geodata for inclusive finance and food

G4IFF

inventory of technology

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Prepared by
Mark Noort, HCP international
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Reviewed by
Mariska Lammers, Netherlands Platform for Inclusive Finance
Josien Sluijs, Netherlands Platform for Inclusive Finance
Mariël Mensink, Fair and Sustainable Consulting

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Introduction

The aim of this paper is to explore the added value of geodata to promote access to finance for agricultural activities. More specifically, for inclusive finance that is directed at smallholder farmers and pastoralists (1). The focus is on just a part of the food chain and the food security ecosystem: the part that ranges from growing crops or raising livestock to selling of agricultural produce (2).

The term geodata, computerised geographic data, used interchangeably with geospatial data, refers to data that has a direct association with a location on the Earth's surface. Although the information provided below focuses very much on Earth observation, all the applications that are presented make use of geographic information systems (GIS) and global positioning systems (GPS).

The use of geodata (geospatial information) can benefit the delivery of financial services. Certain features of geospatial information, such as computerised maps (GIS: geographic information systems) and cadastral information, have been around for a long time. The use of satellite information, including Earth observation (satellite images), for financial services is relatively new. The (full) potential for financial services still needs to be explored. The application of satellite information offers certain advantages in areas where other sources of information are lacking and the target groups of inclusive finance generally live in these areas. This paper gives therefore special attention to the applications of satellite information.

To properly assess the potential benefit of geodata for financial service provision for smallholder farmers, it is important to indicate the priority areas for finance where the application of geodata can add value. These priority areas are:

- Improved risk management;
- Lower costs;
- Well-designed products;
- Increased outreach.

Three different (and partially overlapping) types of smallholders can be distinguished:

A Subsistence smallholders;
B Semi-commercial smallholders in loose value chains;
C Commercial smallholders in tight value chains.

The focus of this paper is primarily on the smallholders of group B and to a lesser extent on those of group C, as they produce for markets and have (limited) access to technology and financial services.

1 Defined as: Smallholder farmers with less than two hectares of farmland or pastoralists that manage less than 10 head of livestock. The equivalent of two hectares of average quality farmland is one hectare of very fertile land or 10 hectares in semi-arid areas.

2 Fisheries and aquaculture are outside the scope of this paper.

1 Geodata for agriculture

The advantages of satellite information are well documented: **repeated coverage of large areas** (including places that are difficult to reach) enables regular monitoring of what happens on the ground, the use of global positioning systems (GPS) provides reasonably **accurate information on location** and intelligent processing of satellite data yields a wealth of information on environmental and agricultural processes. In addition, **huge amounts of satellite data are becoming available free of charge**.

However, there are also constraints that limit a general application of satellite information across the board. Space programmes are, or at least were, not defined in accordance with user needs. **Very accurate imagery (VHR: very high resolution) is costly**. The **appropriate data may not be available** for exactly the right time and the right place. Although most of the data is free of charge, processing and hosting the data is usually not. The **processing of data and the transformation of data into actionable information needs to be done by specialists**.

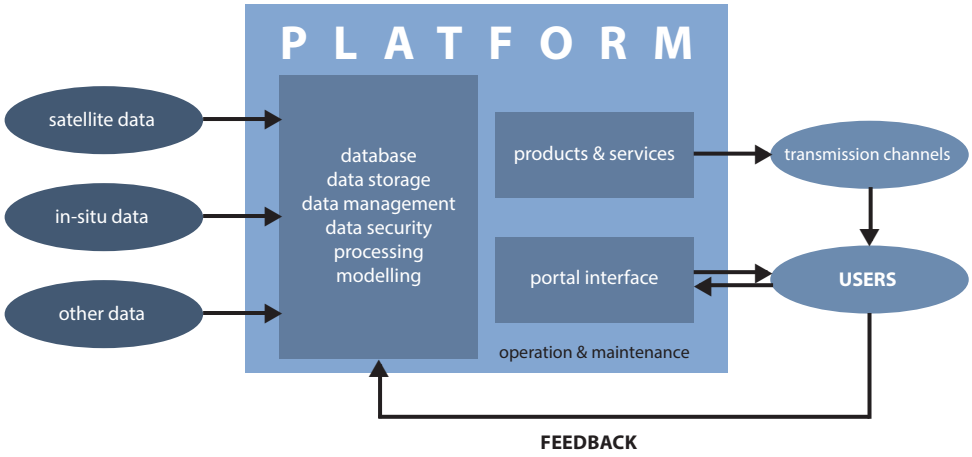
Still, a clear extension of the range of satellite applications for food security is noticeable. Where traditionally satellite information was used for public services (large scale monitoring of the environment and agriculture) and large farms (precision agriculture), now **new products and services are developed for smallholder farmers and pastoralists in developing countries**. The Geodata for Agriculture and Water (G4AW) Facility (3) of the Netherlands Ministry of Foreign Affairs and administered by the Netherlands Space Office (NSO) has been instrumental in this respect. The Facility supports 23 projects that apply satellite information for smallholder farmers and pastoralists, with the aim to set up a sustainable service within a period of three years.

The projects are in different implementation phases and have already yielded valuable information about the feasibility and achievements of the initiatives. The main lessons learned from the G4AW mid-term review (4) that are relevant in this context are:

- A clear focus in offered products and services is important;
- A local, strong and active business partner provides an advantage;
- Smallholder farmers are often not (directly) the paying clients; and
- The whole chain from research to commercialisation should be taken into account to achieve sustainability.

Figure 1
Platform and services for smallholders

An overview of how this type of intervention for smallholders works.



3 https://g4aw.spaceoffice.nl/en/

4 G4AW (2016). *A business case for opening new markets using satellite data for smallholder farmers and pastoralists in developing countries - How "Space for Food Security" works at the local level: An overview of lessons learned in the first years of the Geodata for Agriculture and Water (G4AW) Facility.*
http://g4aw.spaceoffice.nl/en/About-G4AW/Publications/

Of course, this figure presents a very general picture. Factors that affect applications include:

- Crop types and stages of growth, regional differences all have to be accounted for in the interpretation of results;
- The accuracy obtained depends on the scale of the images used, especially for agricultural advice to individual smallholders this may be a bottleneck;
- In-situ data are needed to calibrate the remotely sensed results;
- Analysis of time series needs additional data to arrive at absolute values (e.g. for crop yield: this year's yield is 20% better than last year, one needs to know last year's yield to calculate this year's yield).

Even with these complications, quite a number of projects and services have been developed for smallholders by commercial companies. Table 1 gives an overview of the main ones (5).

Table 1 Ten main geodata topics that companies offer for smallholder farmers and pastoralists (6)

Rank	Category no.	Description	Times offered
1	2	Crop (health and yield) monitoring	27
2	7	Pest and disease management	15
3	11	Soil moisture assessment and modelling	12
4	10	Water use and irrigation advice	11
5	1 21	Agricultural knowledge and information systems Disaster monitoring and impact assessment	10 10
7	26 27	Water resources assessment (surface, groundwater) Environmental / ecosystem assessment / accounting	9 9
9	5 6 14	Weather forecasting Fertiliser advice Flood risk assessment	8 8 8
		Other	79
		Total	**206**

5 Annex 4 gives an overview of the main topics offered within G4AW projects.

6 Based on an inventory of 38 companies (based in Europe, Asia, Africa and North America).

2 Geodata and financial inclusion

In light of a growing world population, smallholder farmers are crucial in supplying the world with sufficient food. In order to achieve this much needed growth, access to affordable and appropriate finance is key. However, financial institutions see agriculture lending as risky and costly and do not easily lend to smallholder farmers.

Apart from specific applications, such as agricultural insurance based on indices derived from satellite information, the interest to combine geodata and financial services was only more recently explored. The publication "Geodata and ICT solutions for inclusive finance and food" (7) and the organisation of the conference "Geodata for inclusive finance and food" (8) (organised in Rotterdam in February 2017) were first steps to explore the potential of the combination of geodata and financial services for smallholder farmers and pastoralists. The main findings of the publication are that a good policy and regulatory environment is needed, that the information packages designed for farmers should be appropriate, that financial institutions need guidance and support in understanding and selecting solutions based on geodata, and that the issue of appropriate pricing is very important. The NpM website contains a database with an inventory of geodata and ICT-related initiatives that are relevant to inclusive finance (9).

To get a good grip on the potential of geodata for financial inclusion, the products and services were categorised in elementary building blocks. Annex 2 presents an overview of these building blocks, their use, paying customers and the potential added value for financial inclusion of smallholder farmers. Annex 3 gives the correspondence of these building blocks with the categories of the database of the NpM website.

If we combine different sets of building blocks, the main features, with which geodata can support financial inclusion are: **improving agricultural performance, managing risks, provision of historical records and support measures for financial operations**. Annex 2 indicates for each building block in which area(s) potential added value for inclusive finance can be provided.

Examples

An example of a **support measure for financial operations** is locating farmers and their holdings through location-based data gathering with GPS (either directly or through farmers' organisations). This information is valuable for financial service providers. Early detection of pests and diseases **improves agricultural performance** in terms of loss reduction and cost saving (i.e. less pesticides are needed).
Historical records derived from crop monitoring provide information on yields of farmers or farmer groups compared to their peers, giving an indication on credit worthiness. A flood risk assessment makes it easier to determine which parcels are prone to flooding, which is especially relevant as the most fertile soils are usually found in low-lying areas. This is important information for financial service providers' (FSPs) **risk management systems**.

7 Mensink, M. and Vranken, M. (2017). *Geodata and ICT solutions for inclusive finance and food security: Innovative developments – An overview.* http://www.inclusivefinanceplatform.nl/documents/npm-20geodata-20and-20ict-20solutions-20for-20inclusive-20finance-20and-20food-20security.pdf

8 http://www.inclusivefinanceplatform.nl/what-s-new/events/271/conference-geodata-for-inclusive-finance-and-food

9 http://www.inclusivefinanceplatform.nl/ict-map

3 Geodata and financial inclusion in the food production value chain

One of the main misunderstandings about geodata for agriculture is that it provides stand-alone solutions. Just as any support mechanism, geodata products and services help make the food production chain more effective and efficient and are part of that value chain. Before elaborating further on the type of services and the conditions for success, it is good to have a look at the value chain, starting with sustainable business models.

Summary of business models used for serving smallholder farmers and pastoralists

- Freemium model: Free service provision. Other paying clients are financing operations;
- Loyalty model: Free service provision avoid switching clients to competitor (also called "direct revenue B2B" in the case of a seed/nutrient supplier or "indirect benefit" in the case of a mobile telecom operator);
- Direct revenue B2C: The smallholder farmer or pastoralist pays directly for a service;
- Inclusive model: Paid service provision bundled into package, e.g. insurance coupled to credit, advisory to input supplies;
- Service model: The client is paying a (subsidised) fee for service provision; the subsidy can come from government or from a farmer cooperative.

As the experience with the G4AW Facility shows, it seems that the loyalty and inclusive models are best suited to achieve sustainability in addressing the needs of smallholder farmers and pastoralists (10). The packaging of services reduces the financial burden for the smallholder farmer or pastoralist, while the paying entity, such as a fertiliser supplier, benefits from an increased customer base. The advantage of these models for the geodata provider is that the direct contact with the smallholder farmers and pastoralists takes place through an entity that has the network already in place.

Geodata products and services are useful for financial service providers because:

- Risk management can be improved through geodata solutions on (natural) risk assessment and early warning and provision of more accurate information on the target group and by providing support to improve agricultural performance (which improves the capacity for loan repayment);
- Costs can be lowered for financial service providers by making use of location-based applications and databases, and by the analysis of historical records, reducing the need for field visits;
- Geodata solutions can be packaged with other products and services that make the offers of financial service providers more robust and attractive; and
- The use of geodata platforms (in combination with mobile solutions) can improve the outreach of financial service providers by increasing the frequency of interactions and the number of people reached, and by gathering information to "know your customer" better (KYC).

10 The findings of various GSMA mAgri evaluation reports also support this, although the GSMA approach is (still) very much based on direct revenue.

Choices with respect to the packaging of services, working in the form of a PPP, the role of an aggregator (11), reaching the end-user, the business model, scaling up, etc. depend for a large part on local circumstances. Apart from the general considerations sketched above, no winning strategy is available that can be applied under all conditions.

A main challenge to address is that the "geodata world" and "inclusive-finance world" need to **find a common language**. The geodata experts need to understand the priorities and requirements of the financial service providers and have to realise that financial service providers are real partners and have to be involved from the start. The inclusive-finance sector needs to know more about satellite information showing only relative differences in greenness of the Earth, the dependency of solutions for smallholder farmers and pastoralists on free data, and the need for local knowledge and in-situ data (12) for calibration and validation.

11 An aggregator provides a platform where a client can shop for different services, and the entity responsible for embedding then ensures that conditions are created for the food producer to use the product or service in the best possible way. The entity can be the aggregator but also another organization.

12 A promising new initiative on in-situ observations, called TAHMO, is expanding operations in Africa: http://tahmo.org/

Annexes

Annex 1 List of acronyms

B2B	Business to Business
B2C	Business to Customer
FSP	Financial Service Provider
G4AW	Geodata for Agriculture and Water
GIS	Geographic Information System
GSMA	Global System for Mobile communications Association
ICT	Information and Communication Technology
KYC	Know Your Customer
MNO	Mobile Network Operator
NGO	Non-Governmental Organisation
NpM	Platform for Inclusive Finance
NSO	Netherlands Space Office
PPP	Public-Private Partnership
VHR	Very High Resolution

Annex 2 Inventory geodata for inclusive finance and food

Introduction

In the next pages Earth observation applications for food security are presented from the point of view of the end user, i.e. the customer that ultimately benefits from the application and/or pays for the product or service. The list is not exhaustive and other configurations may be equally valid. Although the information provided focuses very much on Earth observation, all the applications that are presented make use of geographic information systems (GIS) and/or global positioning systems (GPS). As these technologies are more mature and more integrated in local practice, their role is not separately highlighted, unless they have a key, innovative function in the application. Virtually all Earth observation applications need to be complemented by in-situ observations and/or data from drones.

However, as it will be difficult to obtain the same advantages of scale through using only in-situ observations or drones, Earth observation is taken as the leading technology for describing applications in this inventory.

The value derived from Earth observation applications is increasingly suitable for informed decision making. Factors that contribute to this development are, among others, the availability of free satellite data, the increasing accuracy of these data (in terms of spatial, spectral and temporal resolution) and improved algorithms and models for data processing. As a result, a considerable amount of products, services and platforms have been developed to support food security. Many solutions related to food security and based on Earth observation are now implemented. Some applications and the associated business models are completely operational; others still need further testing and validation.

Earth observation applications can enhance inclusive finance operations. To be effective however, a number of challenges have to be addressed. General challenges can be summarised as follows:

- Technology bias: although there is a plethora of platforms for Earth observation solutions, **an ecosystem that connects and integrates Earth observation and inclusive finance approaches is still lacking;**
- Translation into practice: the proposed solutions are technically sophisticated, but for most applications a considerable amount of validation (in-situ observations) and calibration is still needed to achieve operational applicability.
- Making it all work: implementation of business models and scaling up of Earth observation applications for smallholders is still in a very early stage.

Although these challenges need to be addressed, the general conclusion can be drawn that Earth observation applications contribute to the development of innovative solutions for agriculture, especially when taking into account the lack of data and observation systems in developing countries. The relative improvement on the current situation, integrated in the food security value chain, may therefore be more important, than the provision of break-through, disruptive solutions.

In the next sections a short overview of geodata applications for inclusive finance related to food security is given, with a focus on smallholders.

1 Agricultural knowledge and information systems

What is it used for?

Earth observation is used for parcel identification and measurement, geo-statistics and crop identification, support to field surveys (and vice versa) and subsidy and policy monitoring and control. Earth observation facilitates the combination of data and information on land use, land administration, crop monitoring and agro-ecological zones for better decision making. Earth observation improves accuracy, enables more frequent and better monitoring, coverage of large (not easily accessible) areas and facilitates integration of information.

Who are the users?

Agricultural knowledge and information systems are used by government agencies for the purposes described above. Depending on the situation in a country, there is a specialised system and/or agency to gather and manage this type of information. Although most systems are dedicated to the national level, there are also supra-national systems (EU) and systems for lower levels of government. Countries that have an active and ambitious policy to enhance development of the agricultural sector are particularly interested in agricultural knowledge and information system.

Discussion

Setting up a good agricultural knowledge and information system requires considerable investment and the technical capacity for establishing and maintaining the platform on which the system runs. Data acquisition and management, including in-situ observations for validation of Earth observation, pose a challenge in terms of human and technical resources. Although the resolution of free satellite data has improved with the Copernicus (1) programme, there is still a trade-off between data and processing costs and sufficiently detailed application of crop masks and proper identification of crop types and parcels. A less costly, but also less accurate version, of agricultural information systems can be achieved by geo-locating farms with GPS-measurements and by focusing only on specific crops.

Who pays?

In all cases the government pays, although in some cases the establishment of systems may be funded through cooperation programmes. Parts or all of the work for establishing and running the system can be contracted out to the private sector. Farmers' organisations are input suppliers are also potential clients, usually for less costly version of the information system.

Relation with inclusive finance

Provision of historical records, support measures for financial operations.

1 Copernicus is an ambitious European programme that provides huge amounts of free satellite data that were not available before.

2 Crop (health and yield) monitoring

What is it used for?
Earth observation helps to distinguish between agricultural land and non-agricultural land, different crop types, assessment of crop growth in comparison with historical data and yield prediction (including early warning for possible food shortages). Earth observation improves accuracy, enables more frequent and better monitoring, coverage of large (not easily accessible) areas and facilitates integration of information.

Who are the users?
Ranging from government agencies to individual farmers.

Discussion
The main challenges are providing relevant information at sufficient level of detail, successful applications of crop masks and identification of crop types, especially in cases of mixed cultivation. There is a trade-off between costs and level of accuracy. Scale is an issue: the service is usually not feasible for individual smallholders, although it may work for groups of smallholders, especially in cases of monocultures of easily identifiable crops. The EO application evidently does not capture trade flows, which are essential for a proper assessment of food security. In-situ data for validation and calibration are crucial for achieving sufficient accuracy. The information can also be used for (index) insurance purposes.

Who pays?
Depends on scale at which the application takes place, ranging from international organisations and national governments to individual farmers. Extension agencies, input suppliers and traders are other potential client groups.

Relation with inclusive finance
Improving agricultural performance, managing risks, provision of historical records.

3 Site evaluation

What is it used for?
Site evaluation takes place from the level of agro-ecological zones down to field level and provides a suitability analysis for crops and types of agricultural management, including land use. Site evaluation consists of analysis and modelling of agro-climatic data, biomass and yield data, and soil suitability to achieve optimum and sustainable use of agro-ecological zones. Earth observation provides the input for modelling and analysis: land cover, land use change, crop identification and monitoring, water resources, soil mapping and climate modelling with more accuracy, wider coverage and higher frequency than conventional methods.

Who are the users?
Governments use site evaluation for the implementation of agricultural policy. Extension agencies play an important role in this process as the delivery channel of advice to the farmers. Farmers also can use the service directly.

Discussion
Challenges depend on the scale of application: getting the required level of detail at affordable cost is a challenge. Expert knowledge is required to for a successful application and validation. Calibration of the information derived from Earth observation is needed with in-situ measurements. Datasets with global coverage are available (such as the FAO GAEZ), but where local conditions are variable, additional information is needed to provide actionable advice.

Who pays?
This again depends on the scale of operations: in most cases government is the paying client (in the framework of efforts to increase agricultural production).

Relation with inclusive finance
Improving agricultural performance.

4 Crop selection and calender

What is it used for?
Advice on the best crops or varieties to grow and the optimum mix of crops for the growing season under given conditions. The advice is based on agro-climatic data, agro-ecological data, terrain characteristics, soil conditions and data on current and possible future agricultural practices. In combination with modelling of local climate trends, scenarios can be developed for climate adaptation. Earth observation provides the advantage of providing a comprehensive overview of the different data that are needed and data integration. In addition, Earth observation is used to analyse historical trends over relative large areas.

Who are the users?
Governments with an interest to increase agricultural production and to increase the resilience of farming with respect to climate change. Extension agencies play an important role in this process. The service is also delivered directly to farmers and farmers' organisations.

Discussion
There is considerable uncertainty in climate scenarios, achieving sufficient accuracy is therefore a challenge. However, it may be comparatively easy to identify win-win scenarios. The smaller the scale, the more important in-situ validation and calibration becomes. Expert crop-specific knowledge is required.

Who pays?
Government can be a paying client, although in practice this service is usually paid for by farmers or farmers' organisations. The service is also offered as part of an inclusive package by input suppliers to ensure customer loyalty.

Relation with inclusive finance
Improving agricultural performance.

5 Weather forecasting

What is it used for?
Provision of localised weather forecasts, ranging from 10-day to near real-time, to improve (the timing of) agricultural practices. Earth observation facilitates the provision of accurate local information and (in combination with mobile apps) timely delivery to the farmer. Earth observation supplies the data that is used as input for weather forecast models.

Who are the users?
Ranging from government agencies to individual farmers.

Discussion
This is a low-hanging fruit application that can be applied anywhere. The weather forecasting system needs to be accurate and this requires expert knowledge. Farmers have complained about the unreliability of weather forecast provided through mobile network operators (MNOs) and Earth observation certainly helps providing more accurate information. The weather forecast models that are used (e.g. of ECWMF) are very sophisticated. Absence / scarcity of local weather stations can be a bottleneck. Licence-to-operate has been reported as a bottleneck as well, as the national meteorological organisation (NMO) may have a monopoly on providing weather information.

Who pays?
Whole range from government (providing a free service) to farmers (paying for a weather app). Often part of an inclusive package, paid for by input suppliers and/or farmers' organisations.

Relation with inclusive finance
Improving agricultural performance, managing risks.

6 Fertiliser advice

What is it used for?
Advice on what fertiliser to use, how much and when to apply. Normally a part of precision agriculture, where a farmer has a task chart on his/her machine that is programmed for VRA (variable rate application). More recently applications have been developed that are based on earth observation and can benefit smallholders as well. The availability of Copernicus (1) data opens up new opportunities, although spatial resolution remains an issue. Still, the application of Earth observation can improve current practices. The combination with in-situ observations and/or drones for validation and calibration improves the accuracy and relevance. Efforts for smallholders focus on higher value crops, such as grapes and vegetables.

Who are the users?
Farmers are the direct users; input suppliers also have an interest and include free advice on fertiliser use in their offering, to increase customer loyalty.

Discussion
This type of advice is (until now) based on optical imagery, which makes it less suitable for areas with a lot of cloud cover in the growing season. Combinations with or additional solutions provided by radar are still in the early operational phase. The limited spatial resolution of free imagery may also affect cost-benefit. For smallholders, the limited size of plots and agricultural practices (mixed cropping) is sometimes a challenge. Distinguishing between parts of the field where the advice is relevant and parts where crop growth is less then optimal, because of other reasons is a challenge with automated data processing. This will have to done by the farmer.

Who pays?
In most cases the farmers (or groups of farmers) pay directly or the service is offered as an inclusive arrangement (by input suppliers).

Relation with inclusive finance
Improving agricultural performance.

1 Copernicus is an ambitious European programme that provides huge amounts of free satellite data that were not available before.

7 Pest and disease management

What is it used for?
Early detection and warning of pest and disease occurrence and advice on the best way to combat the pest or disease. Earth observation offers a regular and panoptic view of the areas concerned that makes early detection possible. Although characteristics may be different, depending on the type of crop, cultivation pattern, pest or disease, after calibration and validation on the ground effective measures can be taken. This results in a reduced need for pesticides as the problem is detected earlier and the area to be sprayed remains limited.

Who are the users?
Farmers are the users; suppliers of pesticides have a direct interest.

Discussion
The challenges are similar to those affecting advice on fertiliser use. The application of Earth observation works best in places, where a considerable area is planted with the same crop. However, successes have been obtained in specific cases for smallholders, such as for late-blight disease that affects potatoes. Expert knowledge is a condition for success. Success also depends on validation and calibration, derived from in-situ observations.

Who pays?
Farmers / farmers' organisations or pesticide suppliers, as part of an inclusive service.

Relation with inclusive finance
Improving agricultural performance.

8 Sowing / planting advice

What is it used for?
Advice to farmers on the best time to sow or plant. This service is closely related to weather forecasting, but also includes an assessment of flood and drought risk and of soil moisture. Earth observation plays an important role in all the elements of the service, increasing the temporal frequency of the information and improving the capacity to provide localised information.

Who are the users?
Farmers and/or farmers' organisations.

Discussion
Although the accuracy of the service has improved over time, the risk of failure (action taken on the basis of information that turned out to be incorrect) remains. Taken overall, however, the service is a considerable improvement over traditional practices. Expert knowledge on specific crops is needed.

Who pays?
Farmers, farmers' organisations, input suppliers (seeds) as inclusive service.

Relation with inclusive finance
Improving agricultural performance, managing risks.

9 Harvest advice

What is it used for?
Harvest advice is the result of crop monitoring, and the other inputs that are used for sowing and planting advice. Evidently it is closely connected with estimating the expected yield. Earth observation is instrumental in determining the required parameters.

Who are the users?
Farmers and/or farmers' organisations.

Main (technical) challenges
The challenge depends on the scale at which the service is applied and local circumstances: in general it will be more difficult to provide smallholders with mixed cultivation with relevant advice than large farms or (groups of) smallholders with monocultures.

Who pays?
Farmers and/or farmers' organisations and input suppliers and traders (as part of an inclusive package).

Relation with inclusive finance
Improving agricultural performance.

10 Water use and irrigation advice

What is it used for?
Monitoring of water use, assessment of water use efficiency and advice on when and how much to irrigate. Earth observation provides higher accuracy, wider coverage and more frequent monitoring of water use for agriculture (evapotranspiration). Services based on Earth observation are offered commercially in the US, Europe and Australia; pilots are implemented in Africa, usually in the form of 5 – 10 day forecasts.

Who are the users?
Farmers, agencies responsible for irrigation and management of water resources.

Discussion
Achieving the required level of accuracy is the main challenge. The success of the application also depends on the type of cultivation, uniformity of the land under consideration and the possibilities for in-situ calibration and validation. Opinions differ on whether the application of Earth observation is an improvement compared to more traditional methods. Free datasets are becoming available (FAO WaPor for Africa at 250 x 250 m and 100 x 100 m), but the time series is (still) limited. Accurate assessment of soil moisture is also a challenge. Providing detailed advice to individual smallholders is difficult, but relevant advice can be provided to groups of smallholders.

Who pays?
Government or farmers, depending on the application.

Relation with inclusive finance
Improving agricultural performance.

11 Soil moisture assessment and modelling

What is it used for?
Assessment of available soil moisture for advice on agricultural management or to use as input for index insurance. Earth observation provides the base layers for soil moisture modelling in the form of soil maps, land use maps, digital elevation models and river maps. For soil moisture modelling this information is combined with rainfall data, temperature data and evapotranspiration data (derived from or supported with EO). Through the Copernicus programme the resolution at which soil moisture can be determined directly with Earth observation has considerable improved.

Who are the users?
Farmers and/or farmers' organisations, agencies responsible for water management and irrigation.

Discussion
The resolution of EO-derived soil moisture products was always very coarse, but has improved considerably: several products are developed through downscaling of freely available data. These products have not reached sufficient maturity yet: further testing and probably development is needed to make them fully operational. Earth observation provides information on the top soil layer; for a more in-depth analysis in-situ observations are needed.

Who pays?
Government agencies and farmers.

Relation with inclusive finance
Improving agricultural performance.

12 Soil nutrients assessment

What is it used for?
The determination of soil nutrients provides valuable information on soil fertility, which is crucial for assessing crop suitability and the need for (additional) fertiliser application. The best current practices are based on field spectroscopy (or sampling) and Earth observation is used extrapolation of results to larger areas.

Who are the users?
Farmers and/or farmers' organisations.

Discussion
The biggest bottleneck for general application is the need for (regular) field measurements, which affects cost-benefit. That local soil nutrient conditions may vary over short distances poses another challenge.

Who pays?
Farmers and/or farmers' organisations, sometimes governments for a general assessment of crop suitability and general fertiliser needs and sometimes input suppliers (as part of an inclusive service).

Relation with inclusive finance
Improving agricultural performance.

13 Salinity assessment

What is it used for?
Assessment of salinity in water bodies and soils and salt intrusion from the sea with the aim to improve agricultural conditions. The assessment leads to advice on measures to reduce salinity, such as flushing, or on the cultivation of salinity-resistant crops. Earth observation supports salinity mapping, based on in-situ measurements, through the provision of topographical data and information on terrain conditions. Monitoring of crop health with Earth observation can also provide an indication of salinity levels.

Who are the users?
Farmers and/or farmers' organisations.

Discussion
The need for continuous in-situ monitoring to model salinity levels and trends accurately affects cost-benefit. Advice depends on local conditions, requiring expert knowledge. The role of groundwater (saline or non-saline) is also a factor that has to be taken into account, which means that in many cases the salinity model is also based on a (non-EO) groundwater model.

Who pays?
Farmers and farmers' organisations and government through initiatives to combat (large-scale) salinity problems.

Relation with inclusive finance
Improving agricultural performance, managing risks.

14 Flood risk assessment

What is it used for?
Assessment of flood risk that affects agricultural operations and yields. Earth observation is used for reference mapping, asset mapping (location of farms and parcels), digital elevation models, land cover, soil conditions, etc. Earth observation facilitates regular monitoring for large areas at low cost. The input is used for hydrological modelling of the (partial) watershed concerned.

Who are the users?
Farmers are the beneficiaries; the assessment is usually carried out on behalf of government agencies or insurance companies. Finance providers also have an interest in flood risk assessment.

Discussion
The application is technically complex and requires expert knowledge. Expenses have to be incurred upfront, while the return on investment is spread out over a long period.

Who pays?
Government, insurance companies, financial institutions.

Relation with inclusive finance
Managing risks, provision of historical records.

15 Flood early warning

What is it used for?
Early warning advice on flooding to avoid loss of lives and goods. Earth observation supports hydrological modelling, precipitation mapping and monitoring of upstream areas. The combination with a network of upstream sensors (or in-situ measurements) facilitates early warning.

Who are the users?
The responsibility for flood early warning lies virtually always with government agencies.

Discussion
The challenges are similar to those of flood risk assessment. In addition, if no measures are taken to mitigate flood risk, early warning will only have an effect in terms of saving lives and the harvest is lost.

Who pays?
Government agencies are the paying clients for flood early warning.

Relation with inclusive finance
Managing risks.

16 Drought risk assessment

What is it used for?
Drought risk assessment is a combination of climate monitoring and modelling, drought monitoring and long-term weather modelling and monitoring (El Niño, La Niña, etc.). Advice based on drought risk assessment may lead to adjustments in crop selection, cropping patterns and water use efficiency measures. Earth observation plays a role in all aspects mentioned.

Who are the users?
Government agencies, in particular agricultural and water management agencies. Farmers are the beneficiaries.

Discussion
Although the developed models are sophisticated, the level of uncertainty is still quite high. Considerable expert knowledge is required. The results can be used for decision making at regional level.

Who pays?
Government agencies.

Relation with inclusive finance
Managing risks, provision of historical records.

17 Drought monitoring

What is it used for?
Drought monitoring is composed of a remote sensing component (NDVI), a climate component (precipitation index, drought severity index) and a biophysical component (land use/land cover type, soil characteristics, elevation, ecological setting).

Who are the users?
Government agencies, in particular agricultural and water management agencies. Farmers are the beneficiaries.

Discussion
Similar to those indicated for drought risk assessment. In addition, the capacity of farmers to adjust in a given growing season is very limited. The results can be used for decision making at regional level.

Who pays?
Government agencies.

Relation with inclusive finance
Managing risks.

18 Extreme weather risk assessment

What is it used for?
Assessment of the likelihood of the occurrence of extreme weather events and possible trends as a consequence of climate change. Earth observation data series are available for historical and statistical analysis and analysis of large regions.

Who are the users?
Government agencies, in particular NMOs; insurance companies.

Discussion
Considerable expert knowledge is required. The translation of risk assessment into a successful risk mitigation strategy is a challenge.

Who pays?
Government agencies, insurance companies.

Relation with inclusive finance
Managing risks, provision of historical records.

19 High-impact weather early warning

What is it used for?
Early warning for extreme weather events based on weather forecasting. The role of Earth observation is the same as for weather forecasting.

Who are the users?
Government agencies, in particular NMOs; insurance companies. Farmers are the beneficiaries.

Main (technical) challenges
The accuracy of high-impact weather early warning has improved considerably. The bottleneck has been communication along the chain from specialists to beneficiaries. As with droughts, the options for the farmer to adjust are limited. Insufficient coverage by local weather stations also poses a challenge.

Who pays?
Government agencies, insurance companies.

Relation with inclusive finance
Managing risks.

20 Locust early warning

What is it used for?
Early warning to facilitate combating of locust infestations. Earth observation supports the locust detection and monitoring systems (for desert locusts) that are operational, coordinated by FAO. New warning systems, based on soil moisture assessment with Earth observation, are entering the market.

Who are the users?
Government agencies, farmers are the beneficiaries.

Discussion
Timely communication and response are necessary conditions for success. Once the locusts arrive, there is very little a farmer can do.

Who pays?
International organisations, notably FAO.

Relation with inclusive finance
Managing risks.

21 Disaster monitoring and impact assessment

What is it used for?
Monitoring of disasters that affect agriculture and damage assessment with the aim to provide rapid and effective response and relief. Earth observation provides the background information and a synoptic overview for general monitoring. Earth observation is used to map and monitor flood extent, damaged assets, burned area, etc. Earth observation supports (planning and decision-making for) rescue operations, recovery, rehabilitation and reconstruction operations.

Who are the users?
Government, notably disaster management agencies.

Main (technical) challenges
Cost, operational complexity and technical capacity are the main bottlenecks, as considerable investment in technology and human resources is needed for rapid and effective response and relief action.

Who pays?
Government.

Relation with inclusive finance
Managing risks, support measures for financial operations.

22 Agricultural (index) insurance

What is it used for?
De-risking of farming operations and provision of a safety net through insurance against extreme events and/or reduced yields. Earth observation contributes to the following elements that are relevant to (index-based) agricultural insurance: plot identification, crop identification, crop monitoring, yield estimation, loss event monitoring and verification, risk assessment and determination of insurance product indicators. Products have been developed, based on Earth observation data that relate to precipitation, NDVI, evapotranspiration, drought, extreme weather and soil moisture. By using Earth observation and making use of the index approach, the need for (costly) field inspections is reduced considerably.

Who are the users?
Government agencies, insurance companies, farmers and/or farmers' organisations.

Discussion
Although there are many initiatives for Earth observation-based index insurance, most are still in the pilot or early operational stage. Determining the right basis premium based on available data (EO time series plus in-situ data) is still a challenge. Even in developed countries, there are no agricultural insurance schemes, which are not, directly or indirectly, supported by the government.

Who pays?
Governments can decide to subsidise insurance premiums, insurance companies pay for technical services, farmers and/or farmers' organisations pay the insurance premium. Sometimes insurance is sold in combination with inputs, such as seeds or fertiliser.

Relation with inclusive finance
Managing risks, provision of historical records, support measures for financial operations.

23 Market access assessment and market information

What is it used for?
Market access deals with the availability and planning of transport infrastructure and transport to market (food chain management, including post-harvest losses). Earth observation can be used to analyse the opportunities and constraints for optimum market access of agricultural produce, and to support decision making for planning and improvement of infrastructure, storage and market facilities. Earth observation provides the base layer for spatial information analysis (including crowd-sourcing) and monitoring of agricultural activities (crop growth and land use changes).

Who are the users?
Governement is the user; farmers are the beneficiaries.

Discussion
Both the market access assessment and the implementation of improvement measures require investments in infrastructure and technical capacity. The weakness of institutions involved may be a bottleneck. Earth observation only supplies a small part of the data needed. For proper detection of roads and infrastructure high-resolution imagery is needed.

Who pays?
Government.

Relation with inclusive finance
Improving agricultural performance.

24 Land administration

What is it used for?
Determination of land property and land rights. Earth observation facilitates rapid mapping and change monitoring. Earth observation supports high-speed cadastral surveying, especially in rural areas. Satellite images can provide the base layer for a participatory approach to land administration and help increase transparency of the process. At a more informal level, identification of properties and plots (through geo-location) is needed for reception of individual agricultural advice, participation in insurance schemes and eligibility for receiving credit.

Who are the users?
Government, farmers' organisations, insurance companies, financial institutions.

Discussion
Official cadastral surveys usually take a long time to complete, more informal approaches are often not recognised by the authorities concerned. Considerable investment (technical infrastructure and human resources) is needed. Strength of institutions also plays a role.

Who pays?
Government pays for the official process. Farmers' organisations, insurance companies and financial institutions pay for more informal, but reliable data.

Relation with inclusive finance
Support measures for financial operations.

25 Water quality monitoring

What is it used for?
Monitoring of water quality used for agriculture. Earth observation provides information on coloured dissolved organic matter, suspended matter, vertical light attenuation and turbidity.

Who are the users?
Government, in particular water management agencies; farmers.

Discussion
The water bodies that are relevant for agriculture are in most cases too small to use Earth observation effectively. Although new EO-based methods are under development to address this gap, a combination with in-situ observations is still needed.

Who pays?
Government.

Relation with inclusive finance
Improving agricultural performance, managing risks.

26 Water resources assessment (surface, groundwater)

What is it used for?
Water resources assessment is used for long-term planning and climate change scenarios. Earth observation facilitates the accurate and continuous observation of the long-term dynamics of the different key variables governing the energy and water cycle processes from global to local scale. Earth observation is useful for the following aspects: land use and land cover mapping and change monitoring, water abstraction estimation with respect to crop water demand for irrigated areas, refined land use / land cover mapping, identification of surface water bodies or pools (location, extent, dynamics), digital elevation models and derived products, estimates of basin-wide evapotranspiration and precipitation, water and vegetation monitoring (entire aquifer), and ground subsidence monitoring and its correlation with groundwater abstraction.

Who are the users?
Government, in particular water management agencies, environmental organisations.

Discussion
Considerable investment in infrastructure, processing capacity and human resources is needed. Depending on the level of detail, data acquisition may also be expensive. Additional investment in in-situ measurements is also needed. Some elements, such as groundwater re- or depletion can only indirectly and not very accurately be determined with the help of Earth observation. Products based on Earth observation that make the identification of small water bodies more accurate, are under development. The results can be used for decision making at national or river basin level, or at regional scale and smaller watershed / irrigation scheme level.

Who pays?
Government and in some cases organisations involved in product certification (sustainable water use).

Relation with inclusive finance
Improving agricultural performance, managing risks, provision of historical records.

27 Environmental / ecosystem assessment / accounting

What is it used for?
Environmental accounting is used to assess the sustainability of operations, taking externalities that are not in our current economic system into account. Earth observation provides the basis for monitoring, reporting and verification for environmental and ecosystems accounting. The increased precision of quantification of carbon stocks and ecosystem type classification with Earth observation result in more precise proxies for payment for ecosystem services schemes and ecosystem accounting. For general environmental accounting and for accounting of particular areas / ecosystems, Earth observation is used as background layer and for land use change monitoring. EO-based products for water productivity are becoming operational, as is the FAO water productivity database (WaPOR).

Who are the users?
Government, environmental organisations.

Discussion
Challenges concern establishing the required capacity and access to data, both remotely sensed and in-situ. The major challenge is the acceptance of environmental accounting as the basis for policy and decision-making.

Who pays?
Government, environmental organisations, organisations involved in product certification.

Relation with inclusive finance
Managing risks, provisions of historical records.

28 Climate change modelling and monitoring

What is it used for?
Climate change modelling and monitoring leads to products and services that accurately predict and help adapt to the effects of climate change (and hopefully mitigate climate change). The use of Earth observation leads to reduced costs when compared to traditional field data collection methods. Earth observation also provides more detailed information that is relevant for local decision making, such as change detection and occurrence of extreme weather events.

Who are the users?
Government.

Discussion
Technical capacity, cost and complexity are the main challenges. Earth observation is essential as data source and for the monitoring of trends. The results are useful for decision making at regional scale.

Who pays?
Government.

Relation with inclusive finance
Managing risks, provision of historical records.

29 Pasture and water bodies identification and monitoring

What is it used for?
Provision of information about the presence and quality of pastures, water availability and crop residues in agricultural areas, and the degree to which overgrazing has already taken place, on the terms of trade practiced in livestock markets and on safety. Earth observation facilitates the assessment of biomass availability and surface water availability. New products are being developed that will make it possible to detect small water bodies.

Who are the users?
Government extension agencies, pastoralists.

Discussion
Expert knowledge and sufficient good quality in-situ data are required (for validation and calibration). Successful application of this service across the board may lead to the overgrazing it seeks to avoid. However, also in that case Earth observation is a valuable monitoring tool.

Who pays?
Government and pastoralists.

Relation with inclusive finance
Improving agricultural performance, managing risks.

30 Conflict prevention and resolution

What is it used for?
Earth observation can provide information on the current state-of-affairs, processes, historical trends, future scenarios to help prevent and resolve conflicts, such as those related to transboundary water management and between pastoralists and sedentary farmers. Earth observation can also be used to assess and visualise more 'hidden' problems, such as those related to water use and water productivity.

Who are the users?
Government and other stakeholders.

Discussion
Technical and institutional capacity is required to process the data and understand and interpret the information. In general Earth observation is seen as a transparent and neutral means of visualising the problem, but this needs to be accepted by all parties concerned. For conflicts between pastoralists and sedentary farmers, geo-located data on farms and farmers is required.

Who pays?
Government and interested stakeholders.

Relation with inclusive finance
Managing risks.

31 Agricultural control / compliance monitoring

What is it used for?
Earth observation helps monitoring the correct spending of agricultural subsidies: whether certain areas contain the designated crops, whether an area is really sown or planted (as check on fertiliser subsidies), whether certain measure for nature conservation are implemented, etc. In a similar vein, Earth observation helps monitoring requirements for certification, such as land and water use.

Who are the users?
Government, NGOs.

Discussion
Acquisition of sufficiently high-resolution imagery at the right time is needed, which may be expensive. Automation of data processing is also a requirement for larger schemes. The mechanism needs to be accepted as transparent and neutral by all stakeholders. Monitoring of individual parcels requires considerable investment; for more general monitoring of land and water use (for certification purposes) by groups of smallholders less investment is required.

Who pays?
Government.

Relation with inclusive finance
Provision of historical records, support measures for financial operations.

32 Fire early warning and monitoring

What is it used for?
Earth observation improves early detection and monitoring of forest and grass (or peat) fires. Both types can be caused by agriculture and can damage crops and/or pasture considerably. The method usually consists of detecting heat anomalies with low-resolution imagery, followed by closer monitoring with high-resolution imagery.

Who are the users?
Government, NGOs, farmers.

Discussion
The application is a useful addition to conventional methods. Investment is needed in continuous monitoring capacity and a good temporary resolution is needed. The occurrence of smoke and haze can complicate the use of optical imagery, once the fire has reached an advanced stage.

Who pays?
Government, NGOs.

Relation with inclusive finance
Managing risks.

33 Land degradation / erosion monitoring

What is it used for?
Earth observation is used for the monitoring of large areas and therefore excellently suited for change detection and trends, such as soil degradation, deforestation and desertification.

Who are the users?
Government, NGOs, farmers.

Discussion
As land degradation and erosion are slow processes, investment from the public sector is needed to implement the monitoring process and rehabilitation measures. Thanks to the increasing spatial resolution of free images and historical datasets, the cost of data acquisition is low. In-situ observations and/or monitoring with drones is needed to provide detailed advice to individual smallholders.

Who pays?
Government, NGOs.

Relation with inclusive finance
Improving agricultural performance, managing risks, provision of historical records.

34 Land use change monitoring

What is it used for?
Earth observation enables the detection of land use changes over time. Land use change is part of application 1: agricultural information systems, but also monitors the conversions of forest and wetlands into agricultural land, the disappearance of agricultural land because of urbanisation, etc. The main advantage of Earth observation is that large stretches of land can be monitored, while reducing the need for field inspections considerably.

Who are the users?
Government, NGOs.

Discussion
Operational solutions are available, the cost of data acquisition (for general monitoring purposes) is low and historical datasets are available. Data processing costs may be high and considerable expert knowledge is required. High-resolution satellite data, in-situ observations and/or data from drones are needed to monitor land use change at the level of individual smallholders.

Who pays?
Government, NGOs.

Relation with inclusive finance
Provision of historical records, support measures for financial operations.

Annex 3 Correspondence building blocks geodata and ICT solutions inclusive finance

Geodata & ICT solutions inclusive finance for food security	Building blocks geodata for smallholder agriculture
1 Access to inputs	1 Agricultural knowledge and information systems
2 Agricultural advice	3 Site evaluation 4 Crop selection and calender 5 Weather forecasting 6 Fertiliser advice 7 Pest and disease management 8 Sowing / planting advice 9 Harvest advice 10 Water use and irrigation advice 11 Soil moisture assessment and modelling 12 Soil nutrients assessment 13 Salinity assessment 24 Water quality monitoring 29 Pasture and water bodies identification and monitoring
3 Crop monitoring	1 Agricultural knowledge and information systems 2 Crop (health and yield) monitoring
4 Financial services	1 Agricultural knowledge and information systems 22 Agricultural (index) insurance
5 Holistic service	1 Agricultural knowledge and information systems 14 Flood risk assessment 15 Flood early warning 20 Locust early warning 21 Disaster monitoring and impact assessment 23 Market access assessment and market information 26 Water resources assessment (surface, groundwater) 27 Environmental / ecosystem assessment / accounting 28 Climate change modelling and monitoring 30 Conflict prevention and resolution 32 Fire early warning and monitoring 33 Land degradation / erosion monitoring 34 Land use change monitoring
6 Information sharing	23 Market access assessment and market information
7 Price information	23 Market access assessment and market information
8 Soil information	11 Soil moisture assessment and modelling 12 Soil nutrients assessment
9 Supply chain linkages	1 Agricultural knowledge and information systems
10 Traceability	1 Agricultural knowledge and information systems
11 Weather information	5 Weather forecasting 16 Drought risk assessment 17 Drought monitoring 18 Extreme weather risk assessment 19 High-impact weather early warning 28 Climate change modelling and monitoring

Annex 4 Ten main geodata topics offered within 23 G4AW-projects

Rank	Category no.	Description	Times offered
1	5 16	Weather forecasting Drought risk assessment	12 12
3	2 7	Crop (health and yield) monitoring Pest and disease management	11 11
5	10	Water use and irrigation advice	10
6	6 17 23	Fertiliser advice Drought monitoring Market access assessment and market information	8 8 8
9	4 8	Crop selection and calender Sowing / planting advice	6 6
		Other	21
		Total	**113**