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Geospatial information for African agriculture: a key investment for agricultural policies

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Geospatial information and its derived products, designed to contribute to public agricultural policy making, are not widely used in Africa. The infrastructure, training and skills are lacking, and research and development activities are dispersed and inadequate. More importantly, needs are not formalised and technological resources, driven by the industrialised countries, are ill-adapted to the characteristics of agricultural systems in Africa. Moreover, companies, institutions and projects require a stable environment to ensure operational services, relevant products and useful information. These co-constructed services emerge within long-term partnerships between researchers, consultancies and end users. Research thus offers new opportunities for using satellite imagery to document and explain agricultural transformation processes. Finally, lasting interdisciplinary skills networks are needed to facilitate methodological and thematic exchanges.

In Africa, the importance of up-to-date geospatial information to support public agricultural policy is amplified by the fact that national statistical systems, usually based on inventories, are often inadequate. The continent is nevertheless struggling to produce this geospatial information. Training centres in spatial technologies and university courses in remote sensing (spatial information acquisition) and geomatics (geographical data analysis methods and tools) are in short supply and are concentrated in just a few countries.

Even where these centres exist, access to satellite imagery and processing tools has failed to increase the use of geospatial information and data (see box p. 2). Despite the numerous projects deployed in Africa since the late 2000s, services based on remote sensing data are still limited, mainly due to a lack of skills and interactions between users and information producers.

Many products are available, but their potential is untapped

The main fields of application in agriculture (see figure p. 2) use products derived from satellite imagery that are calculated through pre-calibrated processing operations. **These "generic" products** include:

> global products for surface biophysical variables (leaf area index, soil moisture, surface temperature, spectral vegetation indices, etc.) and land use variables. These are routinely obtained across the globe at a low spatial resolution, from 250 metres to several kilometres. One of the best-known examples is the Land Cover Project by the European Space Agency (ESA) Climate Change Initiative, at a spatial resolution of 300 metres, available since 1992;

> land use maps at a higher spatial resolution, produced on request for large areas, often as part of projects. The Burkina Faso Land Cover Database (BDOT) at 1/100 000 scale is thus produced by the Geographic Institute of Burkina Faso (IGB) with technical assistance from IGN FI, the technical operator for the French National Institute of Geographic and Forest Information (IGN France), in implementing its international projects;

> satellite image maps, in natural colours, which are geo-referenced with an overlay including landscape and infrastructure elements such as roads, towns and waterways.

Most generic products are derived from low resolution satellite sensors. They are primarily developed at the regional and national levels, and are used in modelling the water cycle, the carbon cycle and the energy balance.

Generic land use products also measure changes such as deforestation or urban sprawl. However, they are not precise enough for more operational requirements on a large scale (1/5 000 to 1/50 000), such as land use plans, agricultural statistics or precision agriculture. Developing these applications requires regularly updated land use maps at a high spatial resolution. The simultaneous use of data from the Earth observation satellites Sentinel-2 operated by ESA and Landsat-8 by NASA should enable the development of a land use database equivalent to the European CORINE Land Cover (CLC) inventory, produced under the Copernicus programme, which covers 39 states (wider Europe). The production of these databases meets priority needs for the majority of African countries.

The geospatial information chain goes from satellite data to decision-making; to operate, it must use not only the existing generic products, but also thematic products and information services (see figure p. 3).

Thematic products, or applications, are designed to address a specific question, whether territorial or environmental: risk or potential maps, indicator maps, dashboards, etc. They include generic products and thematic knowledge, in the form of ancillary data sources (statistics, *in situ* observations) or processing operations guided by experts according to their knowledge and appraisal. Their use in decision support and information service provision is restricted by their level of precision, whether spatial (image resolution), temporal (interval between two image acquisition dates), or semantic (thematic classes in the key).

The information services derived from these thematic products are aimed at institutions responsible for the design and implementation of agricultural and resource management policies, as well as at agricultural support structures and some agricultural producers. These end users require recurring information such as areas under cultivation, crop conditions monitoring and yield estimates. Information services produce regular, standardised information that is easy to access and use. Consequently, these services comply with precise specifications, according to the needs of end users.

Thematic decision support products are more complex to design than generic products because they include complementary data and imply adapting methods to local conditions. For example, risk maps of vector-borne infectious diseases require knowledge of the ecology of vectors in order to develop appropriate environmental indicators. Ancillary data and local expertise are not always available, but external technical assistance can help to develop this expertise and to facilitate local appropriation of technologies. Today, other thematic products of interest to several communities are routinely generated, such as vegetation growth anomaly maps, which indicate the relative level of vegetation productivity and which are integrated into the majority of early warning systems for food security.

Earth satellite imagery: available in abundance, freely accessible, but requiring powerful processing capabilities

Earth observation is an essential tool for characterising agricultural areas at the national and transcontinental levels. Around 100 Earth observation satellites are in orbit and provide data at different spatial resolutions, from 30 centimetres to several kilometres, with different revisit frequencies (hourly, daily, bi-monthly, etc.) and in varied and complementary spectral bands.

Access to high spatial resolution satellite data (up to 10 metres) is currently facilitated by the national and international initiatives developed, which propose free access or open access data, for example: the French Data and Services centre for continental surfaces (THEIA, see box p. 4), the European Commission (Copernicus, the European Union Earth observation programme) the CNES (French National Centre for Space Studies, through its Operating platform Sentinel products – PEPS), and NASA (National Aeronautics and Space Administration) in the United States.

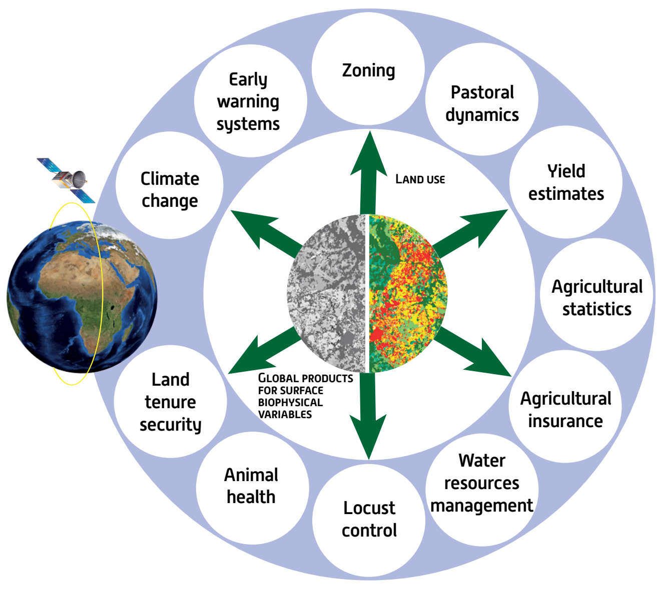
The bottleneck once linked to the acquisition of images and to processing tools has shifted towards the volume of data to be processed. An initial response is provided by cloud computing information technologies, which enable remote access to image computing and processing resources, and by free image processing and geographical information system (GIS) software. These technologies nevertheless require increasingly sophisticated equipment, knowledge and skills, as well as a good internet connection. The democratisation of access to data and tools is real, but their use is linked to a complex, rapidly evolving technology.

Improving the performance of existing products by building partnerships between research and users

There are many reasons to explain the poor performance of existing products or their limited use – First, interactions with end users are lacking. The technology resource strategy, largely driven by the institutions of the Global North, is aimed at transferring data and products that only partially respond to African demand. The methods used are ill-adapted to African agricultural systems, which are more diversified and far less documented than agriculture in the industrialised countries. The environmental conditions, the diversity of farming systems, the lack of images and complementary data, and the challenges of partnerships are just some of the constraints for transfer and adaptation.

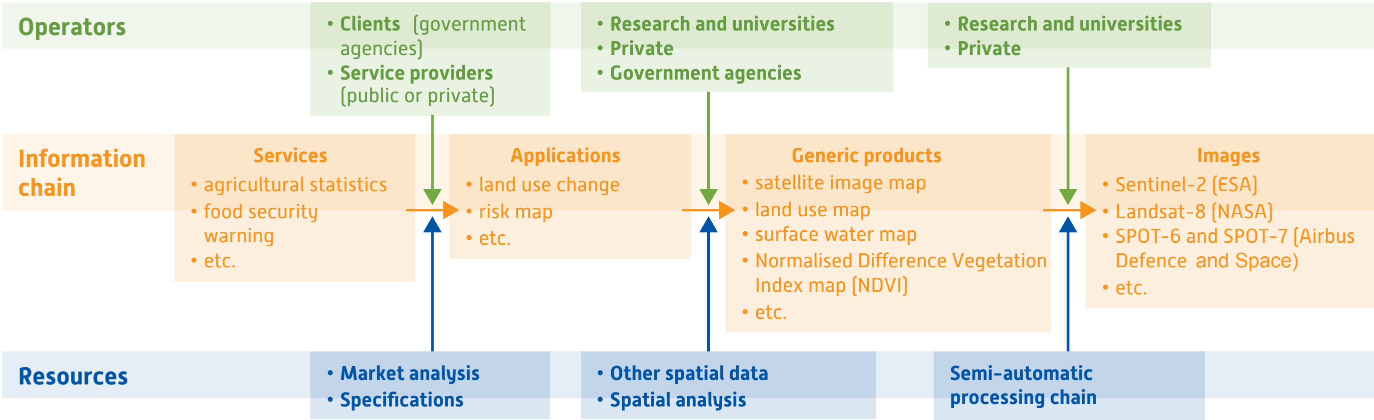
There are also other reasons that compromise the quality of services. Geomatics is a young science and requires applied research. But geospatial information in Africa is hampered by dispersed activities, mainly conducted through one-off projects, which are often in competition when seeking financing. This information is built on remote sensing projects

The main fields of application in agriculture using remote sensing products.



The co-construction of geospatial information services: structuring a community of practitioners and users.

The need for a service, via the production of specifications and a market analysis, makes it possible to define the steps required in its creation: which applications should be developed? Which generic products are needed to develop these applications? Which images should be used to obtain these products?



supported by international donors, in just a few countries, for national and regional public institutions. These projects have equipped centres, trained managers and technicians, and launched applications for agricultural development. But the limited duration of projects has not always guaranteed the maintenance of equipment, the preservation of human resources and the upgrading or transfer of skills.

The need for governance and coordination is mentioned by all actors for equipment, infrastructure, data and training aspects. The importance of pooling resources, through a national and regional (major continental regions) geomatic strategy is evident.

Establishing a favourable environment to guarantee operational information services (see figure p. 3) **–** In order to develop, the African geospatial information sector needs to ensure remote sensing and spatial technologies become tools that are recognised at all levels of both decision-making and appraisal in the agricultural sector. This requires operational information services that are reliable and easy to implement to address the needs of actors in the sector.

An information service connects needs and data in a process that is co-constructed between researchers, consultancies and end users. This service is based on a chain of activities articulating research functions, technical, methodological and financial assistance functions for intermediate operators, and user support functions. This chain of activities covers not only the expression of needs but also the actual implementation stage.

To enable the development of such services, companies, institutions and projects must be guaranteed a sustainable, stable environment. The public authorities need to ensure upfront investment to achieve this. National geomatic strategies are required to encourage the pooling of data and of human and material investments, and to thereby avoid redundant investments. As with the strategy launched in Senegal (National Geomatic Plan, *Plan national géomatique,* PNG), these strategies can coordinate action, define a regulatory framework for the production and use of geographical data and information and, finally, ensure the technical and economic sustainability of services.

All satellite images (recent and historical), adapted processing procedures and computing capacities required must be easily accessible. The images and generic or thematic products, which are often financed by public funds, need to be pooled in order to capitalise on existing resources and to foster innovation. This raises the question of whether or not these services should incur a fee: do they constitute a public service or should users participate financially? In any case, pooling resources helps to reduce costs.

Building a critical mass of technicians, professionals and researchers will enable African countries to master and adapt technologies, and to develop services in line with their socioeconomic and geographical environments. This implies first investing in initial and vocational training and, second, increasing the number and quality of courses. This capacity building will also benefit consultancies and non-governmental organisations, alongside national public institutes.

Ensuring this environment benefits end users – A favourable environment is a necessary but not sufficient condition. It must produce relevant information that is useful in decision-making processes. However, users' needs are not sufficiently formalised and existing services are ill-adapted. Thematic products and services are too strongly driven by supply. The remote sensing sector needs to engage in the co-development of geomatic services. To do so, working groups can connect technical centres, service providers and users, with the goal of transforming needs into formalised, shared demand, which is set out in detailed specifications. Depending on what exists, financing can facilitate the provision of services that are already operational (local deployment, training) or the creation of applications or services that respond to needs expressed that have not been addressed.

Structuring skills networks – Research needs to go further. It must adapt methods to the characteristics of African agricultural systems. It must work in partnership to develop real information services that are in line with needs: in particular, this partnership involves consultancies tasked with developing decision support products and local actors.

The goal is to structure skills networks that foster methodological and thematic exchanges. These networks can operate on the principle of communities of practice. They bring together professionals in geomatics and in other disciplines needed to develop the thematic products anticipated. Research should result in harmonised, adapted methods and in professional references – standardised, common languages, methodologies, practices and tools. The interdisciplinary approaches thus implemented integrate methodologies from different disciplines (computer science, statistics, signal processing, human and social sciences, life sciences, Earth sciences), and data from different origins: satellite images available at high and low spatial resolutions and from other means of observation, such as *in situ* observation, UAVs or nano satellites. ■

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> The Montpellier Remote Sensing Centre, France (MTD, https://www.teledetection.fr);

> THEIA, the French Data and Services centre for continental surfaces (https://www.theia-land.fr/en/theia-data-and-services-center/), whose goal is to increase the use of spatial data by the scientific community and public actors;

> GeoDEV, the network of skills centres working on spatial observation of countries and territories in the Global South (THEIA Regional Coordination Network for the countries of the South, http://www.theia-land.art-geodev.fr/en/);

> the European SIGMA programme (Stimulating Innovation for Global Monitoring of Agriculture, 2014-2017, http://www.geoglam-sigma.info), financed by the European Union Seventh Framework Programme;

> the OSFACO project (Spatial observation of forests in Central and West Africa, 2016-2019, http://www.osfaco.org), financed by the French Development Agency (AFD, https://www.afd.fr/en).

This issue of *Perspective* is part of a global reflection by spatial information actors in which the Montpellier Remote Sensing Centre plays a leading role, in particular in terms of support for end users.

It is also based on the two following reports:

Bégué A., Charrier B., Torre C., Lo Seen D., Tonneau J.P., Leroux L., Morant P., 2016. Observation spatiale pour l'agriculture en Afrique : potentiels et défis. Paris, AFD-CIRAD, collection Notes Techniques 12, 182 p. ISSN 2492-2838. https://www.afd.fr/fr/observation-spatiale-pour-lagriculture-en-afrique-potentiels-et-defis.

PARM, 2018. Access to information system for agricultural risk management in Senegal. Final report - January 2018. A feasibility study conducted by CIRAD for PARM (Platform for Agricultural Risk Management) / IFAD (International Fund for Agricultural Development), Rome, Italy, 138 p. http://p4arm.org/document/access-to-information-system-for-agricultural-risk-management-in-senegal. *(in French)*.

Publications resulting from this research include:

Leroux L., Bégué A., Lo Seen D., D., Jolivot A., Kayitakire F., 2017. Driving forces of recent vegetation changes in the Sahel: Lessons learned from regional and local level analyses. *Remote Sensing of Environment* 191: 38-54. https://doi.org/10.1016/j.rse.2017.01.014.

Leroux L., Baron C., Zoungrana B., Traoré S., Lo Seen D., Bégué A., 2016. Crop monitoring using vegetation and thermal indices for yield estimates: case study of a rainfed cereal in semi-arid West Africa. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing* 9(1): 347-362. https://doi.org/10.1109/JSTARS.2015.2501343.

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Some links

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