Margret Kigozi, farmer in Uganda, SUM-Africa ©NSO/G4AW

Space for Food Security

Stimulating smallholders' access to emerging AgTech and FinTech markets

Part 1: Users and Services

This report has been commissioned by the Netherlands Space Office and supported by the Ministry of Foreign Affairs in the framework of the G4AW programme.

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Abbreviations

API	Application Programming Interface
AWS	Amazon Web Services
B2B	Business-to-Business
B2C	Business-to-Consumer
BPH	Brown planthopper
COVID	Corona virus disease
CROPMON	Crop Monitoring Service (Kenya, G4AW project)
CSR	Corporate Social Responsibility
EC	European Commission
FAW	Fall armyworm
FAO	Food and Agriculture Organization
FEWSNET	Famine Early Warning System
FMO	Nederlandse Financierings-maatschappij voor Ontwikkelingslanden Dutch Entrepreneurial Development Bank
G4AW	Geodata for Agriculture and Water
G4IFF	Geodata for Inclusive Finance and Food Security
GEOGLAM	Group on Earth Observations Global Agricultural Monitoring Initiative
G4INDO	Geodata for upgrading smallholders' farming systems (Indonesia, G4AW project)
GIACIS	Geodata for Innovative Agricultural Credit Insurance Schemes (Ethiopia, G4AW project)
GIS	Geographic Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit / The German Society for International Cooperation
GNSS	Global Navigation Satellite Systems
ICCO	Interchurch Organization for Development Cooperation (part of Cordaid)
IDSS	Intelligent Decision Support System (Bangladesh, G4AW project)
ILK	Indigenous and local knowledge
ISRIC	International Soil Reference and Information Centre
LAI	Leaf Area Index
M&E	Monitoring and Evaluation
MODHEM	Mobile Data for Moving Herd Management and better incomes (Burkina Faso, G4AW project)
MODIS	Moderate Resolution Imaging Spectroradiometer (NASA instrument)
MUISS	Mobile User-owned ICT4 Ag-enabled Information Services (Uganda, G4AW project)
MUS	Multiple Uses of Water Services
NASA	National Aeronautics and Space Administration

NDVI	Normalized Difference Vegetation Index
NGO	Non-Governmental Organization
NpM	Netherlands Platform for Inclusive Finance
NSO	Netherlands Space Office
NRW	Netherlands Water Partnership
ODA	Official Development Assistance
PLB	Potato late blight
PPP	Public-Private Partnership
QR	Quick Response
RVO	Rijksdienst voor Ondernemend Nederland Netherlands Enterprise Agency
R4A	Rain for Africa (South Africa, G4AW project)
SAM	Smart Agriculture Myanmar Programme (Myanmar, G4AW project)
SEBAL	Surface Energy Balance Algorithm for Land
SIDA	Swedish International Development Cooperation Agency
SIKIA	SAGCOT Integrated Knowledge and Information for Agriculture (Tanzania, G4AW project)
SMS	Short Message Service
SNV	Stichting Nederlandse Vrijwilligers / Foundation of Netherlands Volunteers
SOTER	Soil and Terrain Database Programme
SRTM	Shuttle Radar Topography Mission
STAMP	Sustainable Technology Adaptation for Mali's Pastoralists (Mali, G4AW project)
SUM Africa	Scaling Up Micro-insurance in Africa (Mali and Uganda, G4AW project)
TAHMO	Trans-African Hydro-Meteorological Observatory
USAID	United States Agency for International Development
USSD	Unstructured Supplementary Service Data
VHR	Very High Resolution
WaPOR	Water Productivity Open-access Portal
WFP	World Food Programme
WISE	World Inventory of Soil Emission Potentials

Executive summary

One of humanity's biggest challenges is to feed our population, which is expected to grow to almost ten billion people by 2050[1]. The challenges that food producers face have increased and become more severe over the past decades. These include climate change (i.e., a rise in occurrences of extreme precipitation events and more intense and prolonged droughts); regionally varying changes in the severity of crop losses caused by outbreaks of pests; loss of (agricultural) biodiversity; land degradation, and more. At the same time, the population is rapidly increasing in many of the least developed countries in the world, and there is little reduction in the prevalence of undernourishment.

On top of these challenges, the COVID-19 pandemic has shown the vulnerability of food distribution systems that rely heavily on import and export of commodities, and of an agricultural extension system that depends on field visits. Digitization of farming is seen as a key component of climate-smart and corona-smart agriculture. This supports smallholders by providing advice on optimizing their production system and allowing them to sell products to local buyers. Digital innovation is generally considered to be easily scalable and cost-effective. At the same time, it requires digital literacy and access to ICT tools and networks.

Satellites and mobile connectivity are the two pillars of the Geodata for Agriculture and Water Facility (G4AW), a programme to stimulate digital innovation in agriculture and achieve sustainable service provision to millions of smallholders. Smallholders in the G4AW Facility include farmers, but also (agro-)pastoralists.

Increased access to information and financial products helps food producers become more resilient to the effects of climate change. G4AW supports 25 partnerships in 15 countries in Africa and Southeast Asia that have taken up the challenge to develop digital solutions, using satellite and geodata to improve food and/or income security at food producer level. The major findings of these projects and G4AW Programme as a whole are summarized below.

- G4AW has supported opening up a new market and stimulated its development; since there was no market in 2013, the G4AW Facility can be considered as a catalyst for early adoption of geodata-based digital advisory services to smallholders.
- Over time, there has been a shift in the type of organization that shows interest and leads the G4AW partnerships, starting with research organizations in call 1 (2013), NGOs in call 2 (2014) to commercial businesses in call 3 (2017). This demonstrates the emerging market for digital advisory services for smallholders.
- Innovation and market development requires strong entrepreneurship, agility and long-term (financial) planning.
- Public-private partnerships can add value at the start of the innovation process, but can slow down entrepreneurship and business development if roles and responsibilities are not well defined.
- Creative business models are needed since smallholders generally do not directly pay for B2C agro-advisory services.
- Bundling of agro-advisory services with other agricultural or financial products and/or services could lead to a win-win situation for smallholders and businesses.
- Engagement (education, training) with smallholders is essential to understand the benefits of the offered services in relation to their indigenous and local knowledge.
- Satellite and mobile/ICT technologies enable cost-effective scaling of services.
- As a spin-off, the potential of applying geodata to improve financial access of smallholders is stimulated and piloted in the Geodata for Inclusive Finance and Food security (G4IFF) initiative coordinated by the Dutch Platform for Inclusive Finance.
- Sharing lessons learned through the G4AW Facility with partnerships, donors, and other actors supports further development of digital services for smallholder food producers.

[1] United Nations World Population Prospects 2019

An analysis by the Netherlands Space Office (NSO) of over 250 research and demonstration projects on digital and geospatial innovation in the agricultural sector, showed that most project activities ended when project budget expired. The G4AW Facility started in 2013 with the ambition to support the development of digital advisory and/or financial service provision using satellite and other geodata. Each project's objective within this Facility was to reach 100,000 farmers (or 50,000 pastoralists, fisherfolk) and create a sustainable business model.

There have been three calls in the G4AW Facility in the period 2013-2017. Most of the awarded projects (23) targeted smallholder farmers, while a limited number (2) targeted pastoralists and none targeted fisherfolk.

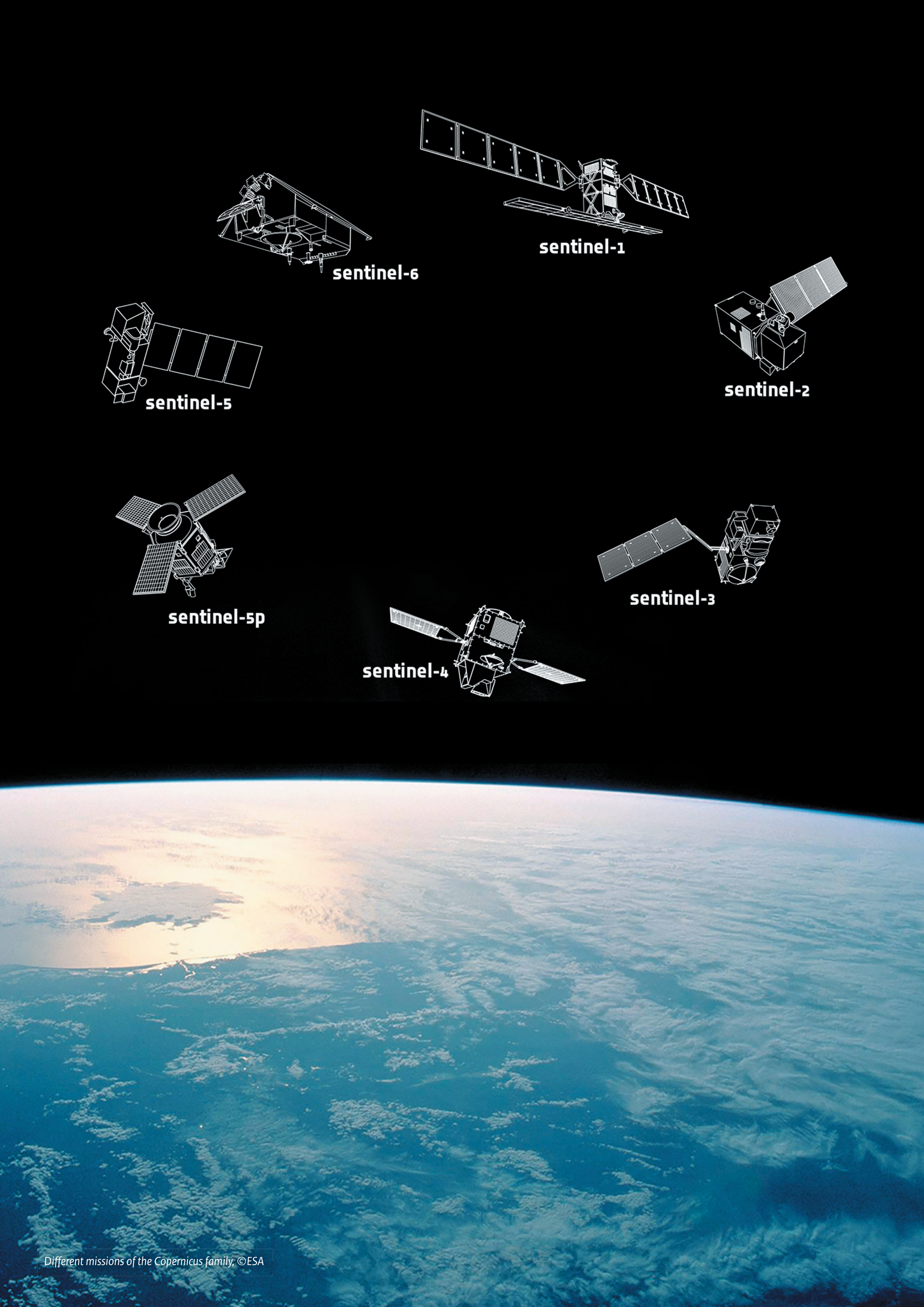
The most important lesson learned is that three years is a very short period to design and develop a proof of concept, reach large numbers of food producers and create a sustainable business model. After three years, most projects have developed proof of concepts, and are at a stage in which additional financing is needed to scale to a sustainable level. The rapidly maturing market has generated a lot of interest from investors, but also increased competition from other service providers focused at digitization of farmers. G4AW might have started slightly too early when it did, in 2013, ahead of the launch of key satellite missions such as Sentinel 1 and 2. Later G4AW calls and other international programs have been able to learn from the early steps of the G4AW Programme.

The importance of involving users in the design of the products was well understood from the start of the programme and has been implemented as a separate working package (User Engagement) in all projects. There is some trade-off between following the rigid planning needed to reach impact in a limited time and the ability of engaging users in different stages. This can mainly be seen at the starting point of the projects: proposals already included the expected 'unique services' and a range of partners able to set these up.

The flexibility that partnerships have shown in dealing with rapidly changing user needs (including COVID-19 related challenges), shows the extent to which users are becoming empowered by being true clients of the services, instead of the traditional recipients. While the food producers' involvement in the initial concept (drafting of the proposal) might not always have been equally high (this was outside the scope of G4AW), most partnerships have been flexible, adapting their services to the emerging user needs.

The initial objective of the digital advisory services was to provide farmers with advice on how to practice climate-smart agriculture. Along the way, the digital nature of the service offering has also shown to be particularly well suited to deal with new challenges that have a) disrupted the traditional functioning of the value chain; b) placed restrictions on online communication; and c) restricted the ability of people to travel and visit farmers in the field. These challenges have been encountered in countries with emerging conflicts (Ethiopia, Burkina Faso, Mali, Myanmar) and in all projects that were still active in 2020 (COVID-19).

Projects in later calls have clearly benefited from lessons from the earlier calls. G4AW has been very active in sharing lessons through meetings, webinars and online media. Many (Dutch) partners have also been involved in more than one project, which enabled them to share their experience. Still, a lot has depended on the local context and the partners involved. Working with public-private partnerships with an average of five partners per consortium (working under time-stress) requires a strong internal balance and willingness/ ability to move through difficult times. This has often been a very successful process.



Different missions of the Copernicus family, ©ESA

Introduction

This document is the first of two publications with lessons learned from the G4AW Facility. The G4AW Facility was launched in 2013 with the objective of creating digital advisory services for smallholders, based on using satellite data. At the start of the project, most of the services were still in the development or testing stages, and were often based on decades of remote-sensing research, which used satellite data with a resolution that was too coarse to provide meaningful insights for smallholders. Some of the most game-changing satellite missions (Sentinel 1 and 2) were all launched between 2013 and 2017. These provide images at a spatial resolution starting at 10 metres and with frequent overpass, enabling the creation of meaningful insights for smallholders.

The G4AW Facility was one of the first programs[2] that supported public-private partnerships in the creation of satellite-derived digital services for smallholders, which led to many new insights. Insights are not only related to the success of services created, but also to the performance of public-private partnerships, the involvement of users, and development of business models. Challenges still persist with a current focus on scaling the created services in a rapidly maturing market with increasing competition. The challenges that the programme and the supported projects have faced have been many and diverse.

The most relevant lessons that have been learned from encountering these challenges, and the solutions that have been applied, are discussed in this two-part series of lessons learned from the G4AW Facility. This first document focuses on the first phase of the project and on challenges related to product design, service delivery and product-market fit. The second publication focuses on the challenges projects face towards the end of project completion and in the subsequent (post-project) trajectory. This includes steps required to scale to a sustainable business: setting up a monitoring and evaluation framework, selecting suitable business models, different scaling options and the role of technical assistance.

This document provides a brief history of the G4AW Facility and the design process of the services. Additionally, the development and delivery of the created services are discussed. This includes a focus on the design trajectory, in which different parties in the consortia and the service users were involved. The different aspects of the services are discussed (type of services, selected countries, targeted groups and commodities, service delivery methods, satellite data used and other relevant aspects).

[2] Similar programmes have been initiated by, amongst others NASA/USAID, SIDA, GIZ and UK Space Agency.

Burundi farmer using the Agricoach app ©Auxfin International/Gap4A Burundi

Need for digital agricultural advisory services

The challenges that food producers face have increased rapidly over the past decades. These include climate change (i.e. rise in occurrences of extreme precipitation events and more intense and longer droughts)[3]; regionally varying changes in the severity of crop losses caused by outbreaks of pests and diseases[4]; loss of (agricultural) biodiversity[5]; land degradation[6], and more. At the same time, the population is rapidly increasing in many of the least developed countries in the world[7], and there is little reduction in the prevalence of undernourishment[8].

On top of these challenges, the COVID-19 outbreak has shown the vulnerability of the food distribution systems that rely heavily on import and export of commodities[9], and of an agricultural extension system that is based on field visits. Digitization of farmers is seen as a key component of climate-smart and corona-smart agriculture[10].

Knowledge is vital for farmers when making decisions on crop and seed selection, crop rotation, effective water use, application of inputs, and more. Pastoralists

3 Seneviratne, S.I., N. Nicholls, D. Easterling, C.M. Goodess, S. Kanae, J. Kossin, Y. Luo, J. Marengo, K. McInnes, M. Rahimi, M. Reichstein, A. Sorteberg, C. Vera, and X. Zhang, 2012: Changes in climate extremes and their impacts on the natural physical environment. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 109-230.

4 Lehmann, P., T. Ammunét, M. Barton, A. Battisti, S.D. Eigenbrode, J.U. Jepsen, G. Kalinkat, S. Neuvonen, P. Niemelä, J.S. Terblanche, B. Økland, C. Björkman, 2020: Complex responses of global insect pests to climate warming, Frontiers in Ecology and the Environment, Volume 18, Issue 3.

5 FAO. 2019. The State of the World's Biodiversity for Food and Agriculture, J. Bélanger & D. Pilling (eds.). FAO Commission on Genetic Resources for Food and Agriculture Assessments. Rome. 572 pp. (http://www.fao.org/3/CA3129EN/CA3129EN.pdf) Licence: CC BY-NC-SA 3.0 IGO.

6 FAO and ITPS. 2015. Status of the World's Soil Resources (SWSR) – Main Report. Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils, Rome, Italy

7 United Nations, Department of Economic and Social Affairs, Population Division (2019). World Population Prospects 2019: Highlights (ST/ESA/SER.A/423).

8 FAO, IFAD, UNICEF, WFP and WHO. 2020. The State of Food Security and Nutrition in the World 2020. Transforming food systems for affordable healthy diets. Rome, FAO. https://doi.org/10.4060/ca9692en

9 Sharma, R., A. Shishodia, S. Kamble, A. Gunasekaran & A. Belhadi, 2020: Agriculture supply chain risks and COVID-19: mitigation strategies and implications for the practitioners, International Journal of Logistics Research and Applications, DOI: 10.1080/13675567.2020.1830049

10 Bodegom, A.J. van, E. Koopmanschap, 2020: The COVID-19 pandemic and climate change adaptation: Some perspectives from alumni of the WCDI Climate Change Adaptation course.

have to make decisions on finding optimal grazing grounds and water, and fisherfolk on when to fish and where to find optimal fishing grounds. Having access to this knowledge is important to improve food security, achieve a higher and more reliable income, and to use inputs more efficiently. Improved decision-making can also contribute to climate-smart agriculture[11], making farming more resistant to climatic shocks.

In many regions, a large share of the decisions that smallholders make are based on their indigenous and local knowledge (ILK)[12]. The rapid changes in weather patterns, outbreaks of new pests and diseases and the availability of new inputs create the need to combine the benefits of indigenous knowledge with new sources of knowledge to adapt to this new context and improve the livelihoods of food producers. Mobile phones (smartphones), soil sensors, weather stations, real-time market prices, and satellite data become more and more accessible (affordable) and are increasingly used to improve smallholders' decision-making.

The term geodata refers to data directly associated with a location on the Earth's surface. Many of the G4AW applications use earth observation data (satellite images) and combine this in (big) data platforms, geographic information systems (GIS), while also using global navigation satellite systems (GNSS). The advantages of satellite information include:

a. repeatedly covering large areas (including places that are difficult to reach due to ongoing conflicts or a lack of infrastructure), which enables regular monitoring of what happens on the ground;
b. providing accurate information on location;
c. data processing yields a wealth of information on environmental (air, water and soil) quality and of ongoing agricultural processes;
d. improving data consistency improves quality and acceptance; and
e. acquiring data over larger areas is less costly than when using *in situ* sensors.

For decades, the application of solutions involving satellite data was considered only appropriate for (large) commercial farms. Thanks to advances in mobile connectivity, the availability of new satellite missions (providing free and high-resolution data), remote sensing research, faster processing platforms and grant programs such as G4AW, satellite applications have also become feasible for smallholders in developing countries.

While there is a clear need for digital services, and there have been rapid improvements in the availability and costs of satellite data, an important challenge is still the delivery of these services to smallholders. Fewer than 70% of food producers in sub-Saharan Africa have mobile phones. Access to the 4G networks that are needed to run the more sophisticated apps is below 10 percent[13]. The G4AW projects in sub-Saharan Africa have found ways to deal with these challenges and have come up with some innovative solutions.

Providing (digital) services to groups that have traditionally been hard to reach has been one of the objectives of the G4AW Facility. G4AW projects offer small-scale food producers and other value chain actors a wide variety of products and services that can be categorized in four general categories[14] as:

1. Weather forecasting and agronomic advice
2. Market information and linkages
3. Financial services including crop insurance
4. Supply chain management services

[11] FAO. 2017. Climate-Smart Agriculture Sourcebook. Second Edition. Summary, Rome, Italy.
[12] Ubisi NR, Kolanisi U, Jiri O. The Role of Indigenous Knowledge Systems in Rural Smallholder Farmers' Response to Climate Change: Case Study of Nkomazi Local Municipality, Mpumalanga, South Africa. Journal of Asian and African Studies. 2020; 55(2):273-284. doi:10.1177/0021909619874824
[13] Mehrabi, Z., McDowell, M.J., Ricciardi, V. et al. The global divide in data-driven farming. Nat Sustain (2020). https://doi.org/10.1038/s41893-020-00631-0
[14] Tsan, Michael; Totapally, Swetha; Hailu, Michael; Addom, Benjamin K. 2019. The Digitalisation of African Agriculture Report 2018–2019. Wageningen, The Netherlands: CTA/Dalberg Advisors

About the G4AW Facility

The Geodata for Agriculture and Water (G4AW) Facility aims to improve food security in developing and transitioning countries by creating digital advisory and/or financial services based on satellite data to reach and support small-scale food producers (farmers, pastoralists or fisherfolk). The G4AW Facility is a Netherlands Ministry of Foreign Affairs grant programme. It falls under the policy priority of food and nutrition security, which focuses on increasing and enhancing sustainable food production in the Dutch ODA focus countries[15].

The G4AW Facility fills a niche in the current range of instruments by stimulating public-private partnerships using (digital) technologies in the nexus of food security, water productivity and climate change adaptation. G4AW started in 2013, has had three tender rounds (Calls for Proposal in 2013-2014, 2014-2015 and 2017-2018) with a total investment of EUR 87.5 million, of which EUR 59 million (67.5%) is a grant from the Dutch Ministry of Foreign Affairs and EUR 28.5 million (32.5%) is raised from private sector contributions[16]. The objectives of G4AW are as follows:

Output:

1. Reaching 4.5 million food producers and informing them about the developed services by using modern technologies and media.
2. Educating and training extension officers and food producers.

Outcome (services):

1. Ensuring 2.25 million food producers use and benefit from the service provision.
2. Improving the output of the agricultural, pastoral and fishing sector in 26 partner countries by providing food producers with relevant information, advice or (financial) products.
3. Reaching at least a 10% increase in sustainable food production and/or an improved financial situation of food producers, by providing them with relevant and timely information services.
4. Helping to achieve a 10% more effective use of inputs for food production (water, seeds, fertilizer, pesticides, etc.).
5. Supporting the opening of new markets for geodata-based product and service providers that contribute to an improved food security.

Impact:

1. Improving food security based on increasing food production and increasing sustainability in agriculture, including water use.
2. Improving income security for food producers.
3. Improving support to food producers in adapting to climate change.

The programme is active with 25 projects[17] in 15 countries[18] in Sub-Saharan Africa and Southeast Asia: Angola, Bangladesh, Burkina Faso, Burundi, Cambodia, Ethiopia, Ghana, Indonesia, Kenya, Mali, Myanmar, South Africa, Tanzania, Uganda and Vietnam.

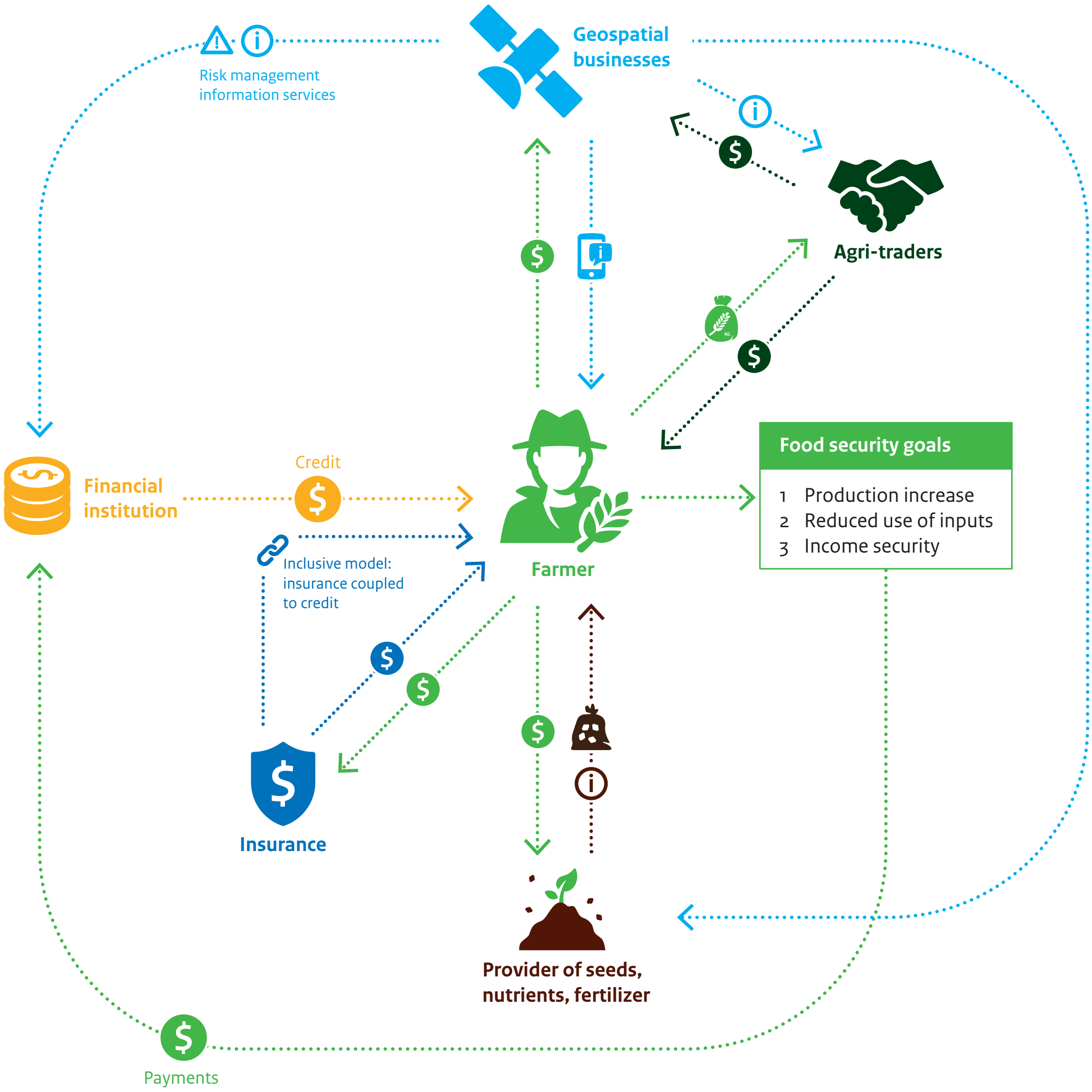
The Netherlands Space Office (NSO), a Dutch governmental agency, is in charge of the implementation, which includes managing the tender process, advising implementation partners, facilitating match-making and knowledge sharing, and monitoring the results at the programme level[19].

Implementation partners generally consist of local service providers, mobile network operators, geodata/ICT companies, knowledge institutes, NGOs, governmental organizations, financial service providers, farmer organizations and other value chain actors such as agribusinesses. These implementation partners are organized in consortia, consisting of an average of five organizations (at least one local and one Dutch) with one lead partner per partnership.

G4AW started with the ambition to challenge partnerships to create and deploy high-end technology for the benefit of the smallholders. The main focus has been on providing insights that contribute to more

[15] The Dutch ODA Policy is described here. Please note that the policy and the focus countries have changed since the start of G4AW Facility in 2013. https://www.government.nl/topics/development-cooperation/the-development-policy-of-the-netherlands
[16] Status per 31-12-2019; generally, private investment is shown to grow over time.
[17] For a project overview, see Annex 1 and https://g4aw.spaceoffice.nl/en/g4aw-projects/g4aw-projects
[18] G4AW Facility was open for 26 focus countries. In 11 countries no projects were granted mostly due to unfavorable safety and/or market conditions.
[19] Each partnership operates a monitoring system at project level

Figure 1 Ecosytem of actors in the G4AW projects



climate resilience and/or improved food production and increased income for small food producers. The G4AW Facility invited organizations to develop and implement a business case incorporating (satellite-sourced) geodata as part of a public-private partnership (PPP). Partnership formation was facilitated by workshops in G4AW partner countries.

When the programme started in 2013, geodata-based products and services for small-scale food producers were a real novelty and the granted projects focused mainly on developing proofs-of-concepts. In the second and third tender calls, the broader digital ecosystems in the project countries were much further developed and NGO's started to embrace farmer digitization in their impact strategies. More smallholders started to have access to mobile phones, internet coverage has rapidly spread, and a lot has come on offer in the digital applications market: both in agtech and fintech services (index-based insurance, digital payments, savings and loans). For G4AW, this changing context means that there are more opportunities to scale, but also that there is a higher risk of competition and market saturation.

Woman farmer tending to her plot ©Netherlands Space Office/G4AW

The objective of the G4AW Facility is a sustainably improved food production system by providing relevant information and services to the agricultural, pastoral and fisheries sectors on a large scale, demand oriented, accurate and on time. This should be based on satellite data and may be complemented by other (geo)data sources. Effective water use is seen as an indispensable element of food production and is therefore an important and integral part of the G4AW Facility objectives.

In order to reach the end user, modern technology such as mobile telephony and related networks are used in addition to traditional delivery methods that include call centres and broadcasts on radio and television. Especially in Southeast Asia, the use of social media to reach food producers is emerging rapidly. Activities such as knowledge building and training of food producers by local actors (extension officers, NGOs, etc.) are considered to be an essential component to increase trust and to make the link to the action perspective of smallholders.

In 2016-2017, the potential use of geodata for financial services was explored with NpM, Platform for Inclusive Finance[20]. After a successful conference, NpM started the Geodata for Inclusive Finance and Food (G4IFF)[21] trajectory together with the Rabobank Foundation, FMO, ICCO and the Bill and Melinda Gates Foundation. The basic idea behind the G4IFF is the recognition that the same geodata and information generated by G4AW services can also fuel services for inclusive finance. The geodata could provide financial institutes with better insights about historical and actual performance of food producers in a specific region, which might result in improved risk management. Another objective of G4IFF was to explore if the services could lead to lower operational costs of the financial institutes.

Ultimately, this would lower the barriers of credit provision to small-scale food producers. With loans, farmers have access to (better) seeds, nutrients and mechanized equipment, which subsequently is expected to lead to improved and more sustainable food production and improved income security. Results of the G4IFF trajectory will be published by NpM and in the second publication of this series.

[20] https://www.inclusivefinanceplatform.nl/
[21] https://www.inclusivefinanceplatform.nl/geodata-for-inclusive-finance-and-food/

Design and development of G4AW services

User-centered design

On a general note, many services focused on digitization for agriculture are developed based on presumptions of their disruptive nature and potential to reach scale easily. And it is true that on paper, such services appear to be very beneficial for various target groups. For example, farmers can make informed decisions about which crops to grow and when/how to do this; input suppliers and buyers can directly link to farmers to know when harvests can be delivered; and financial institutions can de-risk loans to farmers and businesses based on (geo)data. But these potential clients – farmers, banks, buyers, input suppliers – first need to be convinced that these products really work and deliver what they promise. There is a potential mismatch when tech companies do not engage these clients in the development process and develop solutions based on assumptions about what they think their potential clients are looking for.

The importance of involving users in the design process was well understood from the start of the programme, but balancing the flexibility required for user-centered design with the ambitious targets regarding the number of food producers that should be reached, and the sustainability of the business model, has been challenging. Meeting the business and impact-related targets, while also very actively involving users in all stages of the projects, is very difficult to achieve in three or even four years. The G4AW Facility has attempted to balance the quantitative objectives (farmers reached, sustainability of business model) with the more qualitative objective focused on user participation. Especially for ensuring continuing use (returning clients), user participation in the design of the app is crucial.

Users have actively participated in all G4AW projects. This ranges from defining and verifying user needs (often via involved NGO's), basic involvement in testing and validation of services, to more creative involvement in a contest to name the service (see Box 1). Many of the consortia included NGO's and associated local organizations that are in touch with the user base and have a good understanding of their needs. In many cases, workshops were held to design the service to fit the users' needs. In some projects, extensive farmer profiling surveys were executed. As the project proposal already had to provide information on the type of services to be developed, as well as include names of the providers of satellite data with expertise in creation of the required data, the overall focus of the core services did not change significantly in most projects.

BOX 1: User participation in product naming (STAMP/MODHEM)

The name Garbal is coming from a contest on a local radio station in Mali. The name has been chosen by the target group. It's a common term that pastoralists in West Africa use to refer to a livestock market. Initially it was chosen for Mali (STAMP project). In Burkina Faso (MODHEM project) a similar service was in development; it has been very beneficial to have the same brand name in both countries. Including user feedback in product naming has been very useful in the search for a name that is relevant to users in different countries, and for the acceptance of the service. The SNV project lead of the MODHEM/STAMP projects, together with a large mobile operator, is planning to work on cross-border interoperability of Garbal in West Africa. Clear branding of the created services will increase user awareness and strengthen the market position.

The way in which services were provided to farmers (delivery method, visualization, frequency, additional features) has been flexible and was often updated several times during the project. User participation and assessment of their needs have an impact on the selection of the business model by the business owner. In case a certain service is demanded by the users, but is missing in the initial project proposal, the service provider can focus on bundling/purchasing additional services (through third-party contracts) and/or involve other stakeholders who have the required experience to fill these gaps.

COVID-19 has also been a key driver in updating the created services, as farmers required new approaches to sell their products (digital solution: online marketplaces) and to contact agricultural extension officers to receive agronomic advice (digital solution: chat boxes and video content). Listening to these needs and using these to improve the services has resulted in increased user numbers and higher customer loyalty for these services.

"Covid-19 has a large impact on our society. Many countries suffer from (partial) lockdowns. So is Myanmar. In Myanmar, the very stringent lockdown made travelling impossible for agricultural extension officers. In order to continue to provide agronomic advice to smallholders, additional video content was generated."

Myvas4Agri, Myanmar

Partnerships had to identify their key services, and also had to clarify the unique selling points of these services in the project proposal. A comparison of the range of services listed in the proposal, and the services that are now part of the current product offering, shows that most projects have significantly increased the range of services offered. Offering more services is often in response to clear demand among the users.

Although the bundling of services has received a lot more attention in the projects, several service providers did not seize the opportunities to bundle their service with other services. In order to bundle services, other services that are relevant to the same target group need to be available in the region. Especially in the early calls of G4AW, few such services were available. A single service offering often is not as desirable for farmers as a complete package. To be specific, telling a farmer to buy better, but more expensive, seeds is not sufficient when the farmer is not told from what retailer he can purchase this, how he/she can finance this, and at what markets he/she can sell this new product (at the best price).

It is preferable for the service providers to find ways to combine services that support smallholders and other value chain actors in all three areas: access to (1) agricultural advice, (2) finance, and (3) markets. If these are not services developed in-house, the teams could explore developing APIs or other solutions to integrate their service with those of other service providers. G4AW service providers are open to cooperating with third parties to leverage their services if this will help reach scale. Adding services outside of the agricultural value chain, such as health information in relation to COVID-19, can also help increase the value of the services to smallholders.

"An important lesson learned is that the services in the app should be developed with an end market in mind and ensure better engagement with all stakeholders (including buyers of the coffee). Technical features are important, but more attention could have been given to the app's features addressing the marketing and sales aspects. This would help to increase the appetite of both buyers and farmers for the app. Serious buyers would then also see the added value of geospatial data (e.g., deforestation, land suitability) and use it in their direct marketing/communication strategy."

GREENcoffee, Vietnam

Digital inclusion

Digital inclusion is the ability of all individuals and groups to contribute to, and benefit from, the digital economy and society. Digital inclusion requires accessible ICT infrastructure, assistive technologies for people with disabilities, education on digital skills and social inclusion[22]. Social inclusion should focus on all groups that are often excluded from access to ICT tools and required networks. This includes women, youth, and marginalized communities. Of these aspects of digital inclusion, the G4AW projects have especially focused on ensuring social inclusiveness and education on digital skills through training the trainers and the end-users.

[22] EU. Shaping Europe's digital future: Digital inclusion for a better EU society. https://ec.europa.eu/digital-single-market/en/digital-inclusion-better-eu-society. Accessed December 9th 2020.
[23] Klerkx, L., E. Jakku, P. Labarthe. 2019: A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda. NJAS – Wageningen Journal of Life Sciences. Volume 90-91. https://doi.org/10.1016/j.njas.2019.100315

Local languages in the AgriCloud app (Rain for Africa)
To ensure maximum uptake by users, the services should be provided in local languages. In South Africa (Rain for Africa), user engagement sessions demonstrated the need for offering the services in nine different local languages. Surprisingly, these languages did not include English, Zuid-Afrikaans, nor Swahili. Secondly, a large part of the advice is based on the use of simple colours in the AgriCloud app. Days in the agenda are coloured red, orange and green to indicate whether or not conditions for certain farm activities such as sowing are favourable on these days.

The socio-economic context is crucial for the adoption and success of digital agriculture[23]. Marketing should be based on channels used by the target audience. It is very important that the marketing and service delivery approach takes into account the differences in access by gender and age, to ensure digital inclusiveness[24].
An important aspect of digital inclusiveness is ensuring that people have access to delivery channels and, if applicable, the required ICT infrastructure. This includes assessing the literacy levels (including focus on local languages), digital literacy, access to smartphones (and possible gender gap), and overall assessment of the best methods to reach different groups (gender, age, and social background). Specific monitoring of uptake of women and youth has been included in the M&E framework.

Monitoring digital inclusion has been very challenging. Most of the services have direct users (who register for the services), but also have indirect users. These indirect users receive the same advice as the product user, but are difficult to monitor. Without registration, there is no information on the gender and age of the smallholders reached. An SMS Survey in the CROPMON project found that over 70% of farmers shared information with other farmers; 30% of users even share their information with over ten other users. This indicates that when a service has a registered user in a certain village, this will likely result in improved access to this information by a large part of the community, as messages are easily shared with neighbors. Limited ownership of (smart) mobile phones does not necessarily reduce reach of services, but this makes it more challenging to create sustainable business models as few users actually pay. The second publication of this series will elaborate on this aspect.

[24] FAO. 2018: Agricultural services and digital inclusion. http://www.fao.org/3/i7361en/I7361EN.pdf

Promoting digital inclusion in Burundi (Gap4All)

In order to effectively support digital inclusion of farmers in the network of the GAP4A project in Burundi, service provider AUXFIN has organized farmers in groups of 50 neighbouring households, building on existing and natural relations between households in these villages. These groups are governed by three leaders elected by the group and who serve as representatives for the community: male and female, young and old. The groups are voluntary, but excluding members of the community is not permitted.

This makes the G50 system an inclusive approach. Group leaders are trained in good governance and are expected to support the individual group members. The groups are provided with a tablet to have access to the digital services provided by the UMVA platform. AUXFIN key activators, recruited from the villages, make sure that the technology is well understood by the group and its leaders, and encourages the group to start with their self-development. With the increased coherence in the community, group members also provide each other with microloans via the system and start organizing purchase and logistics of goods together.

Many projects have included the creation (and expected future selling) of farmer profiles as a service. This means that information is available that contains the location, age, (farming) assets and gender of the users. While the percentage of women users in these datasets provides meaningful information (as it can be expected that the average share of women in the farming communities is close to 50%), information on farmers' location and age is not useful without understanding of the local situation in the communities. Around 45% of users reached by G4AW partnerships have been under age 35 (youth). It is safe to expect that youth represents a relatively low percentage of the farming community in the targeted countries. This is because a large percentage of youth often decide to leave rural areas for numerous reasons.

This would mean that if 45% of all users reached are under age 35, the actual percentage of youth reached in the farming community is likely much larger. Youth are generally better equipped to use modern farming techniques (including use of digital tools), but also face obstacles in accessing land and credit. The average age of farmers in Africa is about age 60, despite the fact that 60% of the population in Africa is under age 24[25]. Digitization is attractive to young people and is seen as an opportunity to engage more young people in agriculture.

"We are seeing increasing interest from youth for our services. This is based on an increased interest in career paths in science and technology. Our services create a link between the farming activities they are familiar with, and digitization skills that can provide new job opportunities. Youth has shown a strong willingness to study new things, and have been committed to share what they have learned with other people. For example, they are often training their family members on how to use our Angkor SALAD app after completing our training.

Our project is focusing on further empowering youth in Cambodia by working with a local university that provides student training. We are also conducting targeted training and are actively encouraging youth to become facilitators in training on the use of our apps. Students see this technology as a new chapter in agricultural development that enables farmers to better manage farms as a business."

Angkor SALAD, Cambodia

[25] foodandagricultureorganization.pdf (un.org)

Gender aspects

Gender focuses on the socially constructed differences between men and women. It focuses on which formal or informal rules define these roles, and provides opportunities and strategies for change for everyone. G4AW has published a report on 'Including women smallholder farmers: a business case for success'. The focus on social inclusiveness was chosen as one of the appraisal criteria in the quality of the business case ('the partnership substantiates the demand-driven aspects and involvement of the target group, taking the position of women into account'). Furthermore, the percentage of women reached is taken into account in the appraisal of the project quality.

To involve women in service development is a clear mission for the projects. Women should be active participants in the development and implementation of the digital services. It should be noted, however, that in some target groups (especially pastoralists), most activities are carried out by men. Services for pastoralists will therefore mainly be used by men.

There is a clear business case for investing in active participation of women in agriculture, as reaching a large number of women farmers will create more impact and increase sales. Aiming to maximize a product's gender inclusiveness will thus not only increase the social impact of services, but will also increase potential sales and make it easier to create sustainable business models. Differences in women's needs and opportunities should be specifically addressed. This includes an understanding of the type of activities that women perform (including their daily schedules) and the limitations that they face.

'Traditional' norms and values (including access to land rights), as well as women's workload are two factors that still impede women from optimally benefiting from loans, even when these are available. Thus, women benefit more if additional services are provided to develop their businesses, in tandem with the provided loan. This can include financial literacy courses, land registration programs and business development support. Services tailored to cultural and gender norms, such as female extension officers, group savings and other services, can boost the ability to specifically reach women smallholder food producers[26].

Differences in access to (basic and smart) mobile phones and (digital) literacy will result in disparate uptake among different groups. Digital literacy (the ability to use ICT tools) is generally higher for younger people and especially for men. In developing countries, men are 21% more likely to be online compared to women[27]. In systems with cash crops, the use of digital tools is higher[28], as the better benefit to cost ratio (BCR) enables farmers to make larger investments. As men generally focus more on cash crops, while women tend to focus on legumes, vegetables and other crops for home consumption[29], the selection of the targeted crops can also have an indirect impact on the gender balance of the users of the services.

Monitoring and evaluating the gender-differentiated uptake of services has been challenging. The main reason is that advice/forecasts based on digital services are easily shared between users, while men are often the primary user of the ICT technologies that are used for data dissemination. This means that assessment of women users requires a more complex approach than simply registering the gender of the main service user. The gender balance of the food producers reached has been included in the monitoring and evaluation framework and reports. In several projects, basic assumptions have been made regarding the gender balance of users reached. Monitoring and evaluation output for 2020 shows about 30% of food producers reached are women.

Registration of farmer profiles enables retrieving extensive information about the primary users of services. In case of farmer-specific services (financial access, insurance, plot-level advice), this registration offers a good understanding of gender and age diversity. Farmers' profiles provide a kind of track record of the farmers to the financial institutions. This is used to assess the 'credit rating' of smallholder food producers, which is used to set maximum loans and other relevant financial variables.

[26] Sluijs, J., M. Koltai, R. Berendesen. NpM – Platform for Inclusive Finance. 2019: Reach, benefit, and empower women with financial services: Case-based learning paper

[27] Web Foundation. 2020: The gender gap in internet access: using a women-centered method. https://webfoundation.org/2020/03/the-gender-gap-in-internet-access-using-a-women-centred-method/ Accessed December 9th 2020.

[28] Tirkaso, W.T. and Hess, S. (2015), The Role of ICT Expenditure for Cash Crop Production and Income Generation in Southern Ethiopia. The Electronic Journal of Information Systems in Developing Countries, 71: 1-14. https://doi.org/10.1002/j.1681-4835.2015.tb00511.x

[29] FAO. 2003: Gender: Key to Sustainability and Food Security. Plan of Action Gender and Development. Rome, Italy.

Farmer profiles are especially useful for farmers that have registered land rights and have had stable/high yields over several years. The impact on groups with limited (registered) land rights and with frequent crop failures will be limited, as farm profiles currently cannot be used to create a proven/positive track record for these farmers. In order to include women and other marginalized groups, an additional focal point should be registration of owned assets and on access to (agricultural) education. This will strengthen their position towards financial institutions.

For more general services (including weather forecasts, advice on GAP - good agricultural practices), registration of primary users of the services provide few insights into the actual reach of these services, as this data is easily shared within a certain community. Figure 2 shows differences in age and gender for users of the Hwet Toe app developed in Myvas4Agri. This shows a clear peak of uptake by younger farmers (<35), and around 30% female users.

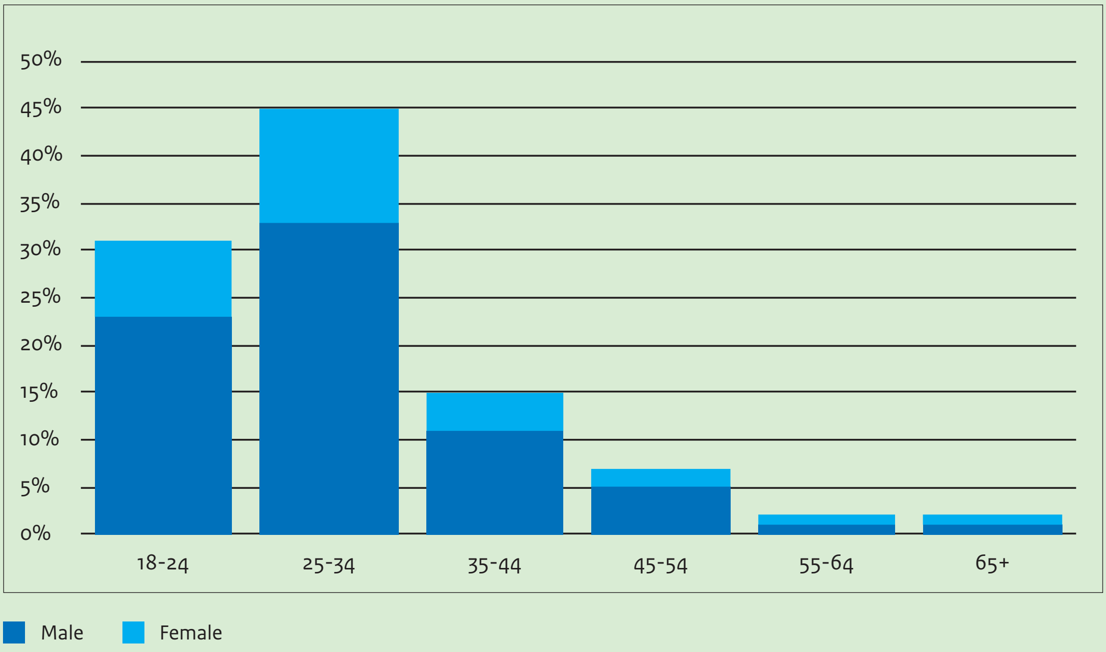
Two-way communication

An important approach to increase user participation in services is by providing the users with the opportunity to communicate through the services. This two-way communication[30] includes crowdsourcing or interaction with experts (chat). Crowdsourcing is used to receive feedback regarding, for example, the amount of rainfall on a certain day. For example, this is used to validate the models that are applied to provide weather forecasts. This approach has been tested in the Gap4All G4AW project in Burundi[31]. In other projects, including SIKIA and R4A, this approach was also tested. Farmer response in these tests, however, was limited. This is mainly due to farmers preferring face-to-face contact to share their insights.

Crowdsourcing was mentioned as a possible additional functionality in the official announcement of the G4AW Facility[32]:

The G4AW Facility will determine whether and how it can be demonstrated that better use of spatial data and information actually leads to more efficient operations and/or a better income. Use of certification or market information systems based on crowdsourcing can support the measurement of outcome and impact.

Figure 2 Users by age and gender of the Hwet Toe app developed in Myvas4Agri



[30] Two-way communication can be facilitated by extension officers, call centers, USSD and mobile applications
[31] Weather Impact 2020: Crowdsources rainfall observations in Burundi. https://www.weatherimpact.com/blog/2020/10/12/crowdsourced-rainfall-observations-in-burundi/. Accessed December 9th 2020
[32] Ministerie van Buitenlandse Zaken, 2017. Besluit van de Minister voor Buitenlandse Handel en Ontwikkelingssamenwerking van 3 maart 2017, nr. IGG-2017.151181, tot vaststelling van beleidsregels en een subsidieplafond voor subsidiëring op grond van de Subsidieregeling Ministerie van Buitenlandse Zaken 2006 (Geodata for Agriculture and Water Facility 2017–2018): https://wetten.overheid.nl/BWBR0039333/2017-03-18

Local embedding

Local embedding is a crucial factor in the successful setting up of a business. The involvement of public and private organizations in the G4AW partner countries ensured that services and (new) businesses are well embedded. This includes all licenses-to-operate are in place, and the IT infrastructure meets the legal framework for storing and sharing private data. An increasing focus on data privacy is a new push towards ongoing embedding of the business. In some countries, specific arrangements with governmental Meteorological Offices were needed to enable operations and dissemination of weather data and forecasts. Cooperation with governmental agencies was also required in other countries to provide financial services such as credits and insurance.

Timeframe

The timeframe (3 years) for design and operationalization of 'G4AW' services has been very ambitious, especially in light of the objectives to reach 100,000 farmers (or 50,000 pastoralists) and simultaneously create a sustainable business model. Almost all projects have requested further extensions (up to 1 year) to reach the objectives. For most projects, even this four-year period has been too short to reach the objectives. Creating a sustainable business in this short timespan has resulted in certain decisions being overly influenced by time stress and investment capacity. This includes dropping services that did not yet provide sufficient customer satisfaction in order to reduce operational costs. Another result of this timeframe is that many developments have been done in parallel. This is efficient from a time perspective, but can have negative impacts on the iterative design process: in some cases, users were involved too late in the testing of services as the development of certain features consumed more time than expected.

Building on experience

In general, successful partnerships build on earlier results: they had experience with the concept before starting the G4AW project. All consortia included at least some partners with experience with the target group and creation of relevant services (part of appraisal criteria), but in many projects, this experience was already gained at the consortium level. Many of the proposals were based on previous projects and studies that part of the consortium worked on in the target country. In most cases, these projects were significantly smaller and more oriented on the underlying assessments and research, or at demonstrating a specific technology.

Chat function in SMARTseeds

SMARTseeds has developed an online consultation feature (chat with expert) to accommodate the needs of farmers to engage with the experts or field officers that they trust. Based on a survey and observations in the field, it became clear that for many farmers, it is too big of a leap to simply trust the content of GAP or fertilizer advice from the app. This is because they are not sure about the reliability of the advice and whether the advice is suitable with the conditions on their farms. This finding has triggered SMARTseeds to find ways to connect farmers with someone they can trust; either experts or field officers, usually a person that they have met in the past.

With this feature, farmers can select the field officers or experts nearby that they know and trust to re-validate or ask further questions about advice provided in the app. In this way, this feature is increasing farmer's trust in the advice that is provided, as well as allowing the service to provide more tailored advice based on the farm profile submitted by the farmers. After launching this feature, it has been noted that this feature has gained fairly good traction among other features, especially during COVID-19. Based on that traction, SMARTseeds is currently preparing a strategy to offer this feature as a premium service to farmers. The idea is that, for a small fee, premium users can get access to unlimited chat with the experts, while a free user can only have one chat per certain period.

In several projects, the partners already worked on a Partners for Water project funded by the Dutch Government and implemented by Netherlands Enterprise Agency (RVO) and Netherlands Water Partnership (NWP). For organizations that work in multiple projects, there have been clear benefits of previous G4AW project experience.

ICCO, for example, has been developing business strategies in G4AW Call 2, and is now successfully establishing social enterprises to ensure sustainability of the businesses created in G4AW Call 3 projects. Service provider Weather Impact initially developed their weather service for two Call 2 projects (CROPMON and R4A), and have used these to continue to improve their services in more projects (incl. GAP4A, Myvas4Agri and SIKIA). The same experience also benefited the Lizard platform (Nelen & Schuurmans) where experience early on (Sat4Rice and IDSS) has provided benefits to several other projects (incl. Angkor SALAD, SMARTseeds and SpiceUp).

Focus of provided services

Developed services

Services provided in G4AW projects can be divided into three general groups: 1) weather forecasts and/or agronomic advice; 2) financial services including insurance; and 3) bundled products (combination of agronomic advice and/or weather forecasts with financial services). An initial limitation of how the G4AW Programme was designed relates to how the first Call for Proposal was communicated in 2013. Applicants were asked to submit an idea for a service that benefits smallholders. Particularly, this narrow request led to projects focusing on stand-alone services for which smallholders were often expected to pay. The assumption that selling stand-alone services to smallholders could be viable turned out to be extremely challenging. This finding helped NSO improve guidance and appraisal criteria for the following G4AW calls.

The limited focus on creation of products based on a single service (especially index-based crop insurance) after the first call does not reflect a lack of interest or success in these services. After the first call, submitting projects with a singular focus on crop insurance only was actively discouraged. The focus was shifted towards (bundles of) agri-focused services in order to provide farmers with both a safety net (insurance) and practical adaptation measures (climate-smart agriculture). Insurance-focused projects have been some of the more successful G4AW projects when it comes to service uptake, investor interest and follow-up. Interest in the role of geodata in financial inclusion has resulted in the development of the Geodata for Inclusive Finance and Food (G4IFF) workstream.

Financial services, such as agricultural input loans, have been included in different projects as part of a bundle (see example in box 2). Bundling of service can be done in different ways:

- Bundling of services within the same overall service group. This includes combining different services directly focused on improved farm management (e.g., weather information, nutrient advice, disease warning)
- Bundling of services from different service groups. This adds services from different groups (e.g., crop monitoring, market intelligence and access to finance) to deal with the limitations smallholders face at different levels in the value chain.

The latter provides farmers with more options, as this covers more aspects of the value chain that are relevant to them. Especially the addition of financial services is highly appreciated by the users as this enables them to purchase new seeds and inputs that help improve production.

The bundling of services may include insurance, access to input loans and market information in addition to the traditional services such as weather forecasts and agronomic advice. The latter (traditional) services have a more evident link to satellite-derived data and often form the core of the products in the project proposal and at the early stages of product development.

Other services that were not specifically mentioned in many proposals, but have been developed in many projects to address user needs, include creation of farmer profiles, location information, sustainable tracing systems and crop selection advice. While location information is a service that is flexible to interpretation (almost all services have some link with the location of the users to provide relevant insights from the geodata), many of the other shifts in created services can be linked to the clear value proposition that these services provide for the business clients.

©Auxfin/GAP4A project

BOX 2: Data bundling in the AgriCoach app (GAP4A)

The AgriCoach app provides information on what to plant, when to do different activities and how to do them. The app includes crop suitability maps and weather forecasts. The business owner and service provider (AUXFIN) is specialized in a system providing low-cost financial transactions. The objective of GAP4A is to enable the farmers to diversify their cultivation. They receive basic information about cultivation and the value of crops. This includes 1-minute crop-specific videos.

Services include information on fertilizer needs, available crop varieties, pests and diseases and a crop calendar. The service provides advice on how much fertilizer they need and where to buy. Once farmers have selected the crops, they can use the 'activity calendar', which includes preparation, crop growing and processing. Additional GAPs are provided relating to application of compost and erosion protection measures. Farmers can order fertilizers as a group through the system, and organize logistics together. Here the financial service (financial coach) and the AgriCoach are really complementary. The different services all converge. There is also a strong relation between AgriCoach and the health coach since farmers are unable to harvest if they are not healthy.

Farmer profiles have been created based on the need to register farmers to provide specific services. Demand for this information by businesses has created an opportunity to move towards B2B services and has made farmer profiles a valuable source of data. Farmer profiles provide businesses with valuable insights. They can find correlations between age, gender and location and cultivated crops and inputs used. This can be used to better market their products.

Crop yield information is another service that provides a clear value proposition for agribusinesses and other businesses (such as traders) that collect and market crops. Crop selection is interesting to suppliers of seeds, as this helps them to find suitable areas to sell their seeds.

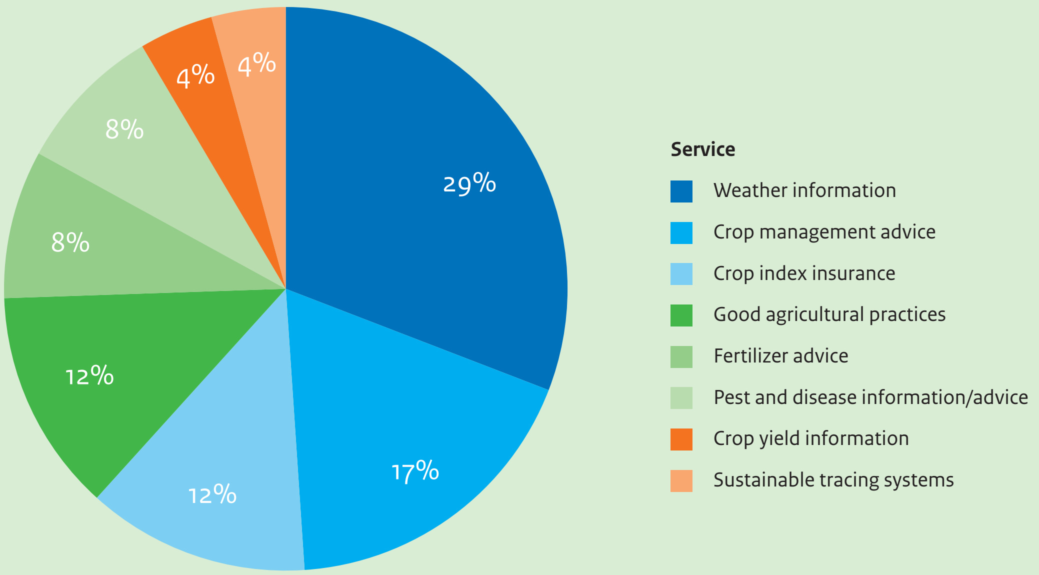
Table 1 Services in G4AW (proposal vs operational project)

Type of service	Proposal	Project
Crop management advice	21	19
Weather information	11	18
Good agricultural practices	10	18
Fertiliser advice	8	13
Market information	8	11
Pest and disease information/advice	8	16
Irrigation advice	6	8
Farmer profile information	4	10
Agricultural input loans	3	5
Crop index insurance	3	4
Crop selection advice	2	9
Crop yield information	1	10
Flood mitigation advice	1	2
Location information	1	8
Sustainable tracing systems	1	4

The average number of services per project has significantly increased from an average of 3.7 in proposal and early project stages, to 6.5 in the currently provided products. Having more services in the product can help create a product that is relevant to more users. Services become more relevant if services across the value chain are included. This includes services in three areas of the value chain, namely: access to (1) agro-advisory services, (2) finance services, and (3) markets.

Weather information is considered by the G4AW partnerships as the most valuable service (see Figure 3). Fertilizer and pesticide advice were both considered the most important in two projects. For fertilizer advice, the relevant projects are Angkor SALAD and Geodatics. These projects have involved specialized organizations and significantly focused on soil sampling. The two projects that consider pest and disease information the most important are SMARTseeds and GEOPOTATO. GEOPOTATO in particular has focused on developing warnings and advice for potato late blight (PLB), and have been able to add this service to existing products provided by larger companies. SpiceUp is expecting tracing systems to become the key selling service: this helps Verstegen Spices & Sauces and its local partners to trace the quality and origin of pepper throughout the value chain.

Figure 3 Key selling point of the created products



It is also worth mentioning that various service providers struggle to deliver on their promise of providing highly precise advisory services when the (earth observation) data they use does not provide this level of accuracy. This is related to the problem with some crops (e.g. coffee, cocoa) to 'translate' the commonly used free data into insights and advice. Around 70% of the key selling services (weather information, crop management advice, crop index insurance and good agricultural practices) do not necessarily require plot/crop-level satellite data in order to provide the services.

Further research and improved availability of very high resolution (VHR) data is needed to improve the plot-level services. There is still a dilemma between making use of free 'high' (> 10m) resolution EO data and using commercial 'very high' resolution (< 10m, often <5m) EO data. The latter can be used to provide a better service, but at a higher cost (due to costs for acquiring, storing and processing data). This implies that VHR is often only a realistic option when applied in a business model that is already at scale.

Weather information

Weather information is high on the priority lists of farmers' information needs. Meteorological parameters are also often used as input for agronomic advice and monitoring of conditions conducive to plant pests and diseases. Several G4AW partnerships expressed a need for more ground stations as a condition for providing more relevant local advice.

Weather-related services can focus on one or more of the following aspects:

a. improved basic weather information in areas where current systems are inaccurate;
b. early warning for extreme weather events;
c. drought modelling and monitoring;
d. improved prediction of the start of the rainy season; and
e. long-term (seasonal) weather forecasts.

Weather forecasts are often linked to the agronomic activities in order to create actionable advice (see quote by R4A project). There are many different types of forecasts that all have different links to activities by the farmer. Short-term (up to one-week) forecasts determine activities such as nutrient application and are useful when deciding whether or not to irrigate; longer forecasts (e.g. start of rainy season) are relevant to determine when to sow and harvest.

Forecasting extreme events can be linked to flood warning services. More localized information (microclimates) is needed to provide information on conditions conducive to pests and diseases . Pests and diseases covered in G4AW include: potato late blight; brown planthoppers (rice); coffee rust; and the fall armyworm (mainly maize).

While weather information is crucial and is still of limited accuracy in many regions, it is not a service that is specific to the plot of smallholders. This means the basic advice can also be disseminated by mass media such as regional radio and TV channels. An important added value of weather forecasting concerns the link with farming activities such as weeding and/or irrigation application.

If we speak of advisory services, we always think about advisories to act. One striking insight from the G4AW Facility is that a food producer can receive an advice not to act. The R4A learned that maize farmers, after having some rain, decided to seed. However, maize requires about 25 mm of rain around seeding time for achieving highest yields. That's why the R4A AgriCloud application provides a seeding calendar in which calendar days use the traffic light system: days are highlighted in green (favorable, best period for seeding), orange (undecided, please make your own choice to seed or to wait), or red (unfavorable, it is best to wait).
Similarly, this approach can be followed for fertilization and spraying. Too much rain may wash away fertilizers and pesticides. Waiting will probably save the farmer money and protect the environment.

Rain4Africa, South Africa

Payment for weather services is an issue, as free alternatives are abundant, and many users consider this a service that should be provided by the government. This means bundling with other services is required to provide the full benefits of the weather forecasts to farmers.

Good agricultural practices (GAP)

Good agricultural practices (GAP) is a bundle of practices that help farmers to sustainably improve their food production. It guides them in their day-to-day actions. As GAP is not a fixed set, different names exist based on the primary focus of the included practices. Climate-smart agriculture contains many of the same elements as basic GAP, but has some additional emphasis on climate-adaptation and mitigation (including improving soil carbon storage).

GAP has been around for decades, and is often derived from research done by local agronomic research institutes. This means GAP is specific to local soils, varieties, and the socio-economic conditions. Many good agricultural practices are related to the timing of inputs, to ensure these will be efficient (in line with current demands of the crop) and result in limited run-off (considering rainfall). Satellite information adds complementary value to GAP.

Weather information is often closely linked to GAP-related activities: the benefit of farmers is in this linkage, as this helps reduce costs based on more efficient application of inputs. Many of the services, such as pesticide and fertilizer recommendations, are intrinsically linked to good agricultural practices if implemented effectively. This means GAP is not always equally visible in the services, as it is attached to the other services.

Smallholders' understanding of good agricultural practices (including practices included in climate-smart agriculture and 'save and grow' practices) is key to reach the G4AW objective to combine an increase in production with a reduction of input use. Reduction of inputs is only useful in regions where the use of inputs is higher than what would be effective to reach a certain production. In most regions in Africa, which has largely missed out on the benefits of the first Green Revolution[33], availability and use of modern inputs is still low. While there is a clear potential for certain climate-smart practices (e.g., Conservation Agriculture, Alternate Wetting and Drying), there is also still room for an effective increase in most inputs.

This results in a different overall focus of GAP in Africa and Asia. In G4AW projects in Africa, understanding of, and access to, new inputs are central. GAP is often focused on the effective use of these new inputs, and many services include some aspects of financial access that enables farmers to purchase useful inputs. In the end, it is likely more inputs will be used to enable higher production. This is mainly due to the low baseline. Projects in Asia generally have a stronger focus on promotion of approaches to reduce the use of inputs. This includes, for example, a manual on how to create and use compost (SpiceUp).

Crop monitoring and crop yield prediction

Crop monitoring includes differentiating between crop growing stages to understand the need for irrigation and nutrients, but also offers information about the number of days up to harvest. Crop monitoring generally requires input from farmers about the type of crop and plot location. Historic data and data of similar crops in the same region give information about the relative performance of the crop. This is based on vegetation indices such as NDVI or the leaf area index (LAI). Crop monitoring can be linked to actions such as application of nutrients if the above-ground biomass is lagging behind what is expected for the crop in a specific plot and period.

Information on crop performance is of limited interest to farmers, as their main interest is focused on the actions required to improve productivity. Crop monitoring can be the basis for fertilizer advice, crop management advice (incl. good agricultural practices), crop yield forecasting, irrigation advice, and, in some cases, pest and disease warning. Almost all G4AW projects include some aspect of crop monitoring and/or detection. Crop monitoring is strongly linked to the vegetation index NDVI, which is the most commonly used indicator in remote sensing for agricultural applications. Most of the G4AW projects have created and used the NDVI in at least one of the services.

Yield prediction is a 'premium' function of crop monitoring, which requires continuous crop-monitoring and calibration/validation (training) data with information on past crop yields in the region. Crop yield information (incl. forecasting) is also relevant for (local) government, financial institutes and traders that facilitate handling and storage. This can be used to monitor the food security situation (current crop stages and yield level compared to multi-year averages) and can be used by financial institutes to extract historical records of farm performance that can be used as the basis to check the credit scores of farmers.

[33] Frankema, E. 2014. Africa and the Green Revolution A Global Historical Perspective, NJAS - Wageningen Journal of Life Sciences, Volumes 70–71, Pages 17-24, https://doi.org/10.1016/j.njas.2014.01.003.

Rice fields in Mekong Delta Vietnam (Sentinel-1),

Fertilizer advice

Fertilizer advice is often based on crop type, growing stage, and crop performance (e.g. NDVI). The advice is derived from a combination of satellite and field observations. The aim is to achieve more effective utilization of fertilizer over time and space. The underlying principle of fertilizer management is the '4R' principle: to provide the nutrients of the right type, in the right amount, at the right time and in the right place[34]. Satellite data can play an important role, as weather information helps assess the right time to apply fertilizers, and spectral data will provide insights on the right place (especially when using Very High Resolution satellite data).

Integrated nutrient management is necessary to maintain or improve soil health. However, accurate implementation is also highly complex and the benefits of this service generally only become clear after a period of several years. Compared to services such as weather forecasting and irrigation advice, for fertilizer advice it is difficult to show benefits within a project duration of three or four years. Costs for the required fertilizers will vary between years, as the requirements will change. This is due to the ever-changing biological soil processes and altered growing stages of the crops (in the case of perennial crops). The benefit-to-cost ratio may be less than ideal in the first few years to show the long-term economic benefits of the recommended fertilizers.

The effectiveness of fertilizer advice is based on a larger context of public programs (e.g. fertilizer subsidy programs), market availability of different products, suitability of fertilizers available on the market, and the existing extension systems. The complexity of fertilizer application and the high investment required make it especially useful to have multi-year demo plots and presence of local extension officers to provide advice.

Suitability mapping for fertilizer use is another area where geodata offers an advantage. The optimal type of fertilizer differs per crop variety and region (e.g. soil type, slope). A good analysis of these characteristics with satellite information can help governments and suppliers adjust their offerings to the specific needs of the users. The Geodatics project, for example, faced the challenge that the composition of the only fertilizer available in the market did not match well with the composition of Geodatics' recommended fertilizer. Recommending detailed blending of nutrients is therefore not always efficient, as markets are often not ready for this level of processing. It was found that more general blends need to suffice.

The Geodatics project has also aimed to use satellite information of above-ground biomass as a proxy of soil nutrient availability in different areas. Biomass as a proxy for soil health is a promising alternative to the traditional and more expensive site-specific estimates of soil nutrient content, as it is easily scalable and can take into account the local variation in the complex terrain in which smallholders often cultivate their crops[35] .

The problem with such a service is that it is still largely in the research stage, and that the required satellite data to assess variation within smallholder plots should have a spatial resolution well below 10 meters. This means VHR data would be required. Small parcels and intercropping pose additional problems for remote-sensing based fertilizer advice, especially when using the currently free satellite data (10m+) to create this advice. The creation of useful products would require the use of commercial, more costly VHR satellite products.

Remote-sensing based fertilizer advice can already be effective in regions where many smallholders grow the same crops (e.g. rice). This allows for comparing crops, which can give an indication of potential nutrient deficiencies in different plots. Fertilizer advice has been included in over half (13) of the G4AW projects - but based on a wide range of approaches. This includes relatively basic approaches (linking growing stage to tables derived from field trials) and more complex ones (satellite-derived assessment of soil nutrient status). ISRIC data (WISE, SOTER and SoilGrids) have played an important part in the G4AW Programme: ISRIC[36] has been mentioned as a direct source of geodata in at least six of the G4AW projects.

Pests and diseases

Pests and diseases can result in significant reduction of agricultural production. The primary challenge to the efficient use of pesticides is deploying the correct substance at the right time. Overuse can reduce the biological control that could be provided by other organisms. Improper use can also cause health problems to farmers or damage the ecosystem. The main role geodata plays in this respect can help in early warning and detection of plants and diseases. This includes: 1) monitoring conducive conditions for outbreaks of pests and disease (rainfall, temperature, humidity, growing stage); 2) providing information

[34] Johnston, A.M., T.W. Bruulsma. 2014. 4R Nutrient Stewardship for Improved Nutrient Use Efficiency. Procedia Engineering 83. 365-37
[35] Schut, A.G.T., K.E. Giller. 2020: Soil-based, field-specific fertilizer recommendations are a pipe-dream. Geoderma 380.
[36] https://www.isric.org/

on known outbreaks (through crowdsourcing); and 3) monitoring vegetation indices that provide information on crop performance (spots of low NDVI in a farm can indicate impact of pests/diseases).

The approach used in most of the projects that are focused on pest warning has involved monitoring when the weather conditions were conducive for certain pests and diseases. These conditions are generally based on existing research. Sixteen of the G4AW have included some aspect of pest and disease management. GEOPOTATO provided pest and disease monitoring as a key service, while it was part of a larger bundle in most other projects. GEOPOTATO provides potato farmers in Bangladesh with early alerts for possible potato late blight (PBL) attacks. The alert text messages include recommendations for when to spray and with what type/brand of fungicide. This is crucial information for smallholders and, in the project phase, many farmers mentioned they appreciated the service. Other pests / diseases covered include the brown planthopper (BPH) in Sat4Rice and the fall armyworm (FAW) in SAM.

Fertilizer advice and pest and disease warning are both based on the same business proposition: 1) farmers increase yield (or reduce losses) by having more knowledge about the type and amount of substance they need to apply (*what, when, where, how*); 2) agrobusinesses will benefit from increased sales of their products (the *what*). The *when*, *where*, and *how* will help the farmers to effectively and safely apply the products. This will help to increase customer loyalty.

The corporate partners in these projects are especially interested in the potential to sell more products, while customer loyalty can also provide interesting benefits. The main challenge in this proposition is to ensure that the increase in sales will not result in inefficient and harmful application of these agrochemicals. Customer loyalty requires the product to be cost-effective, which means the agrobusinesses cannot promote an overuse of the inputs. This is especially the case when different agrobusinesses provide the same general type of products.

Irrigation advice

Using geodata in irrigation advice has a long history and is one of the primary services that can help smallholders. Remote sensing data can be used in different ways: estimate soil moisture, indicate vegetation stress, provide input in surface energy balance models and create weather forecasts. Advice on irrigation can range in complexity, from basic to advanced (linked to dynamic crop growth models). Irrigation advice is very easy to link to actions by smallholders (irrigate yes/no). The challenge lies in also assessing whether these actions can be practically realized, as this depends on the local context.

> *During 2019 it became clear that Fall Army Worm (FAW) was not restricted to African soils, but started to invade Southeast Asian countries as well. The SAM partnership immediately responded by developing and offering a FAW-service (providing alerts and sustainable solutions). When it was ready and implemented, it was found that Myanmar farmers burned down their maize fields. The service still is available, but farmers need more information and education to start using the FAW service.*
>
> **Smart Agriculture Myanmar**

The decision to irrigate is often not fully in the hands of individual farmers, as they are often dependent on decisions at the level of an irrigation scheme. Irrigation by pump (tapping into shallow groundwater resources) can be promising for smallholders in dry regions, but as yet, only 1% of cultivated land is equipped for groundwater irrigation in Africa, compared to 14% in Asia[37]. This means irrigation advice is mainly relevant at the level of irrigation schemes, for which these insights can be used as part of the planning process on water distribution. As direct advice to smallholders, the relevance is still relatively limited in most target countries. Understanding what actions farmers can and cannot take has been part of the user engagement process.

Soil moisture satellite products provide useful information that can be the basis of irrigation advice, but the resolution of these products (starting at 100 metres) is generally too coarse to provide information at the level of smallholders. Soil moisture data can provide interesting insights in the water demand of larger commercial farms and is an important dataset for index-based insurance. Plot-level irrigation advice can be provided by models that use surface energy balance models (e.g. SEBAL) and use optical satellite data as input. The main restriction are still often the relatively high cost, input requirements of farmers, and the need for sufficient cloud-free days in the growing season. This makes it mainly interesting to groups of farmers (irrigation schemes) in seasons in which cloud coverage is not restricting the availability of optical imagery.

[37] CGIAR. 2016. Is groundwater the key to increasing food security in Sub Saharan Africa? Blog-post on https://wle.cgiar.org/thrive/2016/04/23/groundwater-key-increasing-food-security-sub-saharan-africa. Accessed December 9th 2020

Some level of irrigation advice has been provided in 8 of the G4AW projects, although it has never been the key selling service in the created products. Irrigation advice is closely linked to weather forecasts, so irrigation advice can be as basic as: '*weather information shows no rain has fallen in one week, and no rain is expected in the next 5, so irrigate in the next few days*'.

Remote sensing is very well suited to water resources management at the level of catchments. One example is the WaPOR dataset, operated by FAO and funded by the Dutch Ministry of Foreign Affairs (see box WaPOR).

WaPOR

WaPOR, FAO's portal to monitor Water Productivity through Open access to Remotely sensed data, monitors and reports on agriculture water productivity across Africa and the Near East. It provides open access to the water productivity database and its thousands of underlying map layers. It allows for direct data queries, time series analyses, area statistics and data download of key variables associated with water and land productivity assessments. Water and land productivity is assessed in a different way for the three spatial levels: 250m (continental level), 100m (national and sub-national levels) and 30m (irrigation schemes and sub-basin levels). The following main applications are distinguished for WaPOR data:

1. Assessing continental water productivity
2. Monitoring irrigation areas
3. Measuring water productivity
4. Monitoring the impact of drought
5. Assessing the water consumption of crops
6. Monitoring changes in agricultural production
7. Providing advisory services to farmers
8. Assessing water resources at the national level

WaPOR offers near-real-time data (starting 2009) from 21 parameters, including gross biomass production, actual evaporation and interception, net primary production, above-ground biomass, land cover classification and crop phenology. Special emphasis is given to the multiple uses of water services (MUS) in agriculture. MUS can provide the more vulnerable water users with low-cost services for domestic water, water for homesteads, water for livestock, habitats for fish and other aquatic resources and rural enterprise water supplies. The multiple uses of water services often increase the economic productivity of water use in irrigation schemes. Within multiple uses of water services, gender relations are of main interest.

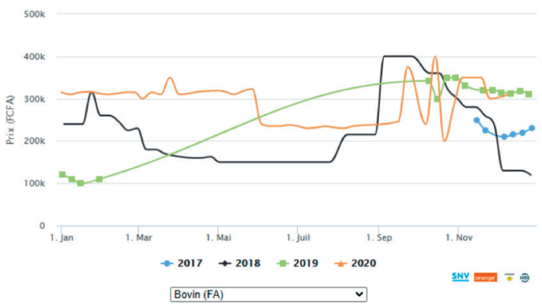
Market information

Market-related services provide information on historic, current and forecast market prices of commodities to both buyers and sellers. Market information can differ both in time and space. Forecasting also plays a crucial role in understanding the best time to buy/sell commodities. Although geodata plays a role, the market information is not based on satellite data.

Small food producers generally have limited options to decide where to sell their produce, as this requires the ability to process the crop or transport it without losing quality. However, for the sale of livestock (fresh meat), prices at different local markets will be an important source of information. This has been implemented in the MODHEM(+) project in Burkina Faso.

The fluctuation in price over time is often more interesting to smallholders (especially forecasts), as they can take actions by either selling now or waiting for a certain period. This will also require the ability to either wait with harvesting or keep the produce fresh after harvest. These options are often limited for smallholders, as weather forecasts and labor availability determine when to yield. Storage can also result in significant losses (pests/diseases).

Figure 4 Variation in price for cattle on a local market between/within years; the market price is disseminated via Garbal to pastoralists (source: STAMP project, Mali)



Market information is rated as a high priority need by food producers, and is often included in the G4AW product offering. Pastoralists also require market information, which is why the service was incorporated in Garbal (see Figure 4). Market information is especially relevant for agribusinesses and traders, as they have more resources to process the product and transport it over greater distances without the risk of affecting the quality of the product.

With the combination of geodata (road network, market locations) and price, companies can calculate the costs (storage and logistics) and benefits of selling products in different regions. There is a clear geospatial component to market information, but remote sensing is rarely used. Remote sensing data is especially useful to predict the amount of produce and the period when it will be available. This can be used to forecast the market price, but also to plan the processing (e.g. millers).

COVID-19 has been disruptive for the traditional marketing process in many developing countries due to lockdowns on the local markets, and in some cases in international trade. Closing borders and additional health checks have slowed down the marketing chain. Farmers have had to find new solutions to sell their crops, for which digital services have been key. This has enabled them to link with local buyers, to have shorter market linkages (see box 3).

Geolocation services

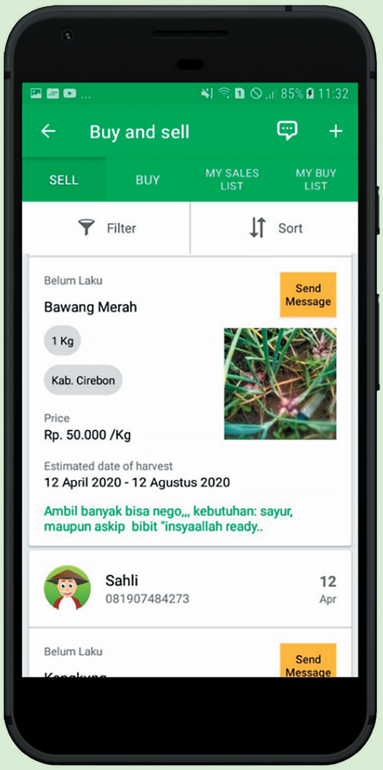
Geolocation services include the location and delineation of farming assets. In the case of services for pastoralists, the current location of the user is used to assess the shortest and safest route towards grazing grounds and water. In some services, location is becoming increasingly important, especially in services that focus on creation of an online marketplace to solve problems that emerged during the COVID-19 lockdown. In these services, sellers and buyers can find each other based on the products and location. Such approaches to reduce the distance to markets have become very important due to restrictions imposed by the COVID-19 lockdown.

In most services, geolocation offers additional support to the actual services. This includes analyzing the size of assets in farmer profiling. The location of the users and/or its assets (plot size) is crucial for extracting the relevant information and creating profiles. In the case of user location, this can simply be monitored through existing mobile networks. In the case of assets, local

BOX 3: Marketplace app for alternative market access

The idea was based on frequent feedback we received from farmers about their need for information about alternative market access. This demand has triggered SMARTseeds to build a marketplace platform. This enables farmers to post their produce in an online forum, and allows buyers to contact the farmers if they are looking for their products. If the buyers or sellers are interested in the offers, they can contact the person directly via the chat feature to complete the transaction. With this platform, farmers can easily access a wider pool of buyers and compare produce prices from these various buyers, while simultaneously allowing buyers to compare produce and prices from a wider pool of farmers.

This feature is now among the most popular in the app, especially during COVID-19, when its traction doubled as suddenly, many offline buyers stopped buying from the farmers due to the closure of many hotels and restaurants. Due to the increased traction of this feature, SMARTseeds intends to link it with an ads-based business model. If sellers or buyers want to be listed as a top result when users search for a product, they can pay SMARTseeds a small fee.



Source: SMARTseeds

staff needs to go into the field and walk around the borders with a GNSS receiver. This will result in all relevant (border) coordinates being stored, creating clear outlines for the plots.

Capturing the outline of plots is a process that requires some training to ensure efficiency and accuracy. In several projects, expertise in this process was available within the consortia. This included a role for the Netherlands' Cadastre, Land Registry and Mapping Agency (Kadaster) in the SIKIA project.

Financial services

Finance-related services include the provision of crop-index insurance and access to agricultural input loans. The main difference between these services and the previously discussed services (weather forecasts and different aspects of crop management advice), is that the finance-related services have a less direct focus on increasing productivity and include farmer profile information and portfolio risk management. The objective of financial services is to provide farmers with affordable insurance and financial access that enables them to invest more in their farming activities, and thus increase their production.

Risk aversion is one of the most important reasons why smallholders are not investing more in agricultural inputs and equipment, especially when the benefits are not yet understood (which is often a problem for promoting any new on-farm activity). Insurance is an important approach to mitigate risks. The two main types of finance-related services are:

Financial access

Productivity on smallholder plots is often low because of limited or inefficient use of inputs. This is partly based on a lack of understanding of the practical use of these inputs, limited availability on local markets, or a lack of financial means to purchase these inputs. Farmer profiles can be created based on geodata, which provides an indication of the location and size of plots and the production achieved in the past years. These profiles improve the understanding of assets and the production results and help financial service providers to improve their ability to estimate risks associated with granting loans to these farmers.

Farmer profiles are used both to monitor the existing customer base and to provide financial access to new customers. General priorities and contributions of satellite information for finance involve: locating farmers and their holdings, monitoring current agricultural performance, maintaining historical records of agricultural performance, and linking this to risk management.

> *"A clear request formulated by financial service providers (government and others) related to geodata is for a check on an area actually sown or planted. Farmers can request soft credits, often in the form of tokens, for fertilizer, based on the size of their farm. The size of the farm is known through farm profiling. However, they do not always use the full extent of their farm for cultivation. Therefore a check is needed to assess farmer compliance, and (VHR-based) satellite information is seen as a solution."*
>
> **Mark Noort, HCP International**

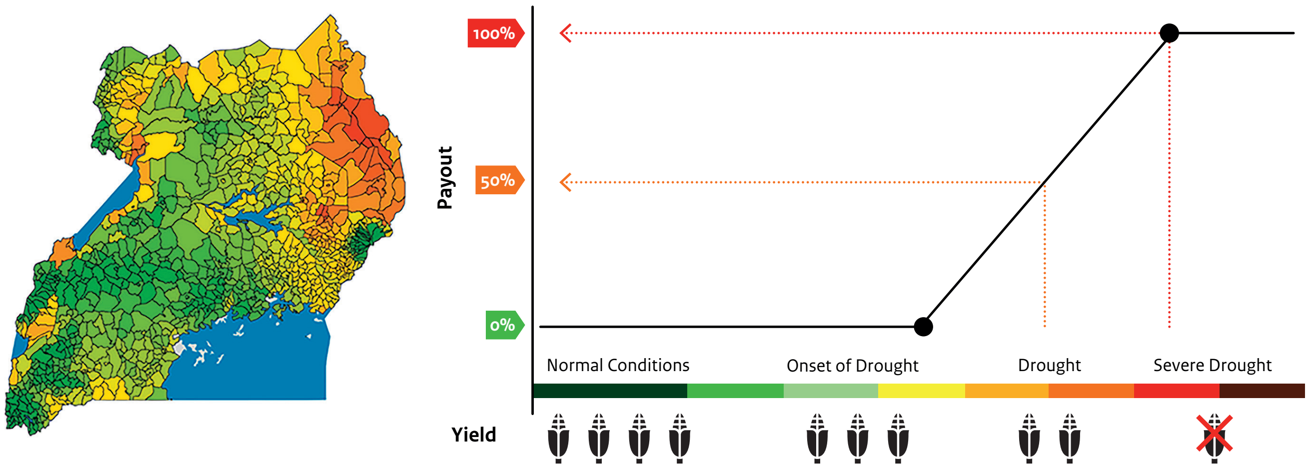
The added value of the use of 'Geodata for Inclusive Finance and Food' (G4IFF) has been studied in 2020-2021 by the Netherlands Platform for Inclusive Finance (NpM) with the support of the Netherlands Space Office (NSO). Projects focused on financial access (farmer profile information as basis to provide agricultural input loans) in the NpM study included CommonSense (Ethiopia), MUIIS (Uganda) and MyVas4Agri (Myanmar). Just as the index-based crop insurance services, the majority of these services have been developed for Sub-Saharan Africa. Findings of the NpM study are reported in the second publication of this lessons learned series.

Index-based insurance

Index-based insurance is insurance that covers the conditions that lead to specific losses, rather than the actual loss itself. The pay-out to farmers is based on the predefined loss related to certain conditions. Conditions that are covered in G4AW projects include evapotranspiration (SUM Africa, MUIIS), and NDVI (GIACIS). Other parameters that can be used for index-based insurance include rainfall, drought (soil moisture), and extreme weather events. The impact of these conditions on crop losses is derived from long time-series of remote-sensing data. If the indicator drops below a certain index, losses will become inevitable, and pay-out will be triggered automatically. The main benefit over traditional (claims-based) insurance is the low costs required for monitoring, taxation and

Smallholder community in Burundi explores Gap4A Agricoach app ©Auxfin International/Gap4A Burundi

Figure 5 Risk rates and associated insurance payout in Uganda (SUM-Africa)



administration. This reduces the need for local staff that have to make time-consuming field visits. Fraud can be reduced, as the index is objective and cannot be influenced by the farmers.

Four G4AW projects (of which three in the first call) have specifically focused on crop insurance: one in Indonesia (G4INDO) and three in Africa (GIACIS, MUIIS and Sum Africa). Index-based insurance provides a clear business proposition. This proposition has attracted a range of other parties, which enabled the service providers to develop similar products outside of the context of G4AW. This scaling opportunity contributes to the expected outcome of G4AW: support the development of an emerging market. It also contributes to achieving a greater impact with G4AW investments.

Tracing

To comply with the requirements of certification, product tracing is required. The idea is that such monitoring can be done more effectively with satellite-derived data. A certification service that is relevant for large companies (e.g. multinationals) and NGOs for monitoring and tracing of commodities requires a combination of remote-sensing data (including monitoring of deforestation, floods and drought), data from staff on the ground, and a robust tracing system. This may include tracking based on satellite-based location services.

Satellite data can contribute by adding relevant insights to tracing (product location, monitoring changes at location of product origin). Real-time tracking of products can also help adjust transport routes based on the occurrence of unexpected changes along the route (roadblocks, overturned trucks, etc.). Tracing is especially relevant for cash crops that are transported over larger distances and of which the conditions need to be monitored to ensure that transport conditions do not reduce the quality of the products.

Tracing is also used to ensure that the production and processing of the commodity is in line with the standards set by different certification schemes. Remote sensing is especially relevant to ensure that the commodity is not derived from illegal land-use practices (deforestation outside designated areas). The overall production of a certain product can be referenced to the land use change that can be seen using earth observation data in the provided location of origin of the product. If this does not realistically match, the production can be expected to be derived from other (possibly illegal) areas.

Services focused on certification and tracing for sustainability are developed in four G4AW projects, although it so far only expected to become a key selling point in one of these. Sustainable tracing systems is expected to become an important component of the SpiceUp project, in which data logging is facilitated by promoting the use of QR coding.

Crops and commodities

A wide range of crops and commodities is targeted in the different G4AW projects. As the G4AW objectives are easiest to achieve by targeting smallholders that (potentially) produce for the market, this leads to a focus on high-yielding staple crops (rice, maize and potato) and high-value crops that can be easily exported (coffee and spices). These are crops for which services attract attention from agribusinesses and traders, as these are easily scalable and economically interesting.

Figure 6 shows the crops targeted by more than one G4AW project. Crops that are covered in only one project include banana, cassava, chickpea, coco yam, eggplant, mango, millet, pepper, sunflower, and sweet potato. In most cases, advice for these crops is integrated in a particular service such as GAP or weather information, while a crop such as pepper has received the full focus of a project (SpiceUp).

Traditional cereal crops such as sorghum and millet, vegetables, beans and lentils are represented in fewer projects. These crops are more often used for home consumption or sold in local markets, which might make them less interesting for the larger agrobusinesses. The bias in G4AW is towards crops; there have been only two projects dedicated to livestock and none to fisheries.

Projects focused on livestock (targeting pastoralists) have a link to the monitoring of grazing land, so have an indirect focus on grassland.

General services, such as weather forecasts, are not linked to any specific commodity and are frequently supplied to farmers cultivating various crops. The type of crops that are covered in the most projects are: a) staple crops (rice, maize and potato); and b) high-value export crops (coffee, sesame, cocoa, chilli pepper, pepper and groundnut). Maize and rice are two of the crops that are generally over-researched in agricultural studies, which can also be seen in studies related to the impact of climate change on crops[38]. The availability of existing research is an important factor in deciding the crops to be targeted.

The available service delivery methods will also impact the crop selection. Providing advice for multiple plots/ crops requires either a smartphone app, or requires several messages on a basic phone. As providing several separate text messages is costly for both the business and the farmer, services that use basic mobile phones to disseminate advice (as is often the case in Africa), are generally focused on weather information and advice for a small set of crops that are cultivated by many farmers.

Figure 6 Crops covered at least twice in the G4AW Facility

[38] Manners, R., J. van Etten. 2018: Are agricultural researchers working on the right crops to enable food and nutrition security under future climates? Global Environmental Change. Volume 53, pp 182-194. https://doi.org/10.1016/j.gloenvcha.2018.09.010

Selection of staple crops may also be preferred for the following reasons:

- these are well researched in different regions, which makes it easy to apply known remote-sensing analyses as the basis for advice, and also to provide Good Agricultural Practices without any need for new (costly) research;
- these crops are generally cultivated on relatively large plots under monocultures with specific conditions (in the case of rice under flooded conditions). These are all factors that make it easy to use open satellite data to provide meaningful advice; and
- they are globally relevant (cultivated in many different regions, with significant export options), which make it a commodity for which the technology can easily be scaled to different regions and countries. Investment can thus be seen in a larger perspective for the service providers and agribusinesses.

Several high-value export crops have also been targeted in G4AW projects. These include coffee, sesame, cocoa, pepper and groundnut. From an economical point of view, this selection is understandable, but providing crop-specific advice for these crops with open available remote-sensing data is more challenging. The focus of services for these crops is often on more general advice such as weather forecast, irrigation advice based on soil moisture status, market information and GAP. These high-value crops are often exported, which make additional services related to traceability and certification relevant. Monitoring of forest clearing is a relevant service to business that market these commodities.

Projects focused on vegetable crops have faced difficulties to provide meaningful advice at the plot level. This was partly based on the mismatch between the small plots of vegetable farmers and the minimum 10-metre resolution of open satellite data. Another reason was the limited availability of calibration and validation data for these crops. The SMARTseeds project is aimed at improving the use of satellite data to create accurate vegetable maps, by requesting additional information from farmers in the registration process. This helps to increase the amount of training data.

In the context of international programs focused on improving food security, a strong focus on cash crops is increasingly under debate, as the benefits to farmers are more indirect. There are two types of relationships between the created services and food security: either direct (more food grown for own consumption) or indirect (higher income through sales of cash crops, which can be used to purchase more food).

Understanding and being able to explain how the different services benefit the farmers is important. Cash crops are still considered an integral part of strategies to improve food security[39], but other (non-donor) funding might also be available to fund the development of services for these crops. Farmers that cultivate cash crops in developing countries are more inclined to invest part of their income in digital tools, compared to farmers that cultivate other crops. This makes a focus on cash crops useful for opening new markets and creating awareness of the potential of digital advisory services.

An important challenge of donor programs such as G4AW, is to ensure that the success of the projects does not result in a further shift towards cultivation of crops for which the geodata-based digital advisory services have already proven successful and economically viable. This could result in a shift towards the larger staple crops and monocultures, which would increase the risk of pests/diseases and reduce dietary diversity. This will require a specific incentive to focus the projects on more diverse food systems, which requires more remote-sensing research and possibly also active promotion of the use of Very High Resolution satellite data.

Targeted clients

Selection of client group(s) depends on many factors: size of market, existence of (and need for) relevant remote-sensing based products with a clear business proposition, and socio-economic conditions of the target group (access to mobile phone, financial access, organizational structures, etc.). When it became apparent that willingness of food producers to subscribe to and pay for the services was low, the (agri)businesses, (local) governments and NGOs became an important target group of the marketing campaigns (for the B2B services) of G4AW partnerships. Figure 7 shows the groups that have been targeted in the different G4AW projects (divided into food producers and institutions).

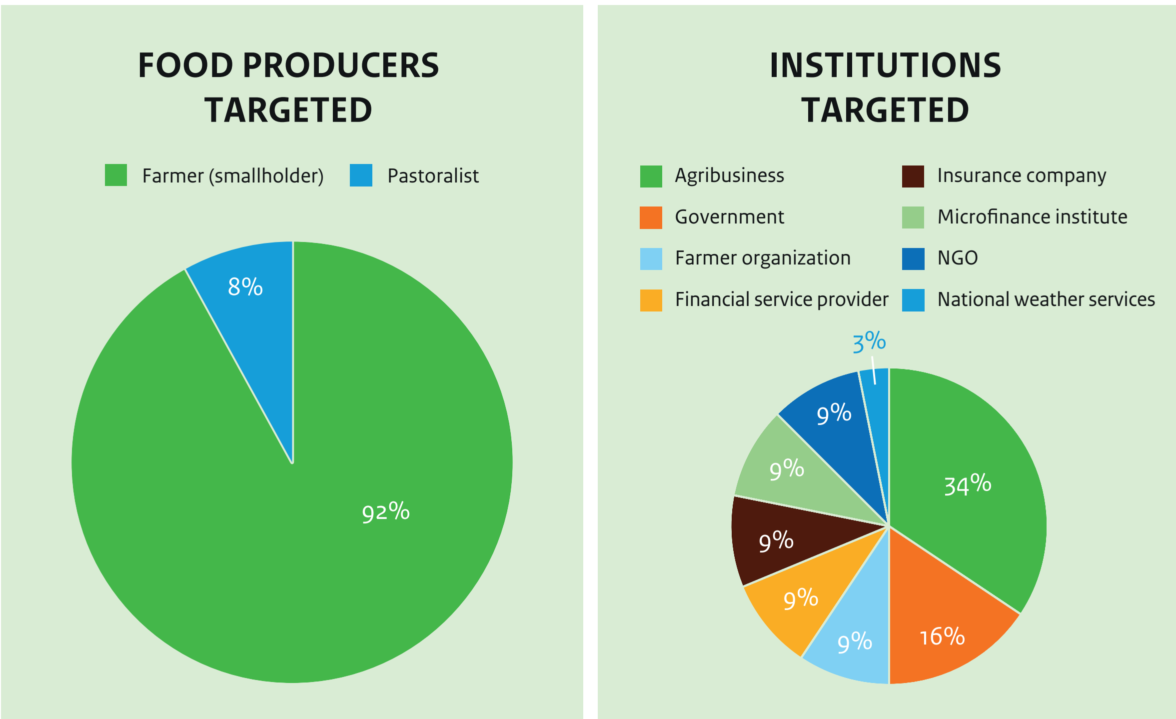
[39] Achterbosch, T.J., S. van Berkum and G.W. Meijerink, 2014. Cash crops and food security; Contributions to income, livelihood risk and agricultural innovation. Wageningen, LEI Wageningen UR (University & Research centre), LEI Report 2014-015, 57 pp.; 20 fig.; 3 tab.; 60 ref.

During the project, the partnerships generally tried different business models and have found which business models are deemed the most likely to succeed. Even the business models that have significant potential, are often not yet sustainably implemented. This takes more time, also to find the best partners for investment and scaling. Almost all projects apply a Business to Business (B2B) model. Projects that are still using a Business to Consumer (B2C) approach, such as STAMP and MODHEM, are also considering a move towards B2B.

This is because B2B provides higher and more stable income. A B2B model requires a business with interest in the smallholders and a CSR mindset aiming for impact on sustainable development goals. The interest of commercial parties is further based on the benefits that the services provide for themselves; this can range from qualitative benefits, such as increased customer retention, to simple quantitative benefits, such as increasing sales through a new marketing channel.

The majority of G4AW projects applies inclusive and/or service-focused business models (see box). The type of business (client) and the expected benefits that the service will provide to them will have an impact on sustainability; this can be seen both at service level (continuity) and environmental level (efficiency). If a business sees a service as a basic means to improve marketing and sell more product, the financial balance will likely be calculated on a short-term basis: if the product does not show clear and direct increase in sales, it might be dropped from the portfolio of the business. Moreover, more sales of certain products will likely be negative for the environment (depending on the baseline and the effectiveness of application). The focus and balance of the partnerships have generally ensured that environmental sustainability remained a key focus of the services.

Figure 7 Targeted groups (direct and indirectly) in the G4AW Facility



The different business models planned for and adopted by G4AW projects are:

- Direct pay: the customer pays for the service provided (on a subscription or case-by-case basis);
- Freemium model: free general service provision; clients pay for more advanced services, for a particular group of clients (e.g., large farmers, buyers), or finance operations (by paying for services or intelligence);
- Loyalty model: free service provision (as an add-on to another product or service) to avoid that clients switch to a competitor;
- Inclusive model: the service is bundled into a package with other services and sold as an integrated set (e.g., insurance coupled to credit, advice on good agricultural practice to input supplies);
- Service model: the customer pays a (subsidized) fee or no fee at all for service provision, and another stakeholder (government, CSR foundations of large corporations) accepts some or all of the costs.

Aggregators

The role of aggregators and business owners is very important. In order to be able to create a sustainable business model and reach 50,000 to 100,000 smallholders in a relatively short period (3-4 years), services must preferably be linked to businesses with a large established customer base with a clear demand for services. These companies can provide services in a cost-effective manner and easily target large numbers of possible clients. This has resulted in a focus towards large (finance/agribusiness) organizations, governments, and companies with a large service offering.

Figure 8 shows some of the aggregators that have been involved in different G4AW projects. These are companies that have been selected (either at the start or during the project) for their network and experience in providing services to smallholders. There is a large variation in organization types involved in Africa and Asia. In Asia, almost all aggregators are agribusinesses. These include businesses that operate at the national level (e.g. Lal Teer Seed, Angkor Green, Myanma Awba Group, Loc Troi Group, ACI), but also companies with a more international focus, such as Bayer, Verstegen and East West Seeds. Aggregators have been found in almost all projects in Asia.

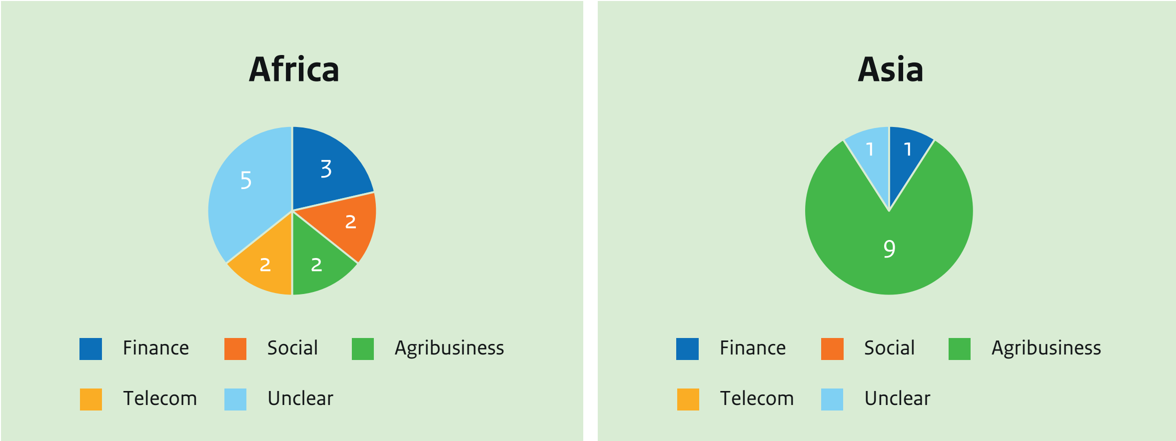
Even with the presence of a large number of potentially interested businesses, as is the case in Asia, finding a good match (with regard to sustainability of objectives and funding) is difficult. Larger companies generally already have inhouse marketing and farmer extension teams, and often already have some experience in using geodata. These companies are likely also targeted by a large number of competing service-providers, which means selling services to these companies is more competitive. Services need to show their usefulness and accuracy in short (trial) periods, and also need to be sold at competitive prices.

In Africa, the role of aggregator is often still not fully or adequately defined yet. The involvement of agribusinesses is limited, although the gap is partly filled by financial institutions, telecom providers and social enterprises. Involved financial (service) institutions include Kifiya (GIACIS), Equity Bank (CropMon), telecom providers include Orange (STAMP & MODHEM), insurance association (Sum-Africa) and involved social enterprises include AUXFIN (GAP4A).

These differences between the two regions indicate a less mature agricultural value chain in Africa, where agribusinesses do not yet have the means or position to distribute the created services to large target groups. The SIKIA project has reached out to over 400 agribusinesses involved in the rice value chain in Tanzania to use and sell the created services. While this is an impressive number, this also indicates a fragmentated ecosystem, in which companies are considerably smaller than their Asian counterparts. The smaller size of these companies makes it more difficult for them to invest in new (digital) technologies.

The main challenge is to find more interested aggregators in Africa (and Asia). This requires creation of a clear business proposition and partnership brokering. This will help partnerships create a sustainable business model and scale their service offerings. Technical assistance and/or business development will be supportive in this process. The role of technical assistance and/or business development will be discussed in the second lessons learned publication.

Figure 8 Type of aggregators in G4AW projects in Africa and Asia



Countries covered

G4AW focused on the list of developing and transitioning partner countries provided by the Netherlands Ministry of Foreign Affairs. For security reasons, three countries (Yemen, Afghanistan and the State of Palestine) were not included in the G4AW list. The G4AW country list was expanded in the second call with some neighbouring countries of the partner countries in the initial list. With this expanded list, projects could target multiple (bordering) countries, which made it possible to realistically aim to reach the targeted amount of food producers. This was especially relevant to reach some of the less populous countries on the list. Angola was added later based on a state visit.

Only two projects (Geodatics and Sum Africa) with a multi-country focus have been approved. While targeting multiple neighbouring countries has benefits for the creation of the satellite-related services (more cost-effective per area covered), the main challenge has been to create the business models. This has been one of the most challenging parts of the projects, and targeting more than one country also means more than one business model must be created. This is because the involved (local) partners and businesses will generally be different. The market readiness is also often quite different; this includes access to finance, ICT tools, but also farmer education and attitude towards new technologies.

Geographic balance (equal distribution of resources) was not taken into account in the first two G4AW calls. Approval of projects was based on the provided eligibility and assessment criteria alone. As three projects from Bangladesh were approved in the second call, the third call included a cap (for the entire G4AW Programme) on the number of projects per country to ensure resources remained evenly spread between the different partner countries. There was no need to enforce this geographic balance based on the proposals submitted in the third call.

Three quarters (19) of the 26 eligible countries are in Africa; the rest in Southeast Asia (6) and South America (1). Applications to the different calls have been in line with this balance: 72% was focused on African countries and 28% on Asia. In terms of approved projects, this balance shifts. Of the approved projects, 56% has been in Africa, while 44% has been in Asia. This shift was based on the quality of the applications (including partnerships and business model). This reflects the more mature market for such services in Asia: a survey (executed for NSO by Bopinc) in 2020 also showed that projects in Asia as such score higher for the entrepreneurial skills in their consortia.

Most eligible Asian countries have been targeted except for Laos. This is also the country with the lowest population amongst the G4AW countries. Regarding the security situation, some conflict countries were targeted (Mali, Burundi and Burkina Faso), while others (Niger and South Sudan) have not. This can be partly ascribed to the deterioration in the security situation in the targeted countries between 2013 and now. Other factors such as the network coverage, market readiness and the presence of NGOs also play an important role.

Successfully delivering services in high-conflict areas is of interest to organizations that focus on the social benefits. This includes NGOs and social enterprises. Providing alternatives to improve livelihoods and reduce conflict allows them to receive funding from (international) donors. This enables them to successfully scale services after the initial G4AW projects have ended. For example, the STAMP and MODHEM projects have been extended through additional funding from the Embassy of the Kingdom of The Netherlands in Mali and Burkina Faso.

The success of the projects depends on scale and sustainability. The obvious problem with low-income countries is that, while social and environmental benefits can be high, the ability and capacity to pay for services is low for the target group. This is due to a lack of disposable income, unclear benefits of the services, and limited financial access. Both of the transitioning countries (with upper middle income levels: Vietnam and South Africa) have been targeted. This was expected, as these countries meet most of the criteria for successful business development: stability, disposable income, high digital literacy and (emerging) smartphone access with good network coverage.

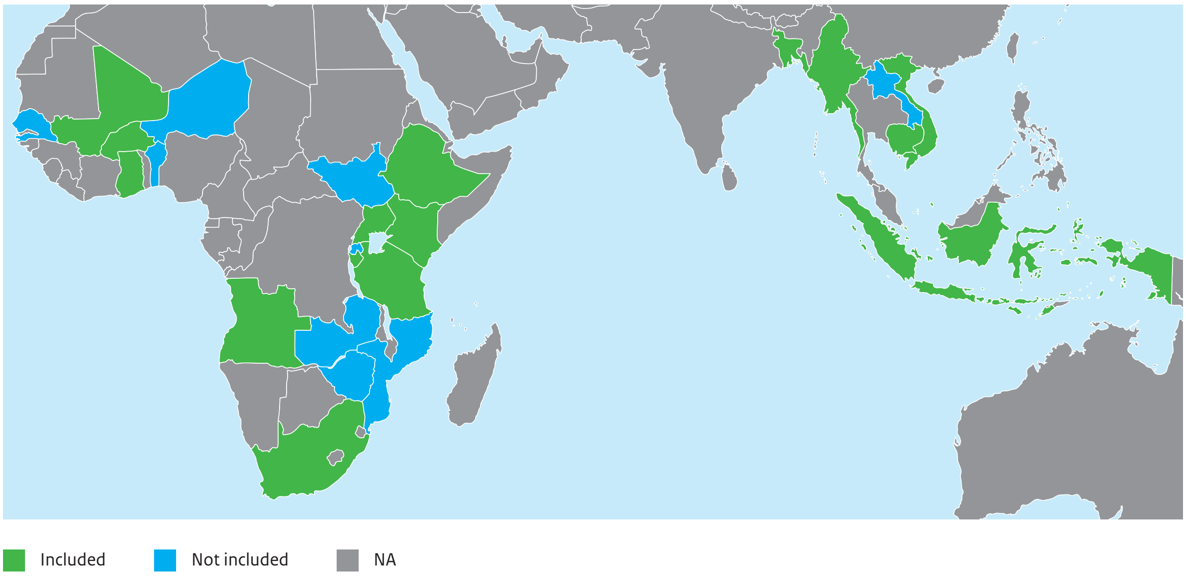
Finally, the only country which can be considered a large global player in the agtech domain that was included as a G4AW country is Indonesia (3 projects). This means that the focus of G4AW was often on countries that can be considered to have a relatively low market readiness for new agtech services. This includes limited access to smartphones, partial and <4G network coverage, and more.

Overall, G4AW has been successfully in opening new markets in countries where the agtech domain did not yet include digital advisory services for farmers. Opening new markets, however, is generally not the most rewarding stage for many of the businesses. A lot of effort is required to stimulate the enabling conditions and showcase the benefit of the proof-of-concepts. Continuing to support and stimulate the agtech markets in the targeted countries, by improving services and bundling with other services in the agtech domain, is likely to provide more benefits to the service providers involved than targeting new countries.

Service delivery methods

In the design of the services, the G4AW partnerships investigated which methods are most suitable to deliver the services to clients. Where possible, two-way communication has been incorporated. Two-way communication provides additional functionalities such as: farmer registration as input for farmer profiles, crowdsourcing of data for validation and calibration, customer feedback on services, and more. Generally speaking, two-way communication will also increase the value proposition towards potential impact investors.

Figure 9 G4AW countries covered and not covered by different projects



Teaching G50 coaches using AgriCoach in Burundi ©Auxfin International/Gap4A Burundi

The service delivery methods used in the G4AW Facility projects converge from a wide range of channels: mostly USSD/SMS messages (dominant in Africa) and mobile apps (dominant in SE Asia), supported by call centres and/or a web portal. Radio, television and social media usage (Facebook, Whatsapp) is mostly used for service promotion and information purposes. Social media is used for several projects in Southeast Asia because of higher feature phone penetration. Africa still relies on more 'traditional' technologies for service delivery.

It is observed that traditional face-to-face contact also remains critical; clients will have more trust in the service provision when there is a possibility to have personal interaction. Agricultural extension officers are very important to promote the services and build trust. In 67% of G4AW projects, extension officers are involved in service provision and/or promotion (see further on). The selected delivery method has implications for most aspects of the service. Table 2 provides an overview of user-oriented functions that are supported by a specific service delivery channel.

The nature of geodata makes it most suitable for mobile apps or other high-tech delivery methods. This enables users to access data on demand. Other reasons why smartphones are often preferred over advice provided through simple mobile phones include the ability to add specific service functionalities, such as:

- providing advice for multiple plots/crops in a single app;
- allowing interactive two-way communication (chat-functions);
- embedding map viewers to show local variation (GIS);
- embedding videos with agronomic advice; and
- creating more advanced features, such as an online marketplace.

There is also an aspect of digital inclusion that needs to be taken into account when selecting the most suitable service delivery method. There is still a gender gap in the use of smartphones[40]. On the other hand, the impact (reach) of mass media such as radio and TV, which are more suitable to target women farmers, is difficult to monitor. The benefit of radio is its affordability and ability to reach multiple users at the same time.

[40] GSMA. 2020. Connected Women: The Mobile Gender Gap Report 2020.

Table 2 Functions of ICT tools, adapted from: Saravan et al (2015) [41]

Functions	Technologies										
	TV		Radio		Basic mobile phones*		Smartphone**				
	Broadcast	Video	Broadcast	Community Radio	Text	Voice	Video	Websites	Apps	Social media	Video call
Awareness creation	5	3	5	5	1	1	5	3	5	5	1
Personal/local advisory	3	3	3	5	3	5	3	3	5	5	3
Mass advisory	5	2	5	5	3	0	1	3	5	5	0
Knowledge sharing	5	5	3	3	3	3	3	5	5	5	1
Technology transfer	5	5	3	5	0	0	5	5	3	5	0
Training	0	3	0	0	0	0	3	0	0	0	5
Facilitate market access	0	0	1	3	5	1	0	3	5	5	0
Financial access	0	0	0	0	5	0	0	3	5	5	0
Business planning	0	0	0	0	0	0	0	0	3	0	0
Monitoring & evaluation	0	0	0	0	3	0	0	5	5	0	0
Collect and respond to farmers feedback	0	0	0	5	0	5	0	5	5	5	3
Linking and partnerships	0	0	0	5	1	0	0	5	1	5	0
Average score	1,9	1,8	1,7	3	1,8	1,3	1,7	3,3	3,9	3,8	1,1

* *Basic mobile phones are assumed to have no internet connectivity*
** *Smartphones are assumed to have internet connectivity. Other internet-enabled devices (laptops and tablets) fulfil similar functions, although these are especially suitable for services that require a larger screen – such as videos).*

However, it has to be taken into account that different user groups listen to radio or watch TV at different times of day. Understanding the different schedules of specific target groups can help to tailor the messages (e.g. with gender differentiated programming[42]). Over one-third of G4AW projects use radio and/or TV to deliver part of the services; radio and TV are used to create interest and reach a large audience.

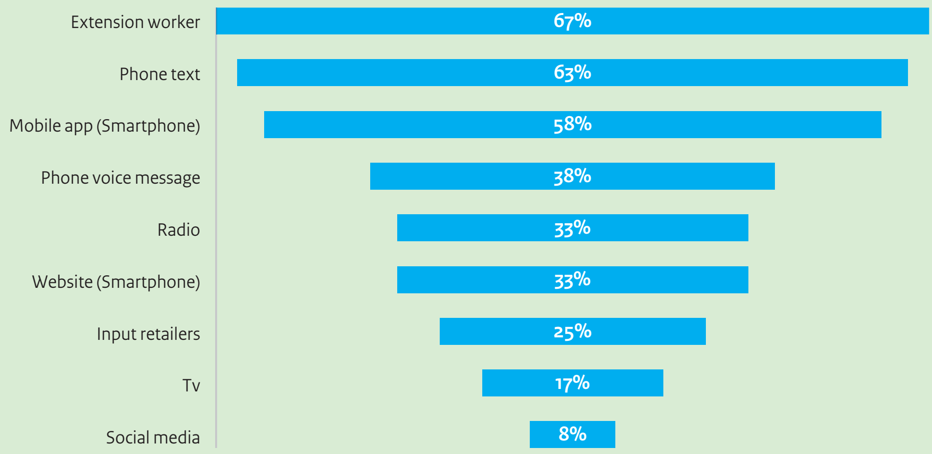
Table 2 shows a set of technologies with a score indicating their expected suitability to fulfil several functions required to provide services and create a sustainable business. While some technologies can fulfil quite similar functions (e.g., voice vs video call), these can be used for different applications. A voice call will require low data/costs, but cannot be used by extension workers to provide visual advice on how to do certain farming activities.

The table shows that especially the smartphones can provide almost all services required to provide digital agricultural advice. Community radio also provides a lot of useful functions, although this is especially relevant at the level of the community and not to provide personal advice. Basic mobile phones can provide many functions at a good level, but are also limited for certain important functions. These include increasing awareness, mass advisory, technology transfer, training, and business planning. SMS surveys can be used to receive information that can be used for monitoring and evaluation.

Especially the lack to transfer technology and train farmers (e.g. videos with advice), means that extension officers are still required when using basic mobile phones. This make it less suitable to provide the full set of service in periods when field visits are difficult (e.g. related to conflicts and pandemics). Most G4AW

[41] Saravanan, R., Sulaiman, R., Davis, K. and Suchiradipta, B. 2015. Navigating ICTs for Extension and Advisory Services. GFRAS Good Practice Note for Extension and Advisory services.
[42] https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/5096.pdf

Figure 10 Service delivery methods used in the G4AW projects

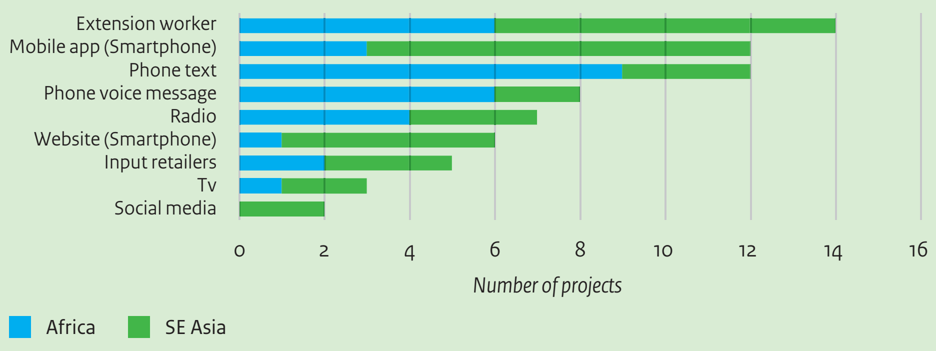


projects have found that a blended approach works best. This allows them to use the most cost-effective and scalable approach for each function that is required in the different stages of the project and follow-up.

Figure 10 shows the different service delivery methods that are used in the projects. On average, 3 to 4 different methods are used per project. Two-thirds of projects actively use extension workers to deliver a part of the services.

The more complex delivery methods such as apps provide more flexibility to add components requested by users and/or businesses. This included adding a chat function in SMARTseeds, and a new 'marketplace' service in SpiceUp and SMARTseeds. Adding these services in 2020 was partly based on the difficulties that farmers faced due to COVID-19 restrictions to 1) contact their known extension officers; and 2) sell their products on local markets. Apps can quickly be extended to fill some of the gaps that have emerged. The main limitation of apps, is that they require a different level of connectivity (4G), which might be limited in some areas (especially in African countries).

Figure 11 Service delivery methods in different regions



Role of geodata

Earth observation

All projects have clarified the intended role of satellite data with respect to proposed service provisions. This was part of the project proposals. During project execution, substantial deviations were observed in the selection of the sensors. This was often due to better insights into user needs and/or unsuitability of the planned sensor for its purpose in the service delivery. Some sensors were only used for validation purposes in the development phase and are not required for the operational phase. Table 3 shows the sensors that have been provided in the proposal vs. the sensors used in the operational products.

As previously discussed, weather information is one of the most developed services and is the key selling service in most products. Geo-stationary and polar-orbiting satellites are intrinsically linked to the provisioning of weather forecasts, but are part of a larger ecosystem of infrastructure (satellites, ground stations, high performance computing), data assimilation and weather forecast models. The relatively coarse resolution (depending on the region) is generally not an issue for most uses, although improvements in accuracy (reliability) are highly valued by farmers to improve their decision making process.

Sensors such as MODIS (250x250 metres) and Sentinel 2 (10x10 metres) are not only used to derive parameters such as NDVI, but also serve as input in the SEBAL model[43] and ISRIC SoilGrids[44] . Due to its role in a wide range of products (linked to its long history, daily revisits and operational stability), data derived from the MODIS sensor is likely the most used optical data in G4AW. The normalized difference vegetation index (NDVI) is still the most used vegetation related indicator in the different G4AW projects. Where improved resolution was required over the 250m MODIS resolution, some services used Sentinel 2 data, while others use Landsat 7/8 (30 x 30 metres) or Spot-VGT/PROBA-V (100 x 100 metres).

Table 3 Satellite (sensors) used in the G4AW projects

Sensor type	Sensor name	Number in proposal	Number in operational service
Optical	MODIS	16	12
Optical	Landsat 7/8	14	5
Radar (active)	Sentinel 1	14	11
Optical	Sentinel 2	14	14
Optical	PROBA-V	4	2
Optical	VHR	4	3
Radar (passive)	SMAP	3	2
Radar (active)	TerraSAR-X	3	1
Radar (active)	ALOS PALSAR	2	-
Radar (passive)	AMSR	2	2
Various	Sentinel 3	2	-
Radar (passive)	SMOS	2	2
Optical	VIIRS	2	1
Various	Envisat	1	-

** Weather-focused satellite data is not included, as limited information is available on which sensors have been used. Data from the SRTM mission is also excluded from this overview, as not all projects have specified the use, while many projects have used directly or indirectly derived products such as the Digital Elevation Model (SRTM-DEM). Different sources of Very High Resolution data are grouped as one type of sensor (VHR), all of which provide <5m optical data (if projects proposed several alternative VHR sensors, VHR data is only assigned once to a project).*

[43] Kiptala, J. K., Mohamed, Y., Mul, M. L., and Van der Zaag, P. (2013), Mapping evapotranspiration trends using MODIS and SEBAL model in a data scarce and heterogeneous landscape in Eastern Africa, Water Resour. Res., 49, 8495– 8510, doi:10.1002/2013WR014240

[44] Hengl T, Mendes de Jesus J, Heuvelink GBM, Ruiperez Gonzalez M, Kilibarda M, et al. (2017) SoilGrids250m: Global gridded soil information based on machine learning. PLOS ONE 12(2): e0169748. https://doi.org/10.1371/journal.pone.0169748

The main restriction to the use of optical sensors is the risk of reduced service quality in areas with many cloudy days. In dry and semi-arid areas optical data might be sufficient, but especially in mountainous and more humid areas, the use of radar data (passive, active) is essential, as cloud cover is a problem. With respect to the use of (active) radar data, Sentinel 1 is clearly preferred above other radar sensors such as TerraSAR-X and ALOS PALSAR. TerraSAR-X has a high resolution but is not free of charge, which limits its usage to validation only.

ALOS PALSAR sensor (L-band) is very suitable for applications related to monitoring of forest and wetlands. This means less imagery is available for agricultural areas, and spatial and temporal resolution have been limiting to its uptake. Another reason why this data is not used in the operational products is its cost (commercial prices) and the lack of long-term operating guarantees (Sentinel-1 is guaranteed by ESA for 20 years). These are some of the key aspects that service providers take into account:

- Spatial resolution of data
- Temporal resolution of data
- Guaranteed life span of the mission
- Costs of the data
- Experience with the data

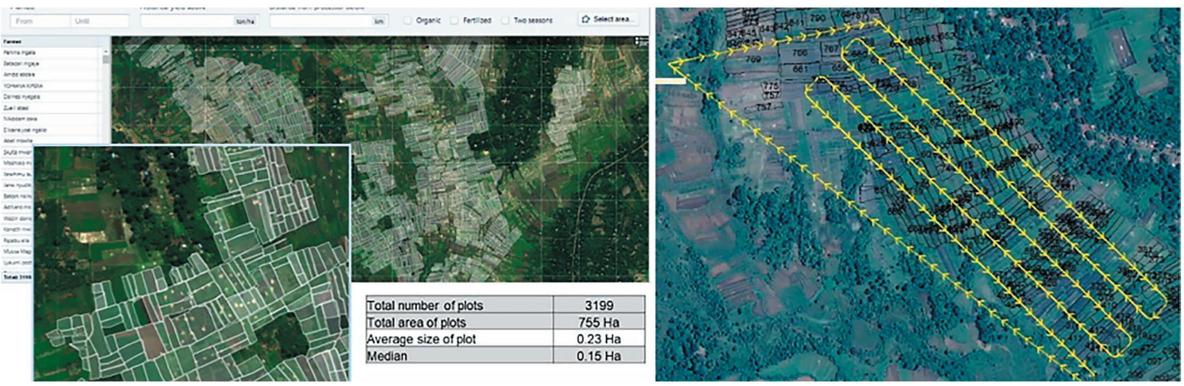
Overall, the use of different sensors has been lower in the operational products than foreseen in the proposal. Clearly, the usage of Landsat turned out much lower, most likely Sentinel 2 has proven it added value in terms of a better resolution and higher availability (due to an improved revisit period). Also, fewer sensors (e.g. VHR) have been used for validation. Reducing the amount of different satellite data streams also reduces operational costs, which has been a very important aspect of creating the sustainable business models in the short term. In the long term, these additional (commercial) sensors might be added again, based on the added value.

Geolocation

Geolocation is often used for locating farmers and their farm plots. Such data is needed for various purposes: localized weather forecast, localized advisories, plot-specific advisories, harvest yields and efficiencies, financial services (credits, insurance). Geo-locations of a farm(er) and farm plots can be measured using mobile phones and specific handheld devices (receivers) that are connected to Global Navigation Satellite Systems. Farmers or local staff can use these devices to create digital outlines of their plots, by walking around the borders while pressing buttons on these receivers. This process is crucial in services that provide plot-level monitoring of crops, as the insights will only be based on data within the plot. Also, when using other remote-sensed data, such as from drones, having accurate insights into the location of plots is crucial in the planning of the flight lines (see figure 12).

Efficient use of GNSS devices requires experience. Organizations with this experience have either provided advice to projects or have been involved in the actual mapping activities. The Netherlands' Cadastre, Land Registry and Mapping Agency (Kadaster) played an advisory role in SIKIA, while AKVO has supported these activities in several of the projects in which they have been involved in Asia. The process of creating plot delineation is

Figure 12 Using plot delineation to plan flight lines for the use of drones in the SIKIA project



Sentinel 2 ©ESA/ATG medialab

often combined with a farmer survey to understand more about the farmers and the crops that are cultivated on the plots (farmer profiling). This results in efficient use of time when working in the field.

Supporting geodata

Satellite data is often supported by *in situ* data. The strength of satellite data is its relatively low costs to create insights for large areas that can be repeated at weekly intervals or with a higher frequency. Satellite data often has to be combined with *in situ* data to move from basic spectral information (such as indices) to variables that are useful in advice to food producers. Types of measurements that often support (or are supported by) satellite data include soil (moisture) data and parameters measured by weather stations.

In the case of soil data, local samples can be scaled from point-based observations to grid-covering insights using geostatistics. The ideal sensors to do this are hyperspectral sensors, as the large number of bands can give more detail about the conditions in the soil (incl. mineral content). The high number of bands is also useful for (machine-learning) algorithms that can be used in geostatistics. Hyperspectral data with a useful resolution and revisit time is generally still too expensive for use in services for smallholders.

In the case of weather services, data from local weather stations can be used to improve weather information. Ground-based sensors can be used to validate the models, and improve understanding of local climates. Weather Impact, partner in various G4AW projects, has used data from local sensors to improve weather data using crowdsourcing. Ideally, officially calibrated ground weather stations are used to evaluate the quality of weather forecasts. However, throughout most of Sub-Saharan Africa, trustworthy and continuous ground data is scarce. Therefore, Weather Impact and AUXFIN decided to set up a crowdsourced rainfall observation network of over 400 rain meters in the Gap4All project in Burundi.

Other data

Active involvement of farmers can very useful, as discussed in previous sections, for specific types of geodata. Farmers can also provide additional data that is needed to improve the accuracy of the services. Typically, such data include seed type, crop type, sowing date, crop stage, harvest date, as well as use of fertilizers and pesticides, and market prices. In models where remote sensing data and crop growth models are linked (data assimilation), farmer feedback is crucial. This will serve as the basis to run the crop growth model, which is kept in line with the satellite data.

Such data is also useful for monitoring and evaluation purposes, and might be turned into business intelligence that can generate revenues from B2B service provision. This data, combined with satellite monitoring, can be used to better predict crop harvest (including expected yield and harvest dates) over a larger area. This is interesting for commercial companies for logistics planning (transport, plant capacity) and marketing purposes.

Data platforms

Data processing and integration platforms are an important part of the created services. Companies that specialize in data integration (database creation, efficient storage, cloud-based grid analyses and fast and stable access through API) have become more important over the course of the G4AW Programme. Operational aspects (uptime and response time) are key elements of a successful product. Operational support is also often provided at the level of these platforms, as these companies have a good overview of the different data flows included in the services. Companies that focus on data integration are often the intermediate between the value-adding companies and local service provider.

Involved G4AW partners rely on a mixture of own developed systems and commercial cloud processing systems such as Amazon Web Services (AWS), Google Cloud Computing Services, Microsoft Azure, SAP Hana. These larger cloud processing systems play a role in many projects, but this will not be discussed in detail.

Specialized platforms that have been used in the different G4AW projects vary between Dutch-based and local solutions. In most cases, the role of platform creator/host was already assigned to one of the initial consortium members, while in some projects, this role was not included and the required software development was done by third parties. Six of the G4AW projects have worked with the Lizard platform (Nelen & Schuurmans), while another Dutch solution included in various projects is HydroNet, developed by HydroLogic.

However, in most cases, local platform solutions were created/provided by local service providers. This was a role that was assigned at the beginning of the project. This included platforms such as Apposit, Ensibuuko, Kifiya, Manobi, mPower and Village Link. In some projects, this was a role that emerged later in the project, linked to the selection of a suitable local business owner that would play a role in scaling. In at least one project, the creator of the platform also took the role of project lead (ImpactTerra in SAM). The necessity of having local service providers and local platforms is also driven by national data policies.

Operational and maintenance costs largely depend on the entity that runs the platform. If the fees charged are too high, the service will be unsustainable. While the business owners frequently decide to reduce the amount of commercial satellite data in the products to save costs, the data platforms will remain a central component in the services, as these combine all data flows, presenting these in an accessible format to the front-ends used in the products. Switching between data platforms is also a difficult step, as this requires recreating all data flows, which can be a time-consuming and expensive exercise. Switching platforms also creates the risk of reduced service performance, which can lead to loss of customers.

Platform selection is therefore an important process, which includes taking into account the technical capacities, adherence to the applicable legal framework, costs, sustainability, and more. Large global platforms can provide the required processing, storage, and access (API) at relatively low costs, but often lack the flexibility to add supplementary datasets and features, and also the specific (agro) knowledge required to provide support in the use of these services. This is why smaller platforms continue to play an important role.

Data policies

A relatively new challenge in G4AW service development was presented by stricter laws focused on data sovereignty and (upcoming) data protection legislation. Many of the data platforms do not only integrate remote sensing data, but also include data related to the location, size and crops grown in different plots. As soon as information related to individuals or assets in a certain country is used and/or stored on a platform, the legal framework must be carefully considered. Many countries have started to realize that the transfer of information related to their citizens could be challenging in terms of privacy laws at different levels. Regulations often require data to remain physically stored inside the country. Local solutions (servers) are increasingly desired, as the frequently used (international) cloud solutions are difficult to place within the national IT infrastructure.

Various partnerships have had to consider a changing regulatory framework relating to data (both in Asia and in Africa), although none have faced serious limitations due to these data policies. The local partners in the partnerships were often aware of plans for new regulations, which enabled the partnerships to create a data ecosystem that would be able to meet both existing and forthcoming policies. These data policies were often drafted with the role of large global tech players in mind, which made them less relevant to the smaller tech companies involved in the G4AW Programme.

Product-market fit

An important aspect in the design trajectory is a consideration of the product-market fit. A good product-market fit means that a product is in a suitable market, with services that satisfy the needs of the market. Whether a product can find the right market fit depends on several issues, such as: a) the added value of the product compared to existing products; b) acceptance by the customer; c) the price and quality of the services provided; d) the entrepreneurial competences of the business owner; and e) the size of the market.

The size of the market is not only based on the number of smallholders that could potentially benefit from a service, but also on these smallholders' willingness and capacity to pay. Capacity to pay depends on issues such as financial access and disposable income, while willingness to pay is influenced by product quality, availability of (free) alternatives and the opinion of customers regarding who is responsible (and thus should pay) for these services. The product-market fit determines the success of design and development of the services.

The G4AW services have reached many smallholders, and most of them have been satisfied with the services. The main challenge is to get sufficient paid and returning customers to create a sustainable business. Increasing the willingness to pay by small-scale food producers has been a key challenge in almost all G4AW projects. Some of the most successful services provide relatively general information, such as Good Agricultural Practices and crop management advice based on weather information. Such information is easily shared between many farmers, and in several countries, similar services are being offered for free in the market. Many of these services come from donor-supported projects. This means that demonstrating (and improving) the added value of the G4AW services will be extremely important for any service to gain and retain customers in the long term.

G4AW Partnerships have aimed to improve the willingness to pay by either changing the market (e.g. targeting more groups, considering scaling to other countries), or the product (bundling of services to be able to satisfy the demand of more farmers). The increase in the number of services provided in each product is a clear sign of the dynamics in the product development. Bundles are not only created with similar service groups (e.g. bundle nutrient advice with weather forecasts), but also with other services groups both within and outside of the agricultural value chain. This includes bundles that include insurance, access to finance, market insights, health information, and more. More information on the approaches that partnerships have taken to effectively market products to smallholders by changing business models and other approaches are discussed in the second report on lessons learned.

Project legacies

G4AW has continued its aim to reach new markets, and has seen many of the most promising developments being taken over by other organizations or by the market. This is the case for satellite-based products focused on crop-index insurance and financial inclusion. These markets have clearly become more mature during the timespan of G4AW. The agribusiness market is still more challenging, as creation of the services (especially plot-level insights) and sustainable business models are more complex: they require crop-specific research and models and plot-level satellite-based insights. Some of the legacies of the G4AW projects concerning different target groups and services are discussed in this section.

Pastoralists

The two services developed for pastoralists have been successful, and further development and scaling is ongoing. The projects have been successful in reaching a hard-to-reach target group in low-income countries with frequent security issues. The success is based on the social benefits of these services, as these help in reducing conflict (caused by pastoralists moving with herds through cropland) and provide simple and useful services. These include weather information, closest locations with water and/or pastures, and market information.

The services are relevant in the day-to-day activities and decision making of pastoralists. More development activities are planned, including services based on financial inclusion and building a marketplace for the dairy products. These services have some key ingredients that make them work:

- Clear added value for pastoralists (as evidenced by high customer satisfaction)
- Ability to reach pastoralists in areas where other activities (face-to-face) in the field are limited due to security concerns.

- Interest from large NGOs and the clear societal benefits (reducing conflict).
- Involvement of a large aggregator (telecom provider) that can easily reach thousands of customers and provide services and support at low costs.
- Low-cost geodata services, which is based on open source developments: products are created on a consultancy basis, and all results are open to reproduction by the business owner. This results in very low operational costs for the products.

***Conclusion**:* the product-market fit is based on the societal benefits that the products provide. This works through the involvement of NGOs, and a lean operational process (reduced costs by working with open data and a large telecom provider).

Crop insurance products

Most of the insurance-related products from G4AW projects have been successful. Success is based on the clear business proposition: it provides food producers with the ability to access insurance, and it helps the insurance companies to sell more insurance products and reduce the operational costs (transparent system with limited need to conduct additional verification in the field). The ability for farmers to insure their crops will also increase income security and help to increase investments in the farm. Generally speaking, risk aversion is one of the key reasons for farmers not to invest in new inputs and mechanization.

Crop insurance will also provide clear societal benefits, as it increases food security. For this reason, countries have been eager to support crop insurance activities, and in some countries, government institutions are actively promoting these services, some even granting a subsidy on the crop insurance premium (in Uganda, 50%).

Farmer in Cambodia ©ICCO/Angkor Salad project

Many different approaches exist in which remote sensing plays a key role. This includes data related to evaporation, soil moisture, extreme events, and more. This is a rapidly emerging market which can be easily scaled to new regions. The customer can choose from different products. There is sufficient competition, which means the products are becoming more affordable.

The basis risk (potential difference between the loss incurred by farmers and the pay-out triggered by the index) is still a concern in index insurance products, limiting the uptake of insurance products in low-income countries[45]. Still, benefits outweigh the costs in most programs based on index insurance.

> ***Conclusion**:* There is a clear product-market fit for remote-sensing based crop index insurance. Some minor challenges exist, such as the level of the basis risk, but products are rapidly being scaled to different regions. Many service providers exist that offer similar services, which results in sufficient competition to push affordable services. In some countries, the governmental framework is not yet ready to provide crop insurance (no legislation, no experience), which has been restrictive to the scaling of some of the G4AW services.

Weather information

Weather forecasts and other weather information is considered very relevant, and has become the key selling service in around one-third of the created products. Weather forecasts are input in many of the decisions farmers make, but do not need to be accurate at the plot level. This means that one central service is the key driver of a number of more specific services (sowing date, nutrient application, pest and disease warning, and more).

This makes it easy to reach many different farmers, as weather information is not necessarily specific to certain crops and farming systems. Reaching 100,000 farmers is easiest when focusing on weather information, although the key benefits are also the main weakness: the nature of the data make it easily shared between farmers. The CROPMON project found that weather information is widely shared within the community. This has clear implications for the business model, which often had to be adjusted for projects that used weather information as one of the key selling services.

Weather information is available from multiple sources, and includes free data. Many users also see weather information provisioning primarily as a government service. This means that the business owners need to clarify the benefits of their service compared with open alternatives. The quote below provide some insights into the relevant challenges.

> *"We could use open weather data that is free, but because this is not as localized, we may not be able to generate very local advice to a specific farm."*
>
> **R4A, South Africa**

This shows that services focused on weather data need to show clear benefits of the service in terms of local reliability. This means that additional investments have to be made to include local weather stations to validate and improve the predictions. Making farmers understand the benefits compared to free alternatives relies on services being easily accessible in the beginning of the service provisioning (low costs). This allows farmers to compare the different data sources, and hopefully convince many to pay a small fee. The challenge of sharing data remains, but the potential target group includes all smallholders.

> ***Conclusion:*** Weather information is the key selling point in many G4AW services. The product is mature and in high demand. The main challenge is extensive competition, including the availability of free alternatives. Standing out in this market requires businesses to: a) show why their service is better than alternatives; and/or b) provide this service as part of a larger bundle of relevant services. If this can be done, products will be sold (although not directly to consumers). Other challenges are the fact that weather information is easily shared, and users often see it as information that should be provided for free by the government.

Crop monitoring and irrigation advice

Crop monitoring and irrigation advice is considered very useful by smallholders. However, smallholder farming often involves (very) small plots and intercropping. Vegetables have been particularly difficult to monitor with satellite data, as these require specific farming practices (sowing on multiple days, intercropping, etc.). Plot specific

[45] A global review of the impact of basis risk on the functioning of and demand for index insurance - ScienceDirect

crop monitoring and irrigation advices often requires use of very high resolution imagery. This is (too) costly for smallholder farmers. Other challenges that emerge for vegetables is the diversity within the cultivated crops (different varieties) and in planting dates. These crops are also often not marketed, which means they provide little disposable income that can be invested in digital services.

For this reason, plot-level crop monitoring is often focused on staple crops (rice, maize, potato, wheat, sorghum, millet). Crop monitoring over large areas provides intelligence for businesses (e.g. logistics, expected yields, market prices) and food security (e.g. expected yields, yield gaps, food shortages). Several global initiatives are addressing food security, e.g. FAO initiatives Hand-in-hand and WaPOR, WFP HungerMap, GEOGLAM CropMonitor, NASA FEWSNET.

There is a clear trade-off between scale and local accuracy. Global initiatives generally provide few insights that are relevant to smallholders. While these global and national initiatives are useful for policy makers and traders, providing services to smallholders will be difficult with these datasets. Even with the relative high accuracy of current crop classification algoriths, everything below 100% certainty can result in unsatisfied farmers that receive incorrect advice. This means farmers will have to provide information on the crop they cultivate (and when) in order to get useful advice related to plot-level crop monitoring.

Crop monitoring and irrigation services for large scale commercial farms are an established market, especially in the countries where plots are large. There is also a clear role for IoT-enabled sensors (e.g., soil moisture sensors) in these services. Satellites can be used to capture data from these sensors in remote areas and process these in the provided services. The challenge remains to introduce such services to smallholders in developing and emerging countries.

Conclusion: Crop monitoring in G4AW had mixed success. In some cases, a clear product-market fit exists (for instance, monitoring of rice and maize), but for many other crops, the products are not yet ready. Yet, crop monitoring can be key in closing the business case for service delivery to smallholder farmers when businesses become paying clients or become a partner in service delivery, as showcased by various G4AW partnerships (e.g. SpiceUp, SMARTseeds, Geobis).

Good Agricultural Practices

Good Agricultural Practices are very useful, and GAP is one of the services that can provide clear improvement to the efficiency of input use. This service can contribute to the overall objectives of G4AW to reduce the use of inputs. The main challenge to these products is to find a suitable market, as GAP in general is not the ideal tool (for businesses) to increase sales. The main benefit of GAP is that it provides farmers with the basics to improve farming. If a fertilizer company provides GAP as part of their services, this helps to improve the effectiveness of their products and will result in greater customer loyalty.

One downside to digital-based GAP is that farmers often need to see new things before they believe it works (seeing is believing). GAP is traditionally provided by extension workers and is linked to the use of demo plots. SMARTseeds has aimed to solve this concern by adding a chat box to the service, allowing farmers to submit questions to the extension workers that they already know and trust. Other solutions to provide GAP without need for field visits is by providing videos or allowing farmers to make video calls. These are all solutions that require internet enabled devices.

For this reason, GAP is still mainly provided by extension workers in Africa. There are some G4AW projects in Africa that provide videos (e.g. GAP4A), but these also focus on creating groups of farmers and providing these with a tablet device. This enables smallholders to access the internet and view videos on relevant GAP for their crops.

Conclusion: GAP is a useful service, but not ideal as digital-only. This requires linking to agricultural extension workers. For businesses, the benefits of providing GAP are mainly increasing customer satisfaction and thereby customer loyalty. For this reason, GAP is mainly used as an add-on to existing services. The same accounts for market price services; these are also provided as an add-on to increase customer satisfaction.

Financial services

Financial services mainly focus on providing financial access to farmers, to give them more means to invest in their farming activities. This is a very different route compared to the way in which agribusinesses aim to increase food production. The latter is more direct, and


Farmer in Bangladesh ©Lal Teer Seed Limited/GEOBIS project

focuses on directly improving the farming activities, while financial services focus on the underlying framework that supports farming. Services provided to smallholder food producers generally require a certain level of financial access on the part of the users, as this will enable them to purchase new products. This is the reason why more services focused on the agri-sector and pastoralists are now also aiming to include financial services. More information on financial services will be provided in a next publication of this lessons learned series.

Conclusion: Financial services have been included in several G4AW projects, but have not been the primary focus of G4AW as its outcome and impact is more indirect. There is a clear business proposition and a rapidly maturing product-market fit. Different G4AW partnerships aim to include financial services in their current offerings to increase their users' ability to purchase more inputs to improve their farming activities.

Way forward

The experiences presented show that there are sufficient services that can benefit smallholders in the different countries and production systems. There are some clear limitations of using certain service delivery methods (e.g. basic phone) to reach individual farmers, but grouping farmers and providing them with the required ICT tools has proven to be a successful solution. Some challenges remain, such as the difficulty to provide crop/plot specific advice for crops that are less researched and marketed. The next section provides a set of recommendations to improve the design and relevance of the type of digital agricultural advisory services that have been created in the G4AW Programme.

Recommendations for service development

G4AW Facility started in 2013 with a vision how the use of new technologies (increased capacity and continuity in satellite monitoring and mobile connectivity) could support bottom-of-the-pyramid food producers. Based on stakeholder consultation, the G4AW grant programme was designed with the objective that during project implementation, the focus of the activities would become business-oriented, leading ultimately to financially sustainable service provision.

The G4AW Facility has been a clear front runner in supporting satellite-based services to smallholder food producers. It came a bit too early to fully exploit the potential of the Copernicus Programme and recent developments in using AI or machine learning on this data. In a next publication of this lessons learned series, we will dive more into the subject of partnerships and entrepreneurship.

Based on our learnings in G4AW Facility, we have come to a number of recommendations that could be considered by other (grant) organizations when designing a grant programme, and for service development for smallholder food producers in general.

1. ***User-centred approach***: For a new grant programme, consider adapting the project setup to a two-stage approach, such as a one-year plus three-year structure, in which the first year is used for assessment of user needs, exploring possible solutions with the users, and attracting the necessary additional (service and/or technology) partners. This provides a better understanding of the user needs and can be used to build a consortium based on user needs and the experience of partners.

2. ***Digital inclusion***: An important aspect related to digital inclusion is to develop a better understanding of the current uptake of digital advisory services. A lot of data is shared within households and the local communities, while monitoring is often mainly focused on the primary (registered) user. Strategies to promote digital inclusion should be based on a robust monitoring and evaluation framework that provides insights into the actual reach and (continuing) use rather than on registrations.

3. ***Weather***: Food producers have a need for local, accurate and affordable weather information and forecasts. Many agro-advisory services and even financial services are fuelled by weather data and/or forecasts. In many countries, the capacity of Meteorological Offices can be strengthened, and is often the target of donor-funded projects (grant or loan). In the design and inception of such projects, the need for free (or affordable) and accessible (open API) localized weather data for smallholder food producers should be taken into account. Cooperation with initiatives such as TAHMO might also be explored. This enables a combination of free satellite data with low-cost ground stations to create accurate weather services for smallholders.

4. ***Crops***: The G4AW projects have mainly focused on well-researched staple crops and cash crops. This is because the projects did not include a research component and thus had to be developed based on existing research. Ensuring an adequate focus on the different crops that provide farmers and agro-ecosystems with the necessary diversity requires improving research of remote-sensing for more diverse agro-ecosystems. Supporting the creation of an adequate research base for a wider range of crops can promote diversity in the focus of services. This gives partnerships a lower level of entry for providing services relating to crops other than the standard staple and/or cash crops.

5. ***Soils***: Many G4AW projects have focused on providing nutrient advice and have often used soil samples as basis. The actual approaches have been very different. Promoting a more harmonized use of soil data and existing nutrient models in such innovations, and focusing on using remote-sensing data to create a proxy for the nutrient status of soils, can result in improved use of satellite data as a basis for fertilizer recommendations. A trade-off with expected procurement costs for the use of VHR satellite data should be part of the analysis.

6. ***Water***: The FAO WaPOR initiative has provided a wealth of useful information regarding water productivity and related parameters in Africa and Middle East. New developments in WaPOR could potentially increase the use of the data in advisory services. Considering use of existing and free datasets, such as WaPOR, can help reduce costs incurred when creating digital advisory services. Use of satellite data, including WaPOR, should also be considered in the mapping of soil salinization in developing countries; this is becoming an important driver of land degradation. Using remote sensing to detect suitability of areas for certain water-saving technologies (e.g. alternate wetting and drying for rice) can furthermore provide the dual benefits of reducing water consumption and lowering emissions of greenhouse gasses.

7. ***Climate***: The focus on climate change has mainly been on adaptation, by enabling farmers to take out insurance independently, or find more suitable crops/varieties. Promoting a focus on the full extent of climate-smart agriculture, including mitigation (such as carbon sequestration), can improve the impact of digital services on reducing the impact of climate change and could strengthen the business case. Payments for relevant ecosystem services, such as carbon sequestration by smallholders, fall outside the scope of most traditional (agri) markets, but can be added to services to receive additional support from international donors, financial institutions and environmental agencies.

8. ***Service delivery***: It is important to ensure services are created in a way in which they can easily be maintained and expanded. This will ensure sustainability of products. Partnerships should anticipate future developments and ensure that they can easily switch delivery of services to new platforms. This includes smartphones and use of social media. At the same time, when selecting a service delivery method, the partnerships should have a full understanding of the trade-offs between the services that can be provided, and the business model that can be created.

   Use of basic mobile phones can provide adequate services to many smallholders, but is difficult to link with the required access to financial services and the ability to make personalized business plans. Grouped use of internet-enabled devices can provide a wide set of services, but makes it more difficult to receive payments from individual users. It is also recommended that the services should be available for offline use when possible. This includes availability of GAP manuals.

9. ***Insurance***: Risk-averse behaviour is a key reason for farmers not to invest in new technologies and inputs. Experience and education are a critical success factor here. A recent and very promising approach is to bundle insurance with the provision of other agro-services, such as seed or nutrient supply. When income security increases, food producers will be able to make more investments in new products and technologies that enable them to make the switch to climate-smart practices. Preferably, agro-advisory services are provided with the insurance to minimize the risk of lower or no agricultural yields - a win-win situation for smallholders and insurers.

10. ***Bundling***: A bundle of services can provide significant benefits to food producers, as food producers generally require more than advice to be able to change their practices. Bundles should cover the main areas that are relevant to smallholders; access to (1) agro/pastoralist-advisory, (2) access to finance and insurance, and (3) information on markets. Understanding what a customer needs and wants, and how the customer is actually using services, will allow for a better assessment of the potential for bundling. Needs of the end users and their willingness to pay should be central in decisions to add or remove services from the bundle.

11. ***COVID-19***: Digitization of farmers has shown to provide important benefits in dealing with the impact of COVID-19. Summarizing and disseminating the lessons from different projects, and creating a new bundle of '3C-smart' agriculture (climate, corona, conflicts) can provide farmers with important information on what to do in future situations that result in similar restrictions on travel and marketing (new pandemics, conflicts, etc.). This may also be applicable to pastoralists.

12. ***Data***: Projects have already benefited substantially from developments in digital platforms and the maturing of the EC Copernicus Programme. It is important to continue and to find ways to capitalize on more recent developments, such as the increased application of machine learning to benefit smallholders and better access to (affordable) VHR satellite data.

    The training data collected in the projects is one of the most valuable sources of information, and can be shared with other projects to increase the availability of data for different users. This training data should be well-structured, documented and stored, in line with its value. It is also important to consider global trends in data protection, as legal frameworks focused on data protection could become limiting to the way data is currently shared.

This report is the first in a series of two and focuses on 'Users and Services' in the context of the G4AW Programme.

Annexes

Annex 1: Project list

Project name	Lead implementer	Country	Type of service	Period
Ankor SALAD	ICCO	Cambodia	bundled products/ services	2018-2021
CommonSense	Alterra (WUR)	Ethiopia	financial services, incl. insurance	2015-2018
CROPMON	SoilCares Research	Kenya	weather forecasts and agronomic advice	2015-2019
G4INDO	Alterra (WUR)	Indonesia	financial services, incl. insurance	2014-2018
GAP4A	Auxfin	Burundi	bundled products/ services	2018-2021
GEOBIS	Lal Teer Seed Limited	Bangladesh	weather forecasts and agronomic advice	2015-2018
Geodatics	ICS	Kenya, Tanzania	weather forecasts and agronomic advice	2015-2018
GEOPOTATO	WUR	Bangladesh	weather forecasts and agronomic advice	2016-2019
GIACIS	University of Twente/ITC	Ethiopia	financial services, incl. insurance	2014-2018
GREENCoffee	ICCO	Vietnam	bundled products/services	2016-2020
IDSS	ACI Agribusiness	Bangladesh	weather forecasts and agronomic advice	2015-2019
Mavo Diami	World Vision	Angola	weather forecasts and agronomic advice	2019-2021
MODHEM	SNV	Burkina Faso	bundled products/ services	2015-2019
MUIIS	CTA	Uganda	bundled products/services	2015-2019
Myvas4Agri	Myanma Awba Group	Myanmar	bundled products/services	2018-2021
Rain for Africa	Agricultural Research Council	South-Africa	weather forecasts and agronomic advice	2015-2019
SAM	Impact Terra	Myanmar	bundled products/services	2018-2021
SAT4Business	Solidaridad Europe	Ghana	bundled products/services	2019-2021
SAT4Farming	Rainforest Alliance	Ghana	weather forecasts and agronomic advice	2018-2020
SAT4Rice	VinaNed	Vietnam	weather forecasts and agronomic advice	2015-2018
SIKIA	TechForce Innovations	Tanzania	weather forecasts and agronomic advice	2016-2020
SMARTseeds	ICCO	Indonesia	weather forecasts and agronomic advice	2016-2019
SpiceUp	Verstegen Spices & Sauce BV	Indonesia	weather forecasts and agronomic advice	2018-2021
STAMP	SNV	Mali	bundled products/services	2015-2018
SUM Africa	EARS (merged with eLEAF)	Mali, Uganda	financial services incl. insurance	2014-2018

Colofon
This study was carried out in the framework of the Geodata for Agriculture and Water Programme by the Netherlands Space Office.

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The Geodata for Agriculture and Water (G4AW) programme stimulates sustainable food production, a more efficient use of water in developing countries, and aims to alleviate poverty by enhancement of sustainable economic growth and self-reliance in the G4AW partner countries. G4AW provides a platform for partnerships of private and public organisations. Together they provide food producers with relevant information, advice and financial products.

G4AW is a programme by the Dutch Ministry of Foreign Affairs within the policy priorities for food security and water, which is executed by the Netherlands Space Office (NSO).

G4AW
GEODATA FOR AGRICULTURE AND WATER

Netherlands Space Office

Ministry of Foreign Affairs of the Netherlands