A Business Case for Opening new Markets using Satellite Data for Smallholder Farmers and Pastoralists in Developing Countries

How 'Space for Food Security' works at the local level

Agriculture is the world's largest employer and the largest industry. If the world is to grow enough food for the projected population of 9 billion people in 2050, agricultural production and productivity will have to increase considerably. All this has to be done sustainably, without negative effects for the environment, depletion of water resources and t aking into account possible effects of climate change. This means including the bottom of the pyramid[1] that is responsible for over half of the agricultural production in the world. It would require an innovative approach to bringing affordable, relevant and accessible information to smallholder farmers and pastoralists to increase income, agricultural production and productivity and to increase resilience. This article digs deeper into the lessons learned from such an innovative approach, namely the Geodata for Agriculture and Water, which was commissioned by the Dutch Ministry of Foreign Affairs. What is needed to develop sustainable businesses that address smallholders' information needs and risk-mitigating measures?

Geodata for Agriculture and Water

The G4AW Facility promotes and supports private investments for large scale, demand-driven and satellite-based information services. It provides a platform for partnerships of public organizations, research institutes, private sector operators, NGOs, farmer cooperatives, satellite data/service operators, businesses and transmission operators. For the past three years, the Netherlands Space Office (NSO) has been responsible for executing the Facility and supporting 17 on-going projects.

G4AW GEODATA FOR AGRICULTURE AND WATER

Netherlands Space Office

Why geodata for smallholder farmers and pastoralists?

The majority of farmers and pastoralists are actually smallholders, covering over 80% of farmland in scale that was unimaginable before sub-Saharan Africa and Asia[2]. Their help is urgently needed to ensure food security for all. With the introduction of the Geodata for Water and Agriculture Facility (G4AW), a unique approach was adopted to improve food security in developing countries by providing services and products to them that are using satellite data. The business initiatives supported by the G4AW Facility enable smallholders to increase production and productivity, and the businesses provide a safety net in the form of increased resilience in dealing with natural disasters and through insurance schemes.

The provision of more satellite data that is often open and freely available creates new opportunities for supporting smallholders on a scale that was unimaginable before.[3] Huge amounts of data can be processed quickly and transformed in accurate and actionable agricultural information and advice. Mobile connectivity that is affordable for all makes it possible to get in touch with new target groups that were difficult to reach before and to process feedback from these groups.

Improving the lives of smallholder farmers and pastoralists

The information needs of smallholders (with less than two hectares of farmland) were until recently overlooked, or at least, not addressed. When looking at the characteristics of their agricultural practice, it becomes easier to understand the challenges faced in providing them with accurate data: there is a high heterogeneity in farm practices, crop varieties, and soils. In addition, smallholders face challenges in light of access to finance, logistics, markets and information.

The G4AW Facility is especially designed to address some of these challenges. The aim is to:

- Reach over at least three million smallholders;
- Provide them with useful and timely (agro-meteorological) advice and/or (financial/insurance) products;
- Improve sustainable food production, increase the effective use of inputs (water, nutrients, seeds, pesticides);
- Support economic development in participating countries;
- Stimulate private investments;
- Establish financially sustainable services after three years;

A new market for providing information services in an international setting

The main innovative aspect of the G4AW Facility - the one that is easy to overlook - is that it makes it feasible to use satellite data for commercial, or at least self-sustaining, products and services for smallholder farmers and pastoralists in developing countries. For many years, the use of geospatial information for agriculture was considered only to benefit relatively large farming enterprises, which could afford the services and products. The most important reason for this was the scale of farming operations.

This problem of scale makes it more difficult to serve smallholders than large farmers. The challenge is to make satellite information relevant at the local level. This entails making a difference in information provision and agricultural advice that really benefits the smallholder. Consortia that received support through the G4AW Facility came up with inventive solutions to crack this challenge. Because of the unique approach of G4AW it is interesting to share experiences and lessons learned to improve the design of future business initiatives. This publication analyzes those aspects that are deemed as essential features of the program[4] and focuses specifically on:

(1) the type of satellite data used and services derived from them;
(2) the business cases for services and products based on satellite and other data;
(3) the partnerships that make it work; and,
(4) the outreach approaches to smallholders.

Type of services

A wide array of services is offered through the projects of the G4AW Facility. Advice on pests and diseases and advice on water use and drought warning top the list, but weather information, advice on fertilizer application and market information are not far behind. Several projects address index insurance, advice on sowing and planting and provide yield forecasts as well. Table A gives a complete overview. A bit of caution is required, as the type of services offered may change during the course of a project to adapt to (changing) user needs.

TABLE A: Types of services offered

Type of service	Number of projects
Pests and diseases (early warning, spraying advice)	8
Water use and drought warning	8
Fertilizer application	7
Weather information	7
Crop monitoring	7
Market information	7
Sowing and planting (advice)	5
Index insurance	4
Yield forecasting	4
Crop calendar	2
Pasture availability	2
Pasture quality	2
Livestock concentration	2
Salinity advice	2
Flood warning	2
Soil moisture information	1
Soil fertility information	1
Weeding advice	1
Harvest date (advice)	1

Most use is made of data from weather satellites, MODIS, Landsat (8 and older) and Sentinel 2 and 1. This shows that virtually all of the services are based on open and free satellite data; cost of 'raw materials' (unprocessed data) being of course an important consideration. Data from the European Copernicus program[5] facilitates the achievement of improved services, both in terms of finer spatial resolution and in more timely delivery, as it allows access to more specific and accurate data suitable to the needs for smallholders. It is expected that Copernicus will give a boost to the (further) development of services to smallholder farmers and pastoralists. Table B gives an overview (again: use of satellite data may change, as the services are in development).

TABLE B: Type of satellite data

Type of satellite data	Number of projects
Weather satellites	15
MODIS	12
Sentinel 1	11
Landsat-8 (and older)	10
Sentinel 2	9
Proba-V	6
Sentinel 3	4
Envisat	3
SPOT VGT	2
ALOS PALSAR 1 / 2	2
TerraSAR-X	2
Cosmo Skymed / Pleiades	2
ASTER	1
SMOS	1
RapidEye	1

The type of targeted crops also varies per project and determines for a large part which kind of services are developed and offered. A number of projects do not specify any crop type. Rice, followed by coffee, potatoes and pasture, are the designated crops for at least three projects. Some projects have not decided yet which crops to focus on. Table C presents the current crop selection.

TABLE C: Types of crops served

Type of crops	Number of projects
Crops in general	5
Rice	4
Coffee	3
Potato	3
Pasture	3
Vegetables	2
Sorghum	1
Barley	1
Cereals (not specified)	1
Sesame	1
Teff	1

Business case for services based on satellite data
As mentioned above, developing a business case for satellite data use for smallholders is perceived as challenging. The costs and accessibility of satellite data, and therefore the accuracy of the data made the heterogeneous farm practices of low-income smallholders less attractive for service providers.[6] The projects supported by the G4AW facility however have been able to develop business models that build on new, innovative partnerships that show promising results of being able to tackle the barriers to the development of a sustainable business case for smallholders.

The different types of business models that are applied in the G4AW Facility are presented in the box below:

Business models used in the G4AW Facility

- **Freemium model:** Free service provision of basic services to smallholders. A number of other clients pay for additional services;
- **Loyalty model:** Free service provision avoid switching smallholder clients to competitor (also called "direct revenue B2B" in the case of a seed/nutrient supplier or "indirect benefit" in the case of a mobile telecom operator);
- **Direct revenue B2C:** The smallholder pays directly for a service;
- **Inclusive model:** Paid service provision bundled into package, e.g. insurance coupled to credit, advisory to input supplies; the smallholder and/or other clients pay;
- **Service model:** Client is paying (subsidized) fee for service provision; the subsidy can come from government or from another (farmers') organization.

There is preference for the *service model* and the *inclusive model* in the current running projects; table D presents the selection of business models by the projects. Few projects changed business models during the inception phase, for example from direct revenue to loyalty and it is also possible for a project to keep several options open. Depending on the local context and (business) insights various types of business models are designed and deployed. After project inception, or later project execution, these business models may be adapted to fit new insights (as happened in some cases already).

TABLE D: Business models adopted

Type of business model	Times adopted
Service model	7
Inclusive model	5
Freemium model	3
Loyalty model	2
Direct revenue model	1

There is no preferred business model in G4AW projects and it is too early to tell which business model will be the dominant one. The selection of the business model depends on a number of factors and circumstances that may differ from country to country and region to region. Key success factors for delivering information services are: tackle a well-defined and specific problem by offering a portfolio of services that builds on an already existing delivery mechanism and that is embedded in the local context. The following checklist helps to assess the potential of the service or product offered and to identify potential bottlenecks:

- fit-for-purpose (does it solve the right problem?);
- comparative advantage (compared to other solutions for the same problem);
- ease-of-use (complexity to the user);
- elegance (appeal of the solution that the client identifies with);
- cost-benefit;
- reliability/continuity of service (including long-term availability of the appropriate earth observation data);
- resilience (is there a back-up if one or several elements of the information chain do not function properly?);
- flexibility (can the solution be adapted quickly and effectively to changing conditions?);
- acceptance (of the solution by the client);
- level of knowledge transfer required (to implement the solution sustainably); and,
- ethics (related to the local situation).

The success of a project, and thus service adoption by clients, depends for a large part on the business owner: the entity that will be the main stakeholder and ensures sustainability after the initial support from G4AW Facility has faded. As can be seen from table E, various options are possible, including mixed arrangements. Although companies come out on top (this can be input providers, business agents, insurance companies or telecom providers), arrangements through government or NGOs are not far behind. A distinction is made

between an aggregator, who provides a platform where a client can shop for different services (such as a farmer cooperative, and an entity responsible for embedding (such as a social development organization), who ensures that conditions are created for the smallholder to use the product or service in the best possible way, but in practice roles are diverse and can overlap.

TABLE E: Envisaged business owner

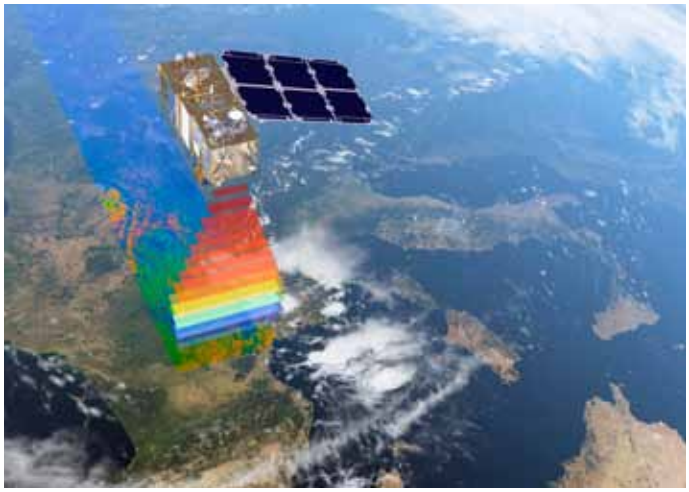
Type of business owner	Times adopted
Company	11
Government organization	8
NGO	8
Farmers' organization (or union)	4

The business owner should have a clear stake in the outcome within the given project timeframe, but also have a forward looking vision for the period after the subsidy has ended. The business owner is the linking pin for upscaling of activities in the country or region concerned.

Experiences until now in the G4AW Facility are promising: in some projects the uptake is likely to far surpass the originally envisaged number of clients. This is partly due to higher ambitions of the project partnership and/or the government agency involved or to cooperation with entities beyond the partnership. Still, acceptance by the end-users, achieving a good cost-benefit ratio and fine-tuning of the solutions (real fit-for-purpose) are the main bottlenecks encountered that will require attention in the coming period of project implementation.

Encouraging partnerships
Application of earth observation based services for smallholder farmers leads to the creation of new and unexpected partnerships with the involvement of smallholders, farmers' organizations, financial institutions, insurance companies, government, input suppliers, traders, mobile service providers, and technology companies. This means that each business case supported by the G4AW Facility is implemented by a mix of stakeholders with complementary qualities and capabilities.

Essential in the selection of the partnerships was their ability to close, what has been coined as, *the information chain*. Here, emphasis was placed on how well-equipped the partnerships are to absorb and convert satellite data into information that is not only reliant, timely and useful, but also transferred in a commercially viable way that it is able to sustainably reach a hard-to-reach market segment: poor smallholders.



A 'closed information chain' would in an ideal situation look something like this: free digital satellite data is collected and (pre-) processed with the appropriate technology (satellite data provider), thematic information is extracted and knowledge is obtained to solve problems (tech and/or knowledge partner), the ensuing information is then transmitted as an easy-to-use and familiar service or product for the farmer (technology provider & commercial partner), farmers are informed of usage and applicability (service delivery agent or aggregator), after which farmers use information and improve food security levels.

Such partnerships have a different approach compared to other initiatives that provide satellite-based services because of the scale of operations (many farmers, many plots) and the requirement for a network of stakeholders that enables the offerings to reach the new target groups. In practice, this turns out to be greatly dependent on working in collaboration with aggregators such as farming cooperatives that deal directly with smallholders, and local service providers that already offer trusted local services to smallholders. Box 1 provides an example of how such collaboration allows a so-called non-viable business case to reach potential scale.

Box 1- GIACIS; a closed information chain

The purpose of the GIACIS public-private partnership is to expand financial service delivery to smallholder farmers in Ethiopia with a geodata-driven risk-mitigation (insurance) product that offers a basic safety net to protect them against weather related risks.

The partnership includes: the public Ethiopian Agricultural Transformation Agency, the Ethiopian technology partner Kifiya Financial Technology and the information provider National Meteorology Agency of Ethiopia.
Led by the Dutch-based Faculty for Geo-Information Science and Earth Observation at the Universiteit Twente (ITC), the partnership allows for a complementary set of competencies:

- from provision of satellite data,
- to delivery of technological know-how how to translate that data to useful informative systems,
- towards a service provider with an existing infrastructure to build on
- and a public counterpart to support the efforts for potential upscaling.

Because of the unique added value of each selected partner in the consortium, it also means that each partner has a distinct stake in the business. This strengthens the probability of the sustainability of the business after the subsidies have faded. Because of the unique proposition and comparative advantage of GIACIS in Ethiopia, the government has expressed the ambition to take over further rollout of GIACIS in other regions.

The biggest challenge for the current partners is ensuring that the technology know-how that is currently embedded with the lead organization, ITC in the Netherlands, is transferred to local institutions that can carry the developments further after the project subsidy by the G4AW Facility ends. While the consortium itself has a closed information chain, it thus needs to make sure that the chain is as much locally embedded as possible.

Reaching and understanding the smallholder farmer and pastoralists

Developing services and products for the purpose of smallholders carries great potential in terms of numbers reached and the development impact it could have on their daily lives. At the same time, because of its unique focus, it also carries great risk as the products and services are aimed towards a market segment, where the main actors are often illiterate and low-skilled, and have limited or no (access to) capital or resources for investment, and are therefore traditionally *risk-averse*.

This risk-averse nature entails at least two things: (1) smallholders are in need of coping strategies that will help them to avoid or to deal with risks; and (2) smallholders have to be strongly convinced of any type of new service or product as they have everything to lose. Here, it becomes clear how important it is to know your customer as a first step in creating a viable business case for such a cautious target group. In G4AW strong emphasis is placed on gathering baseline information on the target group, the market and its viability.

Once the target groups are defined, the next and perhaps most important step should be taken, as G4AW business owners have emphasized: building trust. Smallholders need to be convinced that the service or product they are buying or committing to, will actually benefit their agricultural business. If they would use the wrong type of fertilizer at the wrong time as a consequence of information that they were relying on, they could lose a harvest and their income for the next half-year.

We find in the business cases specific approaches to address trust issues. Some send trainers out to the field for training-of-trainers exercises among high-potential smallholders. As they believe encouragement from within works best, they seek out those smallholders with a strong network to 'spread the word'. Others choose to work through aggregators which smallholders turn to anyway for their information needs for their agricultural practices. A third type of business case places agents of the service providers strategically in the field to inform smallholders personally, and virtually through door-to-door service, what they can expect and where they can turn to when the service would fail them.

What appears is that services and products that are built into systems that are already in place seem to build trust more easily. In the business case of GEOPOTATO we find that as farmers were already using their products for other extension services, it was only a small step to accept an additional product that served an unmet need. As it was built upon strong knowledge of the local context, the products were more easily transferred. In Box 2 we present a description of their approach. From this example, we learn that having an established and trusted local partner in place that has a strong local infrastructure helps.

Box 2- GEOPOTATO; Reaching out from within

The GEOPOTATO business case has as an objective to sustainably improve resource use efficiencies and profits in potato production in Bangladesh by providing to smallholder farmers a decision-support service to control the late blight fungal disease. The ambition of the partners is to reach approximately 15% of the total of 750.000 smallholder farmers in Bangladesh that produce an irrigated potato crop in the dry winter season. They aim to do this by providing an SMS information service on subscription base.

Innovatively, the partners have taken into account the potential illiteracy levels of the target group and have developed the product to be either based on text messages, or voicemail services that requires no literacy standards. Their cooperation with a development partner with extensive working experience on the ground, the Dutch NGO ICCO, allowed the partners to have a solid understanding of the target group demographics and their needs.

Also, this local knowledge contributed to developing an outreach strategy in which the service is implemented at fields owned by exemplary or lead farmers within the organized farmers groups of the development agency ICCO, and other partners: AIS and Bombay Sweets. They have previously trained local extension agents and business advisors on the ground that already have a trustworthy relationship with the farmers. The 'exemplary farmers' have been chosen because of their farm production levels, but also because they are respected and looked up to in the villages. Only with local knowledge of the dynamics and structures of the local communities would such an outreach strategy therefore be possible.

Scaling initiatives
Upscaling of the activities is an important goal of the G4AW Facility. The biggest challenge is to reach sufficient smallholder farmers and pastoralists to make the service economically feasible. Technically this seems to be very well possible: the mechanism and design of the solutions can be copied relatively easy to other situations. Organizational upscaling is more difficult: a well-defined plan to reach, inform and train the smallholders should be in place and be realistic. The success of the projects and the financially sustainable service provision relies very much on this organizational capacity. However, the limited experiences gained with this in the G4AW Facility until now shows that in practice this is not so easy to realize. The business model, embedding in the local context, and possibly the type of partnership, all need adaptation to be successful elsewhere, whether across regions within borders, let alone across borders. There are also issues related to the license-to-operate that have to be dealt with and are more complicated in one country than another.

Impact on food security

The challenges to measuring impact
Food security interventions in general are notoriously difficult to evaluate[7]. The Dutch government reported, "Interventions aimed at raising agricultural production and productivity experience relative ease of evaluating, and therefore are producing more results". However they find that at the level of impact concerning improving food markets, value chains or policy, these aspects are less represented in evaluations and therefore only little evidence exists. In the case of G4AW projects stumble against these same issues as they too are starting to realize "measuring impact of food security interventions is extremely difficult, requiring complicated techniques and substantial human and capital resources"[8]. Often projects are able to show the commercial benefits and figures of the business case, but fail to deliver on manageable frameworks to measure impact at the level of the smallholder or the impact their interventions have on the market.

Although food security comprises many aspects and the contribution of G4AW in terms of improved food security was difficult to establish in of the early stages of project implementation, there is good potential for such a contribution in terms of:

- Increase of the production volume, through the increase of the (locally) available food production and increase in smallholder income; and
- Provision of a safety net for smallholder farmers and pastoralists through index insurance and decreased vulnerability to natural disasters.

Opportunities for climate change adaptation
The FAO describes the effect of climate change on agriculture and food security as follows: "Climate change affects agriculture through higher temperatures, elevated carbon dioxide (CO_2) concentration, precipitation changes, increased weeds, pests and disease pressure". Such changes will have more or less severe impacts on all components of food security: food production and availability, stability of food supplies, access to food and food utilization."[9] Clearly, addressing increased production level and improved efficiency of agricultural production through the use of satellite data will therefore directly or indirectly contribute to climate change adaptation.

The topics presented below illustrate how G4AW projects are directed at adaptation to climate change:

- Identification of grazing grounds and water availability for pastoralists. The experience gained and time series of data created allowed the target group to adapt to conditions hampering their livelihoods.
- Sustainable use of water, including water harvesting. Water harvesting was applied in one project, where the stored water was used for irrigation in dry periods (and for fish farming when the water was not needed). The projects dedicated to drought and excessive rainfall insurance also generated valuable time series for adaptation planning.
- Insurance (apart from creating time series with data on natural phenomena) and the existence of the insurance scheme itself provided a tool for dealing with the consequences of climate change.
- Advice on the crop calendar helped the target group adjust to changing circumstances. In addition, the time series of data on which crop calendar advice was based provided a valuable input to local climate modelling from which adaptation plans can be derived.
- Similarly, (near) real-time local weather forecasting (or improved local weather forecasting in general) improved the quality of adaptation plans, through an analysis of the wealth of gathered data.

Opportunities for sustainable water use

Although advice on water use and drought warning are important elements of many G4AW projects, water use is never the main topic. The scale of satellite data for water poses challenges to providing services to individual smallholders: the resolution of free images is too coarse to provide relevant advice at parcel level. Cloud cover also poses a problem.[10] This is why many G4AW projects take water on board as a part of the general agricultural advice portfolio (e.g. drought insurance and early warning, insurance based on general evapotranspiration estimates measured over a large area and water harvesting). A European study[11] estimates that irrigation advice costs between € 2.5 and 4.3 per hectare, which implies that such a service would be financially feasible in the European context, but how this translates to the situation of smallholder farmers in developing countries is still an open question.

However, satellite data on water use has certainly a comparative advantage when looking at larger areas, such as a watershed, an irrigation scheme or the aggregated land of a farmers' cooperative. Adoption of water accounting schemes or water markets is a solution that makes business cases based on sustainable use of water economically feasible. This would address the problem of water pricing (often not priced at all, or too cheaply (subsidized) leading to inefficient and unsustainable use), and the fact that water scarcity will be one of the biggest problems in the coming decades at a global scale. One way out of the problem is (enforcement of) regulation, by government or by the community itself. There are (historical) examples of successful self-regulation, especially in times of drought.

A third and closely related solution is the application of certification of agricultural production that is based on a monitoring and evaluation system that includes sustainable water use. The introduction of certification mechanisms gives farmers a reward for good practice while improving their farm efficiency. Again, the application of satellite data is very relevant here, as the analysis takes place over large areas and not at the level of the individual smallholder farmer.

A business case for gender

Women comprise an average of 43 percent of the agricultural labor force of developing countries[12] . According to the FAO, should women farmers have the same access to productive resources as men, they could increase yields on their farms by 20-30 percent, lifting 100-150 million people out of hunger. It is important to note the wording: "should women farmers have the same access". Development organizations worldwide concur that many obstacles still exist for women in terms of access to finance, land, technology and decision-making power. [13,14] Such aspects are essential components of the farming business as credit is essential to invest, land ownership helps to ensure sustainability

of the business, technology allows access to crucial information, and the power to decide determines whether women can choose what fertilizers to use this season or how to re-invest profits.

A proper understanding of the target group from a gender perspective is essential if the product or service is expected to be used by those actually benefiting from the services provided. Culturally embedded structures and beliefs can hamper women to own mobile phones for example. While many of the G4AW projects emphasize that a large proportion (sometimes the majority) of their target group is female, their business cases would be even more supported if a gender analysis would underlie their outreach strategies. This would help them to unravel how their services and products could be developed in such a way to address specifically the needs of both men and women.

Future perspectives

In a few years the projects will have completed their implementation period and it will become clear which business initiatives are successful and deserve replication and further development. To reach smallholder farmers and pastoralists more effectively, there is a need for active advocacy and knowledge exchange and/or the creation of a knowledge base to share success stories and learn from mistakes. The G4AW projects provide a wealth of information that can be used to validate the results of national and global monitoring initiatives, such as the Global Agricultural Monitoring of the Group on Earth Observations (GEOGLAM). This will improve the accuracy of these systems and consequently their contribution to achieving global food security.

Only time will tell what the real impact of the G4AW Facility is.[15] However, there are indications that with the help of satellite data the livelihoods of smallholder farmers and pastoralists can be improved with viable business models. Although success of individual private sector actions is not ruled out, the best way towards scaling of activities seems to be through partnerships with a strong business partner with government participation or at least government support. Initiatives of the G4AW Facility also provide tools to give more attention to adaptation to climate change, sustainable use of water and gender aspects, which could be further developed if given appropriate focus in future endeavors.

[1] Smallholder farmers with less than two hectares of farmland or pastoralists that manage less than 10 head of livestock. The equivalent of two hectares of average quality farmland is one hectare of very fertile land or 10 hectares in semi-arid areas.
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[6] This was an important rationale for establishing the G4AW Facility.
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[14] BSR (2016). Women's empowerment in global value chains – A framework for business action to advance women's health, rights and wellbeing. https://www.bsr.org/reports/BSR_WomenDeliver_Womens_Empowerment_Value_Chains_Consultation_Draft.pdf
[15] External impacts, such as political instability, have not been taken into account in this study, but of course their effect may be huge.

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