

How could satellite imaging support sustainable agriculture for smallholder farms in developing countries?

Introduction and background

Satellite imagery is the field of using images made by satellites situated in space. Observing the earth is done by 'earth observation satellite' or 'earth remote sensing satellite' which are specifically designed for earth observation. Those imaging satellites are often operated by governments or businesses all over the world and a large part of satellites is of public domain (freely available). By monitoring changes of the earth surface over time, different types of analysis can be performed and characteristics of events such as droughts, vegetation and water pollution can be assessed (1). With the use of artificial intelligence researchers can assess differences between certain soil and vegetation types, monitor grape health and estimate wheat harvest size (2).

The use of satellites for communication was already reported in the late 1950s in the U.S. Civil Space Program, while the first more sophisticated (three-dimensional) satellites for imaging were developed in the 1960s (3). The use of satellites to get information about vegetation patterns, moisture levels and weather has been reported since the early 1990s (4) and nowadays it is of common use in the connected world (5). However, smallholder farmers, i.e. farmers who cultivate crops at small plots of land with low rental values (6), in developmental countries are usually not connected to internet and often only have access to a mobile phone. On top of that, they often have low-resources and are very dependent on the harvest for living since the entire family income is determined by this. Since the income largely depends on 'rainfed' agriculture (4), i.e. 95% of existing farmland in sub-Saharan Afrika receives its water trough rainfall (7), extreme weather events among which a great variability of rainfall leads to drought and food insecurity (8).

The use of satellite imaging may help coping with these circumstances. Using satellite imaging several processes can be visualized. Some applications of the use of satellite imaging are visualising soil vegetation and moisture levels based on high density images (4), weather forecasting based on long term databases (9) and early warning signals by indication of water pollution or detecting fires (10) which can save people's lives. As indicated, satellite imaging can be used in two ways: 1) to create models that can estimate daily weather, droughts, crop loss, insect infestations or toxicity of peanuts and 2) to detect events such as fires or water pollution. In the first case, models are built based on data collected over a long period of time. Depending on the aim, satellite images and information gained out of this may be combined with ground-based information.

The aim of the current essay is to investigate how satellite imaging could support sustainable development for smallholder farms in rural areas. First, a short explanation about the working of satellite images is given. Accordingly, different applications and manners in which satellite images can help farmers are explained. The paper ends with a critical discussion about the current developments within this field ending with a summarizing conclusion.

In what ways could satellite imaging influence agricultural development?

As was described in the previous paragraphs, satellite imaging can be used to visualize events on the earth surface and to assess differences in soil and vegetation. At the moment, data of satellites can be instantly fed through a remote computer. This data can be made accessible for farmers by applications that translate data into information suitable for farmers in rural areas. The current paragraph explains how this information can help farmers directly as well as indirectly.

Direct help

Satellite images include information that might elaborate the knowledge of the farmer from ground-based inspection. With this additional knowledge, soil vegetation and moisture levels can be mapped

more specifically. Based on this, farmers can adapt their land use planning such that it suits better to the soil characteristics at a certain moment in time. Land use planning involves both selecting which crop will be cultivated within a certain season as well as deciding how to divide the land among the selected crops and or animals. Both the areas of land that are best for boosting crop yields as well as ecologically important areas that shouldn't be disturbed (i.e. forest) can be assessed using satellite imaging. According to Harper and Meado (7), this approach could prevent deforestation and increase food security in this area. On top of that, during the season (when the land use is already divided), satellite imaging can provide information that may support farmers in decisions such as how to prepare their land, when they should plant, what will the best plant density be and when to harvest. An example of such a tool that send informative SMS messages based on satellite images is the Intelligent Agricultural Systems Advisory Tool (ISAT) which has been developed for groundnut farmers (11). After such advising agricultural interventions, the impact of these interventions is evaluated using by, again, comparing satellite images before and after the intervention (12). In this way, the evidence on the efficacy of particular interventions could be expanded.

While land use planning depends on satellite images at a certain moment in time, the knowledge used during the in-season will depend for a certain extent on predictions and estimations that can be made from large datasets collected over several years. Since farmers will not be able to perform such analysis themselves, scientific work should precede this.

Beside these information systems that help making decisions about land allocation and harvest decisions, satellite images could also be used for detecting event such as insect infestations, droughts and other natural disasters. With the use of satellite images, early warnings could be provided such that preparations can be made and, if needed, emergency support can arrive quickly (13).

Indirect help

In addition to directly support farmers with advice or information, most research has focused on indirect methods to increase knowledge about farming under conditions in rural areas.

First of all, satellite images are used for monitor sustainable rural development (14) in order to increase our knowledge about this. A lot of effort has been put into understanding and investigating soil composition in countries with food scarcity (might be the key to improving quality of life and reducing malnutrition issues). A lot of effort has been put into understanding the magnitude and determinants of yield gaps (12). When a large amount of data based on satellite images is gained over time, large improvements in investigating and understanding this can be made (12). Since a number of hypotheses about the sources of yield gaps are gathered, these could be evaluated.

Second, because a lot of the information that has been transferred to farmers or has been used on the basis of several applications, research still uses satellite images to enhance yield forecasts. On top of that, methods for calibration and validation of satellites are still being improved. This is done by combining ground-based observations and measurements with satellite images (4). In order to obtain sufficient ground-based observations, collaborations with farmers is often needed.

At last, governments in developing countries use satellite imaging to monitor the degree of crop loss, draught or other factors. Once the satellite data indicates a pre-defined threshold is reached, an insurance payment is made to the farmers that insured themselves (12). Also humanitarian disasters on a larger scale, such as famine and drought, can be detected using satellite images. When using these, earlier detection could be done such that help can be sent to these areas. In this way, a lot of people can be saved. This system also works with pre-defined thresholds.

Discussion of current issues

The current paper provides a short review about the current literature about the use of satellite images to support agriculture for smallholder farms in developing countries. After a short explanation about the working and possibilities of satellite images, several applications of this technique were proposed. This

implied both directly as well as indirectly support for farmers. Although, the review indicates several possibilities of satellite images to help agriculture for smallholder farms in developing countries, some issues should be mentioned.

First of all, the use of satellite images requires some hard- and software infrastructure. To acquire satellite information, mobile phones are needed implying sufficient electricity and connection. Moreover, several applications are internet-based. Since this applies internet connection and working smartphones, accessibility for smallholder farms, that often are not connected to the internet and have no (knowledge about) smartphones. Even if both requirements are fulfilled, applications should be adapted to the lack of continuous and high speed connections in many rural areas. Besides devices to receive information, satellite hardware should also be present.

Second, a lot of applications are still not sufficiently adapted to the context of rural areas. As was described in the previous paragraph, some applications work internet-based. Besides that, a lot of tools to make information from satellite images accessible are text-based (11). Although no internet connection is required for these applications, literacy is required. However, since a large part of the farmers in rural areas is not literate and don't have internet connection, such applications are not usable for these farmers. This was also found by Richardson (15). Lio and Liu (16) investigated the impacts of ICT on agricultural productivity in 81 countries. They show several gains in efficiency of production advice, but also point out that the returns from ICT in agricultural production of richer countries are about two times higher than those of poorer countries (16). The use of internet-based and text-based applications may support these deviation even more.

Third, the current literature about research that uses satellite images to investigate agricultural development indicates conflicting interests. As the headline is often promising, the content of much literature often puts the most effort on 'increasing knowledge' or 'estimating drought and famine' instead of how to help poor farmers on the short term. However, in order to investigate these aims, information of farmers (such as ground-based observations) is highly needed. Since farmers may not be able to understand what is investigated exactly and what the value of their information is, farmers will benefit less than they should in return for their information. Although the final aim of the research may support farmers, retrieving benefits may take years and will often remain absent.

At last, a linear approach is often seen. Interventions are often designed from the office without investigating the real context and discussing the needs with the farmers in the areas of interest. This may lead to misunderstandings so that products may not fulfil the real requirements. Besides, when a product has been developed, effort should be put in familiarization of the end-users with the ICTs and their applications. Without this, programmes are likely to fail (15). Rural population should attend training on the use of the application and the design should be easily adaptable. On top of that, final products should be sustainable. Since a lot of projects are based on finite donations and interventions are designed linear, proper investigation of financially sustainable business models is not done (16).

Conclusions

To conclude, satellite imaging seem quite suitable to support agriculture for smallholder farms in developing countries. This can be done by direct support including advice on land allocation, land use and crop cultivating but also early warning signals for possibly disastrous events. On top of that, satellite images could help farmers indirectly by investigating yield gaps and food scarcity, by investigating ways to improve yield and weather forecasts and by defining thresholds for insurance payments or the need for help. Although direct support seems promising, indirect support seem to be much less (or not) beneficial for farmers. When direct support systems are adapted to the right context (i.e. low literacy and no internet connection), satellite imaging will be very suitable to improve agricultural development and enhance crop yields of smallholder farms in the near future.

Literature

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