# Sen4Stat Concept Paper

## Satellite Earth Observation for Agricultural Statistics

Increasing sustainable agricultural productivity is the number one challenge of the "The Future of Food and Agriculture" report [1] of the Food and Agriculture Organization in response to a projected increase in demand for food by 50% between 2012 and 2050. A wide range of timely data and information on agricultural practices and natural resources is required at national to global scale to address such a challenge in an effective way, to analyze and understand trends, plan, prioritize and design solutions. Monitoring of the Sustainable Development Goals (SDG) raises a similar need for information at the national level to report on improvement of the different goals, of which SDG targets[2] 2.4 and 6.4 are most relevant for sustainable agriculture. In 2011 the G20 agricultural ministers further identified the transparency of agricultural markets as essential for food security and launched the GEOGLAM initiative[3] to "strengthen global agricultural monitoring by improving the use of remote sensing tools for crop production projections and weather forecasting". In all mentioned cases agricultural monitoring at national scale is a prerequisite for assessing and analyzing the agricultural resources by mandated authorities, usually the agricultural National Statistical Offices (NSO). National agricultural monitoring data is in general collected by farm and household surveys, but recently the potential of satellite Earth Observation (EO) for agricultural statistics has been recognized as well[4].
The advent of the Copernicus program and its observations collected by its Sentinel satellites provide unprecedented open and free data relevant for national agricultural monitoring, down to the field scale. In particular, the Sentinel-1 and -2 missions can provide geospatial information on crop area estimates, crop type and status as well as on agricultural practices in a timely fashion. As an example, the potential of Sentinel-2 observations for national scale agricultural monitoring was successfully demonstrated by the Sen2Agri project[5] involving national stakeholders of three countries (Mali, South Africa and Ukraine) and is currently used as open source tool around the globe (>800 downloads).

National agricultural monitoring systems based on open satellite EO data, such as the Sen2Agri toolbox, can deliver cropland masks, crop type maps and crop status that can boost statistical information systems in many ways: master frame construction (census & surveys), sampling design optimization (stratification),

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[1] The Future of Food and Agriculture report, FAO 2017: http://www.fao.org/publications/fofa/en/
[2] SDG 2.4.1 indicator is defined as follows "percentage of agricultural area under productive and sustainable, https://unstats.un.org/sdgs/iaeg-sdgs/
[3] G20 initiative GEOGLAM: http://www.geoglam.org/index.php/en/
[4] Handbook on Remote Sensing for Agricultural Statistics: http://gsars.org/en/handbook-on-remote-sensing-for-agricultural-statistics/
[5] Sen2Agri website: http://www.esa-sen2agri.org

estimation of crop areas (calibration estimators), estimation of yields (through e.g. NDVI, LAI), early warning systems (real time monitoring with imagery every 5 days). However, without dedicated support, national agricultural statistical services are often not sufficiently equipped to take advantage of EO tools and derived products. Such capacity is highly recommended to be developed in mandated organizations at a time when new data sources are needed to monitor progress towards the SDGs at national scale.

For a successful uptake of EO information by agricultural National Statistical Offices (NSO) further steps have to be achieved in terms of additional information products, methodological development and support for effective integration in their operational workflows and reporting obligations. To raise the awareness of NSO for EO and to lower the technical entry barrier the following potential activities are identified, which will have to be further discussed with national and international stakeholders:

- Engage and develop together with NSO dedicated applications and workflows to integrate EO agricultural products in their operations *(initial list of potential applications – to be developed & prioritized with NSOs):*
    - Agricultural census and surveys (support their effectiveness and timeliness e.g. intermediate updates)
        - *Migration from list to area-sampling frames (e.g. in Mali)*
        - *Incorporating EO maps of small-scale irrigation into the national revolving agricultural survey (e.g. in Mali, Ethiopia…)*
        - *Derivation of census and survey Enumeration Areas from latest cloud-free image composites or crop mask on entire country.*
        - *Monitoring of specific national agricultural policies (e.g. Ethiopia's agro parks or large scale investments)*
        - *Monitoring expansion of high value crops such as soya and rice (e.g. in Senegal and Nigeria)*
    - SDG national reporting especially for SDG 2.4. and 6.3 targets.
    - Monitoring of sustainable agricultural practices
    - Early warning system
    - Natural resources monitoring for pastoralism
        - *Incorporating dynamic EO estimates of surface waters into pastureland monitoring (e.g. in Mali)*
    - Assessment of land abandonment (e.g. urban migration)
    - Impact of conflicts for emergency response
- Demonstrate timely and dynamic agricultural monitoring at national scale enabled by cloud computing – e.g. early season crop acreage estimates and yield forecast
- Development and enhancement of agricultural EO products making full use of the observations of Sentinel-1, -2 and -3.
- Development or improvement of field survey protocols and tools (geo-statistical sampling, mobile applications e.g. WFP mVAM, chatbots) integrating field surveys efficiently into timely production of EO information.

Further support surveyors in order to boost the efficiency of fieldwork and to increase real time quality checks of computer assisted data acquisition.

- Prepare and make accessible (addressing technical & privacy issues) national statistical data sets (e.g. socio-economical information, land registries). Relevant national agricultural/household surveys are conducted by e.g. AGRIS (FAO), LSMS-ISA (World Bank), WFP, USAID, CGIAR, Comprehensive Africa Agricultural Development Program (CAADP, AUC). Access to national surveys will be instrumental for integrating and creating synergy with satellite EO in national agricultural statistics.
- Develop innovative data analytical tools to combine national scale EO layers with local in-situ intelligence for enhanced agricultural statistics
- Timely crop production estimations at national scale based on representative crop model (DSSAT, CGMS, APSIM) simulations using cloud computing combined synergistically with EO data and products (e.g. crop growth, soil moisture, ET, rainfall), field data and crop area estimates.
- Demonstrate the unique potential of the Sentinel constellation to develop a new generation of near-real time agricultural monitoring systems in support of Food Security early warning systems..
- Consider the approach of FAOSTAT[6] and System of Environmental-Economic Accounting for Agriculture, Forestry and Fisheries[7] (SEEA) of FAO for statistical reporting allowing for inter-comparison between countries.

Having in mind the recent commitments taken by the international community with the SDG's and the needs assessment done by the Global Strategy to Improve Agriculture and Rural Statistics[8], the Sen4Stat project will focus on demonstrating the potential of satellite EO for monitoring and reporting of the SDG targets related to agriculture. In this context algorithms and data analytics will be developed to combine EO data most efficiently with national statistical data sets and surveys. The ultimate goal is to transfer such capabilities to mandated NSO to support them in the uptake of satellite EO for agricultural statistics.

It is recommended to identify a representative set of countries with various stages of statistical system complexity and performance as well as covering a range of major crops, agricultural practices and landscapes. A list of priority countries for the selection of Sen4Stat pilot countries has been compiled (annex A) based on relevant agricultural statistical programs. In each selected pilot country the mandated national agricultural statistical services need to be engaged and a local technical facilitator is recommended to facilitate the technology adaptation and transfer. A three years project duration would favor the sustainability of the adoption of the EO technology in the local statistical production process. A dedicated steering

[6] FAOSTAT: http://www.fao.org/faostat/en/#home

[7] SEEA: http://www.fao.org/fileadmin/templates/ess/ess_test_folder/Publications/Agrienvironmental/SEEA_AFF_FINAL_Clean_03.pdf

[8] Global Strategy to Improve Agriculture and Rural Statistics Initiative: http://gsars.org/en/

committee has been proposed to guide and support the Sen4Stat activity. The following institutions currently confirmed their participation in the steering committee FAO, World Bank, WFP, CGIAR, JRC, DG-Agri and OECD.

## Annex A:

Sen4Stat priority countries selected based on relevant agricultural statistical programs. The availability of agriculture or household survey data as well as the engagement of the respective NSO will be prerequisites for the final pilot countries selection. Additionally interested OECD countries will be considered with preference in Europe.

| Country | AGRIS[9] | LSMS-ISA[10] | CGIAR | WFP | SDG pilot[11] |
|---|---|---|---|---|---|
| **Ghana** | **X** | | | | |
| **Senegal** | **X** | | | | |
| **Uganda** | **X** | **X** | | | |
| **Burkina Faso** | | **X** | | | |
| **Ethiopia** | | **X** | x | | |
| **Malawi** | | **X** | | x | |
| **Mali** | | **X** | **X** | | |
| **Morocco** | | | | | x |
| **Niger** | | x | | | |
| **Nigeria** | | **X** | | | |
| **Rwanda** | | | | | x |
| **South Sudan** | | | | **X** | |
| **Tanzania** | | x | | | |
| **Ecuador** | **X** | | | | |
| **Costa Rica** | x | | | | |
| **Guatemala** | x | | | | |
| **Uruguay** | **X** | | | | |
| **Georgia** | x | | | | |
| **Armenia** | x | | | | |
| **Kazakhstan** | x | | | | |
| **Cambodia** | x | | | | |
| **Nepal** | x | | | | |

**X**: Relevant data sets or surveys available or currently ongoing
x: Availability of relevant data sets to be confirmed. For most AGRIS countries surveys are planned in 2019-20.

[9] The Agriculture Integrated Survey (AGRIS): http://agris.fao.org/
[10] Living Standards Measurement Study – Integrated Surveys on Agriculture (LSMS-ISA) http://surveys.worldbank.org/lsms/integrated-surveys-agriculture-ISA
[11] SDG 2.4.1 pilot countries (March 2017)