
  - enabling the mapping of crop land and crop land statistics as well its changes over time
  - enabling the mapping of agricultural systems, shifts in cultivation practices and room for intensification of productivity
  - assessing impact of agriculture on the environment, both due to intensification as expansion
- Development and exploitation of an integrated, OGC compliant data and information portal combining **both satellite and in situ data t**o enable data access for the agricultural monitoring stakeholders community.

1.4.1 Contribution to the GEOGLAM Work Programme

The goal of the GEOGLAM Initiative is to strengthen the **international community's capacity** to produce and disseminate relevant, timely and accurate forecasts of **agricultural production** at **national**, **regional** and **global** scales through the use of Earth Observations (GEO, 2012).

SIGMA strongly contributed to GEOGLAM at several levels. Looking at the updated GEOGLAM structure, SIGMA contributed to GEOGLAM on EO data coordination, with its data management component, supporting the operational R&D component and strengthening the monitoring systems and national, regional and global scale.



GEOGLAM Structure January 2017

SIGMA mainly supported the Operational R&D component of GEOGLAM (i.e. JECAM. The overarching goal of JECAM is to reach a convergence of approaches, develop monitoring and reporting protocols and best practices for a variety of global agricultural systems). Several SIGMA test sites are also JECAM sites and as such SIGMA research ensured that work could be continued on these sites. Next to this SIGMA set up several cross site comparison experiments. To mention a few there are the;

- Large field mapping experiment
- Small field mapping experiment
- Yield estimation experiment

Results are published in SIGMA reports, peer reviewed papers and are being integrated in best practice document of JECAM.

- Crop land definition and updated cropland definition
- JECAM Guidelines: Definition of the Minimum Earth Observation Dataset Requirements

The data component of SIGMA was used to share and store data of the different sites and JECAM saw potential in the AGROSTAC database to be used as data warehouse for in situ data.

Since JECAM is a voluntary networks, SIGMA facilitated the annual research meeting of JECAM. Together with the S2AGRI project, SIGMA ensured that the annual meetings were jointly hosted, allowing the JECAM network to meet.

SIGMA coordinator was part of the GEOGLAM implementation team (IT)

Though it's training activities SIGMA supported the GEOGLAM on strengthening the national, regional and global monitoring systems.

1.4.2 Networking of agricultural and environmental monitoring and research organizations

SIGMA is a partnership of 22 partners in agricultural and environment research and monitoring. Through the various project meetings, workshops and training sessions a strong network was built; strengthening and facilitating interaction and information / expertise and sharing. Each of the consortium partners are well-known in their domain and area, and on their own have a large network which was engaged in the SIGMA activities. Also project partners are involved in other agricultural monitoring activities. So throughout SIGMA linkages and networking was done with the following activities.:

- GMES, GIO (GMES Initial Operations – Global Component) and MARSOP concerning access to European data streams and agricultural/environmental monitoring techniques, through VITO and JRC
- the Global Strategy on Agricultural and Rural Statistics, providing a framework and methodology that will improve the quality and availability of national and international food and agricultural statistics to guide policy analysis and decision making in the 21st century through FAO
- MESA to build EO capacity in Africa, through VITO and ITC
- Globcover, ESA Climate Change Initiative, GEOLAND-2, concerning the automation of land cover mapping through UCL
- GYGA methodology, to analyse yield gaps and intensification potential implemented by Wageningen University, University of Nebraska-Lincoln and Alterra
- GEOGLAM Ensuring the SIGMA activities are in line with GEOGLAM. SIGMA partners are playing key roles in the GEO implementation and feeding back information to the consortium. Attending GEOGLAM- IT meetings and follow up
- GEOSS data core SIGMA contribution to GEOSS data core meetings to ensure data availability over the SIGMA sites. SIGMA was present during GEOSS data provider workshop in Florence Italy
- AFRIGEOSS; SIGMA was present during the KO meeting in Victoria Falls and attended the dedicated session during the AARSE conference in Kampala. To ensure outreach of SIGMA activities on the continent. SIGMA partner GEOSAS was very active in doing outreach activities for NEPAD also linking the AFRIGEOOS and AFRIGAM activities.
- JECAM can be considered as the research part of GEOGLAM. UCL as one of the SIGMA partners is co-lead of this activity within GEOGLAM. SIGMA has already contributed a lot to JECAM. Ensuring budget for site activities, support in document development and definitions. During the Annual meeting in Beijing it was agreed to jointly organize annual meetings in 2015 , 2016 and 2017.
- ESA-funded Sentinel 2 for Agriculture (S2-AGRI); Coordination is done at the site level and methodological level. Coordination is done through UCL (the lead of this project at ESA)
- AGMIP (the Agricultural Model Inter comparison and Improvement Project); The AGMIP community is dedicated to the modelling aspect of agricultural monitoring. Within SIGMA a number of modelling activities are ongoing and coordination and comparing model results should be the focus of this activity
- CABI (http://www.cabi.org/), SIGMA in its search for global validation data sets for agricultural monitoring was contacted by CABI to collaborate field data collection and the sharing of field data sets
- ESA-TEP food security, The recently started TEP FS is an answer of ESA on bringing the data to the user. It is a platform where agricultural expert can and implement new techniques to better monitor agriculture. Techniques developed within SIGMA should be implemented. As VITO is part of the TEP-FS consortium and JRC is part of the user board the link is made.
- European Commission, DG Joint Research Centre, MARS Unit, Facilitate coordination with GEO agriculture task, GEOGLAM and Global Agriculture Community of Practice

1.4.3 Capacity building

SIGMA included a dedicated work package on capacity building, where specific capacity building activities were performed. As set out in the beginning of the project the collaboration between partners, sharing expertise and knowledge on ground-based issues is considered one of the main benefits and results. Within all WP' s of SIGMA dedicated trainings sessions were organized between scientific leads and site partners. This approach supported the capacity building at national level and regional level and as such enhancing the monitoring capabilities at these levels. Increased monitoring capacity at these levels also increases capacity at global level. GEOGLAM's crop monitor is built upon national and regional capacity and monitoring.

1.4.4 Improved transparency and international coordination for risk-management capacity

SIGMA supported the international community in developing new methods and best practices documents on agricultural monitoring and the impact of changes in the agriculture on the environment. Future scenarios of changes were analyzed and the impact assessed. Capacity building on all of these techniques and the findings was provided. Products and results were made available through the SIGMA Geonetwork server.
Next to this, SIGMA through its partners attended over 40 international conferences and was part of international coordination initiatives.
All this contributed to an improved transparency and international coordination for risk management capacity.

1.4.5 European leadership for an initial global agricultural land monitoring system

SIGMA, *for the first time*, brought together European partners with world-wide renown in agricultural monitoring. Strongly building upon (unique) European assets such as (global) expertise in land cover mapping, satellite data infrastructure (SPOT-VGT, PROBA, Sentinels, EUMETCAST), SAR, agro-meteorological and environmental models and earth observation derived Soil Moisture and evapotranspiration products.
As such, key components of an initial global agricultural land monitoring system are brought together. In addition the project largely capitalized on the Sentinel and PROBA-V satellite series, which is a major European Investment.

1.5 Public website and relevant contact details

1.5.1 Relevant web links

- SIGMA Website
  - http://www.geoglam-sigma.info
- Product Distribution Facility with links to all components from WP2:
  - http://www.sigma.geoportal.vgt.vito.be.

1.5.2 SIGMA partners and logos

VITO (Flemish Institute for Technological Research), Belgium http://www.vito.be

Stichting Dienst Landbouwkundig Onderzoek (ALTERRA), Netherlands http://www.alterra.wur.nl

Université Catholique de Louvain (UCL) Belgium http://www.uclouvain.be

Agricultural Research Institute for Development (CIRAD) France http://www.cirad.fr/en

ITC-UT (Faculty of Geo-information Science & Earth Observation), Netherlands http://www.itc.nl

IIASA, Austria http://www.iiasa.ac.at

Food and Agricultural Organization of the UN (FAO), Italy http://www.fao.org

Space Research Institute (IKI), Russia http://www.iki.rssi.ru/eng

Space Research Institute of National Academy of Sciences of Ukraine (SRI), Ukraine

EC DG Joint Research Centre (JRC), Italy

Institute of Remote Sensing Applications Chinese Academy of Sciences (IRSA), China

National Satellite Meteorological Center, Chinese Meteorological Administration (NSMC), China

DEIMOS Imaging S.L, Spain http://www.deimos-imaging.com

Sarmap SA (SARMAP), Switzerland http://www.sarmap.ch

EFTAS Fernerkundung Technologietransfer GmbH, Germany http://www.eftas.com

GeoVille, Austria http://www.geoville.com

RCMRD (Regional Centre for Mapping Resources for Development), Kenya
http://www.rcmrd.org

AGRHYMET (centre Regional AGRHYMET), Niger
http://www.agrhymet.ne

Geosas Plc , Ethiopia
http://www.geosas.net

Instituto Nacional de Tecnologia Agropecuaria (INTA), Argentinia
http://inta.gob.ar

GISAT s.r.o, Tsjech republic
http://www.gisat.cz

SARVISION, The Netherlands
http://www.sarvision.nl

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2. Use and dissemination of foreground

2.1 Section A

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES										
NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[3] (if available)	Is/Will open access[4] provided to this publication?
1	Identifying global changes in vegetation dynamics using satellite remote sensing	Franziska Albrecht	n.a. IN PROGRESS							
2	Global trend analysis of Earth Observation based phenology and vegetation productivity	Roel Van Hoolst	AGU conference			AGU fall meeting, San Francisco	12-16 December, 2016			
3	Performance of commonly available global data sets in regional crop yield forecasting	Boogaard, H.L. Hoolst, R. Leo, O. Zhang, M. Plotnikov, D. Kussul, N. Traore, S. Bako, M. Veron, S.R. Deabelleyra, D.	n.a. IN PROGRESS	n.a.	n.a.		n.a.	n.a.	n.a.	
4	Mapping short-rotation plantations at regional scale using MODIS time series: Case of eucalypt plantations in Brazil.,	Lemaire G., Dupuy S., Nouvellon Y., Araujo Loos R., R. Hakamada	Remote Sensing of Environment	152	Elsevier		2014	136–149.	10.1016/j.rse. 2014.05.015	No

[3] A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view) or to the final manuscript accepted for publication (link to article in repository).
[4] Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

5	Spatial modelling of agro-ecosystem dynamics across scales: A case in the cotton region of West-Burkina	Jahel C., Baron C., Vall E., Karambiri M., Castets M., Coulibaly K., Bégué A. D. Lo Seen	Agricultural Systems		Elsevier		2016		10.1016/j.agsy.2016.05.016	No
6	Driving forces of recent vegetation changes in the Sahel: Lessons learned from regional and local level analyses	L. Leroux A. Bégué D. LoSeen A. Jolivot F. Kayitakire	Remote Sensing of Environment	191	Elsevier		January 2017	38-54	10.1016/j.rse.2017.01.014	No
7	A Combined Random Forest and OBIA Classification Scheme for Mapping Smallholder Agriculture at Different Nomenclature Levels Using Multisource Data (Simulated Sentinel-2 Time Series, VHRS and DEM)	V.Lebourgeois S. Dupuy E. Vintrou M. Ameline S. Butler A. Bégué	Remote Sensing	9, 259	MDPI		March 2017		10.3390/rs9030259	yes
8	A remote sensing approach for regional-scale mapping of agricultural land-use systems based on NDVI time series	B. Bellón, A. Bégué, C. de Almeida D. Lo Seen M. Simões	Remote Sensing	9, 600	MDPI		June 2017		10.3390/rs9060600	yes
9	Geostatistical disaggregation of polygon maps of average crop yields by area-to-point kriging	Brus, D.J Boogaard, H.L. Ceccarelli, T. Zhang, M. Traore, S.	n.a. IN PROGRESS	n.a.	n.a.		n.a.	n.a.		
10	From field to atlas: Upscaling of location-specific yield gap estimates	van Bussel, L. G. J., Grassini, P., van Wart, J., Wolf, J., Claessens, L., Yang, H., Boogaard, H. L., de Groot, H. L. E., Saito, K., Cassman, K. G. & van Ittersum, M. K	Field Crops Research	177	Elsevier		June, 2015	98-108	10.1016/j.fcr.2015.03.005	
11	Harmonization and translation of crop modeling data to ensure interoperability	Porter, C.H., Villalobos, C., Holzworth, D., Nelson, R., White, J.W., Athanasiadis, I.N., Janssen, S., Ripoche, D., Cufi, J., Raes, D. and Zhang, M.,	Environmental Modelling & Software	62			2014	pp.495-508	10.1016/j.envsoft.2014.09.004	
12	Comparison of biophysical and satellite predictors for wheat yield forecasting in Ukraine	Kolotii, A., Kussul, N., Shelestov, A., Skakun, S., Yailymov, B., Basarab, R., Lavreniuk, M., Oliinyk, T. and Ostapenko, V.,	The International Archives of Photogrammetry, Remote Sensing and Spatial Information	Volume XL-7/W3	Copernicus GmbH	Gottingen	January 2015	39-44	10.5194/isprsarchives-XL-7-W3-39-2015	

			Sciences							
13	National-scale cropland mapping based on spectral-temporal features and outdated land cover information	Waldner, F.	PLoS ONE	In press	Public Library of Science		2017			yes
14	Towards a set of agrosystem-specific cropland mapping methods to address the global cropland diversity	Waldner, F.	International Journal of Remote Sensing	37(14)	Taylor and Francis		2016	3196 –3231	10.1080/01431161.2016.1194545	yes
15	A Unified Cropland Layer at 250 m for Global Agriculture Monitoring	Waldner, F.	Data	1(1):3	MDPI		2016		10.3390/data1010003	yes
16	Automated annual cropland mapping using knowledge-based temporal features	Waldner, F.	ISPRS Journal of Photogrammetry and Remote Sensing	110	Elsevier		2015	1–13	10.1016/j.isprsjprs.2015.09.013	no
17	An information-based criterion to measure pixel-level thematic uncertainty in land cover classifications	Bogaert, P.	Stochastic Environmental Research and Risk Assessment		Springer		2016	1-16	10.1007/s00477-016-1310-y	yes
18	Mapping priorities to focus cropland mapping activities: Fitness assessment of existing global, regional and national cropland maps	Waldner. F	Remote Sensing	7(6)	MDPI		2015	7959–7986	10.3390/rs70607959	yes
19	Where can pixel counting area estimates meet user-defined accuracy requirements?	Waldner, F.	International Journal of Applied Earth Observation and Geoinformation	60	Elsevier		2017	1-10	10.1016/j.jag.2017.03.014	yes
20	Regional scale crop mapping using multi-temporal satellite imagery	N. Kussul	Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.	vol. XL-7/W3			2015	pp. 45–52,	doi:10.5194/isprsarchives-XL-7-W3-45-2015, 2015.	yes
21	Harnessing the power of volunteers, the Internet and Google Earth to collect and validate global spatial information using Geo-Wiki	See, L.	Technological Forecasting and Social Change	98			2015	324–335	doi:10.1016/j.techfore.2015.03.002	yes
22	Improved global cropland data as an essential	See, L.	Global Food Security	4			2015	37-45	http://hdl.handle.net/1056	

	ingredient for food security								8/51392	
23	Mapping global cropland and field size	Fritz, S.,	Global Change Biology	21			2015	5	doi: 10.1111/gcb.12838	yes
24	Efficiency Assessment of Multitemporal C-Band Radarsat-2 Intensity and Landsat-8 Surface Reflectance Satellite Imagery for Crop Classification in Ukraine	S.Skakun	IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing				2015	3712 - 3719	doi: 10.1109/JSTARS.2015.2454297.	
25	Land Cover Changes Analysis Based on Deep Machine Learning Technique	Kussul, N.	Journal of Automation and Information Sciences	48			2016	42-54	10.1615/JAutomatInfScien.v48.i5.40	
26	A Unified Cropland Layer at 250 m for Global Agriculture Monitoring. Data, 1(1), 3.	Waldner, F.	Data				2016		doi:10.3390/data1010003	yes
27	Hotspots of uncertainty in land use and land cover change projections: a global scale model comparison	Prestele et al	Global Change Biology	vol. 22, issue 12			2016	3967–3983	DOI: 10.1111/gcb.13337	yes
28	Assessing uncertainties in land cover projections	Alexander et al	Global Change Biology	vol. 23, issue 2			2017	767–781	10.1111/gcb.13447	yes
29	Biophysical parameters mapping within the SPOT-5 Take 5 initiative	Shelestov, A.	European Journal of Remote Sensing				2017	1-10	http://dx.doi.org/10.1080/22797254.2017.1324743	yes

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES

NO.	Type of activities[5]	Main leader	Title	Date/Period	Place	Type of audience[6]	Size of audience	Countries addressed
1	Conference	VITO (Roel Van Hoolst)	AGU fall meeting	12-16 December 2016	San Francisco, USA	Researchers	>1000	>10
2	Conference	CIRAD (C. Jahel)	Land pressure and agrarian mutation, spatial modelling of farming systems evolution from plot to regional scale in West Burkina Faso	7-10 Sept 2015	Montpellier (France)	Scientists	30	Burkina Faso
3	PhD	L. Leroux (CIRAD)	Suivi et caractérisation des dynamiques de la production agricole en Afrique de l'Ouest par télédétection à moyenne résolution spatiale	4 December 2015	Montpellier (France)	Scientist + civil society	50	West African countries
4	Workshop	CIRAD (M. Bonin)	Hot-spot identification and driving forces at national scale	April 2016	Nicoya (Costa Rica)	Civil society + policy makers	20	Costa Rica
5	Conference	CIRAD (C. Jahel)	Disentangling factors of landscape changes in Burkina Faso; the nexus between spatial modeling and remote sensing	30 June 2016	Montpellier (France)	Scientists	30	Burkina Faso
6	Conference	CIRAD (A. Bégué)	Satellite Based Multi-scale methods to support the governance of the Low-carbon Agriculture Plan (ABC Plan)	14-16 Sept. 2016	Enschede (The Netherlands)	Scientists	30	Brazil

[5] A drop down list allows choosing the dissemination activity: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.

[6] A drop down list allows choosing the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias, Other ('multiple choices' is possible).

7	PhD	C. Jahel (CIRAD)	Caractérisation de la dynamique des systèmes de culture en zone soudano-sahélienne de l'Afrique de l'ouest par modélisation spatialisée des cultures et analyse de séries temporelles d'images satellites	7 December 2016	Montpellier (France)	Scientists + civil society	50	Burkina Faso
8	Conference	CIRAD (C. Jahel)	From satellite images to agricultural systems maps: A remote sensing multi-level object-based approach	16-18 March 2017	Montpellier (France)	Scientists	30	
9	Conference	CIRAD (B. Bellon)	A generic remote sensing approach for large-scale land cover and land use systems mapping	20-23 march 2017	Paphos (Cyprus)	Scientists	30	Brazil
10	Workshop	CIRAD (M. Bonin)	Hot-spot identification and driving forces at national scale	30-31 March 2017	Antsirabé (Madagascar)	Civil society + policy makers	40	Madagascar
11	Conference	CIRAD (B. Bellon)	From satellite images to agricultural systems maps: A remote sensing multi-level object-based approach	8-12 May 2017	Pretoria (South Africa)	Scientists	30	Brazil
12	Conference	CIRAD (V. Lebourgeois)	Mapping smallholder agriculture using simulated Sentinel-2 data; optimization of a Random Forest-based approach and evaluation on Madagascar site	8-12 May 2017	Pretoria (South Africa)	Scientists	30	Madagascar
13	Conference	CIRAD (L. Leroux)	Herbaceous biomass productivity dynamics monitoring and its drivers in Sahelian croplands and rangelands to support food security policies	8-12 May 2017	Pretoria (South Africa)	Scientists	30	West African countries
14	Conference	CIRAD (M. Bonin)	Agricultural dynamics associated with forest recovery. A case study in Región Chorotega, Costa Rica.	March 29 - April 2 2016	San Francisco (USA)	Scientists	30	Costa Rica
15	Workshop	Alterra (H Boogaard, S Hoek), JRC (O. Leo)	WP4 crop yield forecasting workshop	14-15 December 2015	Ispra, Italy	Scientists	7	Algeria, Tunisia, Niger, Somalia

16	Conference	Alterra (H Boogaard)	Digital Earth Conference - AGRO-STAC: Management of In-situ Agronomy Data	7 July 2016	Beijing, China	Scientists	25	Mainly Asia
17	Training	Alterra (H Boogaard, A. de Wit)	Crop yield forecasting and modelling training SIGMA-Kiev	14 October 2016	Kiev, Ukraine	Scientists, policymakers	30	Ukraine
18	Conference	SRI (A. Kolottii)	Comparison of biophysical and satellite predictors for wheat yield forecasting in Ukraine	11-15 May 2015	Berlin, Germany	Scientists	30	Ukraine
19	Training	Alterra (H Boogaard, S Hoek), JRC (O. Leo)	Second MARS-SIGMA workshop/training on Crop monitoring and Yield estimation - Africa (WP4)	13-15 February 2017	Wageningen (The Netherlands)	Scientists	10	North Africa
20	Workshop	Alterra (H Boogaard)	Highlights SIGMA and cross site experiment on crop yield forecasting	6 April 2017	JRC, Ispra (Italy)	Scientists	10	Global
21	Workshop	Alterra (H Boogaard)	Yield forecasting using remote sensing & models	12 July 2017	IKI, Moscow (Russia)	Scientists + policy makers	50	Russia
22	Workshop	Alterra (H Boogaard)	Joint GEOGLAM/AgMIP Workshop “Integrating Earth Observations with Models to Forecast Within-Season Crop Production at Multiple Scales”	10-11 March 2015	Beltsville, MD, USA	Scientists + policy makers	50	USA, globe
23	Workshop	Alterra (Ceccarelli)	Best Practices & New Opportunities for Improving the Measurement and Estimation of Crop Yields in Smallholder Farming Systems (Convenors: Global Yield Gap Atlas Project (GYGA), Global Strategy for Ag & Rural Statistics (GS), and the FAO Statistics Division (ESS))	30 June – 1 July 2015	FAO, Rome, Italy	Scientists	20	Globe
24	Workshop	Alterra (Boogaard), VITO (Gilliams)	SIGMA workshop on crop monitoring and crop yield forecasting	6-15 July 2015	Alterra, Wageningen, The Netherlands	Scientists	20	JECAM site countries
25	Technical Workshop	EFTAS	Thematic map validation	01.2016	Khartoum	National Research Centre/RSSA	6-8	Sudan
26	Technical Workshop	EFTAS	Thematic map validation	12.2016	Khartoum	Ministry of Livestock	40-50	Sudan

27	Technical Workshop	EFTAS	Thematic map validation	02.2017	Eschborn	GIZ experts	20-30	International
28	Regional Workshop	ITC	Thematic map validation	03.2017	Nairobi	International experts	20-30	International
29	Technical Workshop	EFTAS	Thematic map validation	05.2017	Bad Neuenahr	GIZ experts	20-30	International
30	Publication on website	EFTAS	http://www.eftas.de/en/eftas-content-pool.php?fromIndex=1#post-level-up http://www.eftas.de/en/eftas-content-pool.php?fromIndex=1#post-sigma-validation-protocol	2015 / 2017	-	internet	-	International
31	*Poster*	*Waldner, F.*	*Combining expert-based and crowdsourcing approaches in a two-tier sampling design for validation: global experimental results for cropland maps*	*14-16 March 2017*	*WorldCover Conference; ESA-Rome*	*Scientific community*	*150*	*EU countries, China, US*
32	*Poster*	*Blaes, X.*	*Sentinel-1 SAR time series for regional cropland mapping*	*March 14-16, 2017*	*WorldCover Conference; ESA-Rome*	*Scientific community*	*150*	*EU countries, China, US*
33	*Thesis*	*Waldner, F.*	*Yearly cropland mapping over large areas with high resolution satellite image time series*	*17 May 2017*	*Université catholique de Louvain, Louvain-la-Neuve, Belgium*	*Scientific community/Civil Society*	*50*	*EU countries, US*
34	*Presentation*	*Waldner, F.*	*Annual Cropland Mapping in Five Contrasted Agrosystems with Medium to Large Field Size*	*13 November 2017*	*JECAM annual meeting; Brussels, Belgium*	*Scientific community*	*50*	*JECAM partners*
35	*Conference*	*Blaes, X.*	*Automated Classification for Improving the Global Cropland Extent*	*9-13 May 2016*	*ESA-Living Planet Symposium, Prague, Czech Republic*	*Scientific community*	*150*	*EU countries, US*
36	*Presentation*	*Blaes, X.*	*STARS smallholder farming experiment using VHR time series*	*June 30th, 2017*	*JECAM annual meeting; FAO-Rome*	*Scientific community*	*50*	*JECAM partners*
37	*Presentation*	*Waldner, F.*	*On the effect of sampling schemes on cropland*	*11 October 2016*	*JECAM annual meeting; Kiev,*	*Scientific community*	*50*	*JECAM partners*

			classification accuracy		*Ukraine*			
38	*Presentation*	*Defourny, P.*	*Assessing the effect of roadside data collection for cropland mapping*	*30 June 2017*	*JECAM annual meeting; Rome, Italy*	*Scientific community*	*50*	*JECAM partners*
39	*Presentation*	*Waldner, F.*	*Advances in EO Technologies for Agricultural Monitoring*	*20 April 2016*	*Crop Estimation Liaison Committee, Pretoria, South Africa*	*Scientific community; Industry; Policy makers*	*50*	*South Africa*
40	*Poster*	*Waldner, F.*	*A fully automated classification method for mapping the annual cropland extent*	*14 December 2015*	*American Geophysical Union Fall Meeting; San Francisco, USA*	*Scientific community*	*200*	*US*
41	*Conference*	*N. Kussul*	*36-th International Conference on Remote Sensing of Environment*	*11-15 May 2015*	*Berlin, Germany*	*Scientific Community*	*743 participants*	*International*
42	*Conference*	*Lavreniuk, M., Kussul, N.*	*IEEE International Geoscience and Remote Sensing Symposium, IGARSS 2015*	*26-31 July 2015*	*Milan, Italy*	Scientific Community	*2106 participants*	*International*
43	*Conference*	*Krisztin,T., Leclère D.*	*The System Analysis Conference 2015*	*11-13 Nov 2015*	*Laxenburg, Austria*	Scientific Community	*303 participants*	*International*
44	*Conference*	*Krisztin,T.*	*9th International Conference on Computational and Financial Econometrics (CFE 2015)*	*14 December 2015*	*London*	Scientific Community	*700 participants*	*International*
45	*Conference*	*Leclère, D.*	*iCROPM 2016 Conference*	*15-17 March 2016*	*Berlin, Germany*	Scientific Community	*300 participants*	*International*
46	*Conference*	*Leclère, D.*	*European Geosciences Union General Assembly (EGU) 2016*	*17-22 April 2016*	*Vienna, Austria,*	Scientific Community	*14000+ conf. part.*	*International*
47	*Conference*	*J. Kroes*	*International Symposium on Earth Observation for One Belt and One Road (EO-BAR)*	*16-17 May 2016*	*Beijing, China*	Scientific Community		*International*
48	*Conference*	*Krisztin,T.*	*56th Congress of the European Regional Science Association (ERSA)*	*23-26 August 2016*	*Vienna, Austria*	Scientific Community	*1000+*	*Europe*
49	*Conference*	*N. Kussul*	*International training on combating desertification organized within UNCCD Program*	*22-26 of May 2017*	*Turkey*	Scientific Community	*70+*	*Eastern Europe, Caucasus and Central*

								Asia
50	*Conference*	*N. Kussul*	*2017 IEEE First Ukraine Conference on Electrical and Computer Engineering (UKRCON)*	*29 May – 2 June 2017*	*Kyiv, Ukraine*	Scientific Community		*Ukraine*
51	*Conference*	*N. Kussul*	*South Central and Eastern European Regional Information Network 5 (SCERIN-5)*	*20-23 June 2017*	*Pecs, Hungary*	Scientific Community	*50+*	*South Eastern and Central Europe*
52	*Conference*	*Leclère, D.*	*The 2017 World Impacts conference*	*10-13 October 2017*	*Potsdam, Germany*	Scientific Community		*International*
53	*Workshop*	*VITO*	SIGMA Presentation at the GEO Scretariat	*23-October 2013*	Geneva, Switserland	Scientific Community	*10*	*International*
54	*Workshop*	*VITO*	GEOGLAM regional workshop	*29-October 2013*	Moscow, Russia	Scientific Community	*20*	*International*
55	*Conference*	*VITO*	AfricaGIS / GSDI	*4 Nov 2013*	Addis Ababa, Ethiopia	Scientific Community	*200*	*International*
56	*Conference*	*VITO*	International Meeting on Food Security, Earth Observations and Agricultural Monitoring	21 Nov2013	Brussels, Belgium	Scientific Community	*200*	*International*
57	*Workshop*	*VITO*	GEOGLAM Side-meetings	22 Nov2013	Brussels, Belgium	Scientific Community	*20*	*International*
58	*Conference*	*VITO*	GEO X Plenary	14 Apr 14	Geneva, Switserland	Scientific Community	*200*	*International*
59	*Conference*	*VITO*	GEO Workplan symposium	28 Apr2014	Geneva, Switserland	Scientific Community	*20*	*International*
60	*Workshop*	*VITO*	GEPW - european GEO Projects Workshop	12 Apr 2014	Athens, Greece	Scientific Community	*200*	*International*
70	*Workshop*	*VITO*	JECAM Science Meeting	21 jul 2014	Ottawa, Canada	Scientific Community	*60*	*International*
71	*Conference*	*VITO*	IMAAFS	1 Oct 2014	Addis Ababa, Ethiopia	Scientific Community	*200*	*International*
72	*Workshop*	*VITO*	GEOGLAM-AGMIP	10 Mar 2015	Beltsville, USA	Scientific Community	*60*	*International*
73	*Workshop*	*VITO*	DG RTD ESA EOP meeting	10 Mar 2015	Brussels, Belgium	Scientific Community	*20*	*International*
74	*Conference*	*VITO*	Development Opportunities for Global Agricultural Monitoring	23 Apr 2015	Moscow, Russia	Scientific Community	*10*	*International*
75	*Workshop*	*VITO*	Space4Food workshop	11 jun 2015	Milan , Italy	Scientific Community	*20*	*International*

76	*Workshop*	*VITO*	9th GEO European Projects Workshop	15 Jun 2015	Copenhagen, Denmarks	Scientific Community	*300*	*International*
77	*Conference*	*UCL*	Sentinel 2 Symposium	19 Nov 2013	ESA Frascati italy	Scientific Community	*200*	*International*
7!	*Conference*	*CIRAD*	GV2M conference	3 Feb 2014	Avignon, France	Scientific Community	*(0*	*International*
79	*Conference*	*IIASA*	2nd Global Land Project Open Science Meeting	19 Mar 2014	Berlin, germany	Scientific Community	*60*	*International*
80	*Conference*	*CIRAD*	IEEE International Geoscience & Remote Sensing Symposium	13 jul 2014	Québec (Canada)	Scientific Community	*200*	*International*
81	*Conference*	*VITO*	JECAM Science Meeting	21Jul /2014	Ottawa, Canada	Scientific Community	*50*	*International*
82	*Conference*	*CIRAD*	Multitemp	22Jul 2014	Annecy France	Scientific Community	*300*	*International*
83	*Conference*	*UCL*	40th COSPAR Scientific Assembly	2 Aug 2014	Moscow, Russia	Scientific Community	*20*	*International*
84	*Conference*	*IIASA*	RAQS: 4th International Symposium on Recent Advances in Quantitative Remote Sensing	22 Sep 2014	Valencia, Spain	Scientific Community	*200*	*International*
85	*Conference*	*VITO*	Big Data from Space (BiDS'14)	12 Nov 2014	Rome, Italy	Scientific Community	*150*	*International*
86	*Conference*	*VITO*	AGU, Fall meeting	15 Dec 2014	San Francisco, USA	Scientific Community	*20000*	*International*
87	*Conference*	*CIRAD*	Climate Smart Agriculture	16 Mar 2015	Montpelier	Scientific Community	*20*	*International*
88	*Conference*	*UCL*	36th International Symposium on Remote Sensing of Environment	11 May 2015	Berlin, Germany	Scientific Community	*400*	*International*
89	*Conference*	*CIRAD*	IEEE International Geoscience & Remote Sensing Symposium (IGARSS)	26 Jul /2015	Milan, Italy	Scientific Community	*500*	*International*
90	*Conference*	*UCL*	Second Conference on Global Food Security	10 Oct 2015	Ithaca (New York), USA	Scientific Community	*100*	*International*

2.2 Section B

2.2.1 Part B1

TEMPLATE B1: LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.					
Type of IP Rights[7]:	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Application reference(s) (e.g. EP123456)	Subject or title of application	Applicant (s) (as on the application)
Patent	Yes	30/6/2019	TBC	CROPSAR (sar optical fusion)	Kristof Van Tricht

[7] A drop down list allows choosing the type of IP rights: Patents, Trademarks, Registered designs, Utility models, Others.

2.2.2 Part B2

Please complete the table hereafter:

Type of Exploitable Foreground[8]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[9]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
	Ex: New superconductive Nb-Ti alloy			*MRI equipment*	*1. Medical* *2. Industrial inspection*	*2008* *2010*	*A materials patent is planned for 2006*	*Beneficiary X (owner)* *Beneficiary Y, Beneficiary Z, Poss. licensing to equipment manuf. ABC*

In addition to the table, please provide a text to explain the exploitable foreground, in particular:

- Its purpose
- How the foreground might be exploited, when and by whom
- IPR exploitable measures taken or intended
- Further research necessary, if any
- Potential/expected impact (quantify where possible)

[19] A drop down list allows choosing the type of foreground: General advancement of knowledge, Commercial exploitation of R&D results, Exploitation of R&D results via standards, exploitation of results through EU policies, exploitation of results through (social) innovation.

[9] A drop down list allows choosing the type sector (NACE nomenclature) : http://ec.europa.eu/competition/mergers/cases/index/nace_all.html