Mobile weather services for small-scale farmers

SUCCESS FACTORS FROM AFRICAN CASE STUDIES

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Weather Impact
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Weather Impact

Summary

Africa's population is growing at an exceptional rate and its overall food demand is expected to double by 2050. This poses enormous challenges for the local agricultural sector, which consists to a large extent of small-scale farmers. These farmers depend mainly on rain-fed agriculture, and their crop production is very sensitive to weather variability and climate change. The question is how these farmers can prepare themselves to deal with the new reality, and whether modern weather services can help them. This paper presents case studies performed in various African countries where we currently provide weather services to thousands of small-scale farmers, through various communication channels, on a daily basis.

Small-scale farmers can easily be reached by mobile phones such as 'feature phones'. These basic phones also allow location to be determined and weather information to be downscaled. The importance of building trust and user confidence was demonstrated during field research. We found that these can be achieved by:

- *Location-specific and reliable forecasts*; down to the level of the farmer's crop fields, and also showing forecasting uncertainties.
- *Information and technology tailored to user needs*; crop-specific, in the local language and using available channels.
- *Services embedded in existing local networks*, both social and professional.
- *Approval of the service by national weather services*, who should preferably be involved in local monitoring and broadcasting.
- *Involving the right business partners*; creating partnerships with local business developers in the agronomic value chain is essential.

Our aim in this paper is to inspire current and potential new partners to further develop local weather information services with us. We provide details of the results, lessons learned and success factors from three case studies:

- Satellite-based farm-management advisories in Kenya.
- User validation of the local weather service in Northern Ethiopia.
- A value chain of public-private partners in South Africa.

With localised information services and using existing mobile technologies, we are seeking to contribute to solving weather, climate and food problems. African small-scale farmers are the target group as they have the highest potential to increase agricultural production and provide the continent with long-term food security.

Trends in small-scale farming

The African continent is facing huge population growth and rapid urbanisation. Projections show that demand for food in Africa is set to double by 2050. Local agriculture has a critical role to play in making Africa food-secure over the next 30 years. Within the agricultural sector, small-scale famers have high potential to increase production and improve food security. However, a general lack of technology, education, inputs, limited infrastructure and changing weather patterns are just some of the challenges that these farmers face. If small-scale farmers can overcome or deal with these challenges, the future for African agriculture looks promising [1, 2]. In this paper we focus on the challenges that weather variability poses for rain-fed agriculture and provide ideas for using straightforward and robust technology to help small-scale farmers deal with weather variability and make them more resilient to climate change.

Weather challenges of rain-fed agriculture

Most small-scale farms in Africa are rain-fed; in other words, the farmers have no access to irrigation, and the water available for crop growth is determined by natural rainfall patterns. This means that these farmers' yields are highly dependent on local weather conditions. Knowledge about current and upcoming weather is thus crucial for successful farm management. Small-scale farmers usually receive their weather forecasts via radio or television. This information is currently provided for large areas or provinces and is not location-specific. Farmers often complain that forecasts are too regional and, partly for that reason, unreliable.

Climate change poses even more challenges. The impact of climate change on agriculture can already be seen today [3, 4]. Africa is experiencing significant increases in temperature, while rainfall patterns are highly variable and are influenced by various large-scale processes, including the West African Monsoon and El Niño. As further climate change is expected over the coming decades, the associated risks of extreme weather will increase. This, in turn, will inevitably impact on agricultural production [5, 6].

Farmers often complain that their traditional ways of managing their farms no longer work because rainfall patterns of the past have been disrupted or changed. Whereas sowing could previously start in early June, farmers now find their seeds germinating poorly due to delayed rains. Whether the cause of these delays is deforestation, climate change or natural climate variability is of no importance to the farmer. The fact is that the resultant waste of energy and inputs could be avoided, particularly if farmers had more information about local weather and forecasts.

Mobile: the new channel

Mobile is the platform for digital solutions in Africa. Phones are used for activities that people on other continents usually use computers for. Prices for mobile devices and data are falling, and that means they are becoming accessible for many more people, including in rural areas [7, 8]. Most mobile phones in rural Africa are basic devices, with text messaging (SMS) and telephone functionality (often referred to as 'feature phones'), while the adoption of smartphone services in Africa is still far below the global average. The major causes of this are the relatively high costs of such devices and subscriptions for people in rural communities, and this is expected to remain a critical barrier for the adoption of such services over the coming years [9].

Mobile phones allow farmers to use various interaction mechanisms, such as text messaging or interactive voice response. Table 1 lists some of the benefits and limitations of the various types of services available for communications between service providers and farmers.

Baseline studies show that most farmers receive their weather information and forecasts via television or radio [10]. These services are often provided by the national weather services and via local radio broadcasts. Radio and television are indicated as the preferred means of communication [11]. One of the disadvantages of radio and television, however, is that it is difficult to make the forecasts location-specific or tailored towards user needs. A solution for this problem can be found in the use of mobile services. Since the adoption of smartphones remains low in rural Africa, services for farmers that are accessible via feature phones are likely to be more successful and to have a higher impact.

Examples of such services are text messaging (SMS), interactive voice response (IVR) and interactive messaging services (Unstructured Supplementary Service Data, or USSD). An IVR service allows a farmer to call and communicate with a computer, while a USSD service enables interactive text messaging between a computer and a farmer. Various mobile services with farm advisories or weather forecasts have already been successfully implemented [12, 13], and mobile service providers can play an important role in supporting weather services for agriculture [14].

Figure 1: Feature phone with a localised weather forecast for the next week.

	Benefits	Limiting factors
SMS – Short Message Service	Available on all mobile phones. Cheap technology.	No more than 160 characters. Users need to be literate.
USSD – Unstructured Supplementary Service Data*	Available on feature phones. Interaction with users is possible.	Users need to be literate. Each interaction has a cost.
IVR – Interactive Voice Response**	Available on feature phones. Interaction with users is possible. Accessible for illiterate users.	More expensive than text messages.
Mobile Apps - for smartphones	Almost unlimited information and intuitive visualisations possible. Full interaction with users.	Low levels of smartphone ownership in rural Africa. Mobile data is expensive.

*) Interactive text messaging service between a computer and a farmer.
**) A telephone service allowing a farmer to talk to and receive spoken answers from a computer.

Table 1. Benefits and limiting factors of mobile solutions for providing weather information in rural Africa.

Value of localised information

Impact of weather on farm activities

Many farmers state that reliable weather forecasting is key to improving their farm management. Studies of farmers' experiences of weather variability indicate that farmers attribute decreased crop yields mainly to changes in weather patterns [15]. For rain-fed agriculture, it is crucial for farmers to know when the rainy season will start. The questions to which farmers need answers include: whether sufficient rain is forecasted for them to start sowing, and whether the first shower will be followed by another period of drought. Although farmers trust the historical patterns for the start of the rainy season, the onset of this season is not as clear as it used to be, or as clear as farmers think it used to be.

During the growing season, many actions can be optimised if farmers have timely and localised weather forecasts:

- Costly top-dressings, fertilizers and pesticides should be applied in dry weeks to prevent wash-out and to control the amount of inputs needed [16].
- Crops can be protected against excessive rainfall by making drainages.
- Surplus rainwater can be harvested for use in drier periods.
- Outbreaks of pests and diseases are highly weather-dependent. Although small-scale farmers often lack the means to apply pesticides, a timely alert can prompt them to go to their fields to manually remove pests.

- Timely alerts for bad weather can prevent crop damage in the harvesting period, when the crops are at their most vulnerable.
- Rain forecasts enable the planning of labour for harvesting.

Such warnings and associated measures help to reduce crop damage, increase harvesting volumes, lower costs and optimise the entire growing season. Location-specific weather information for small-scale farmers represents a big step towards making the right farm-management decisions at the right time.

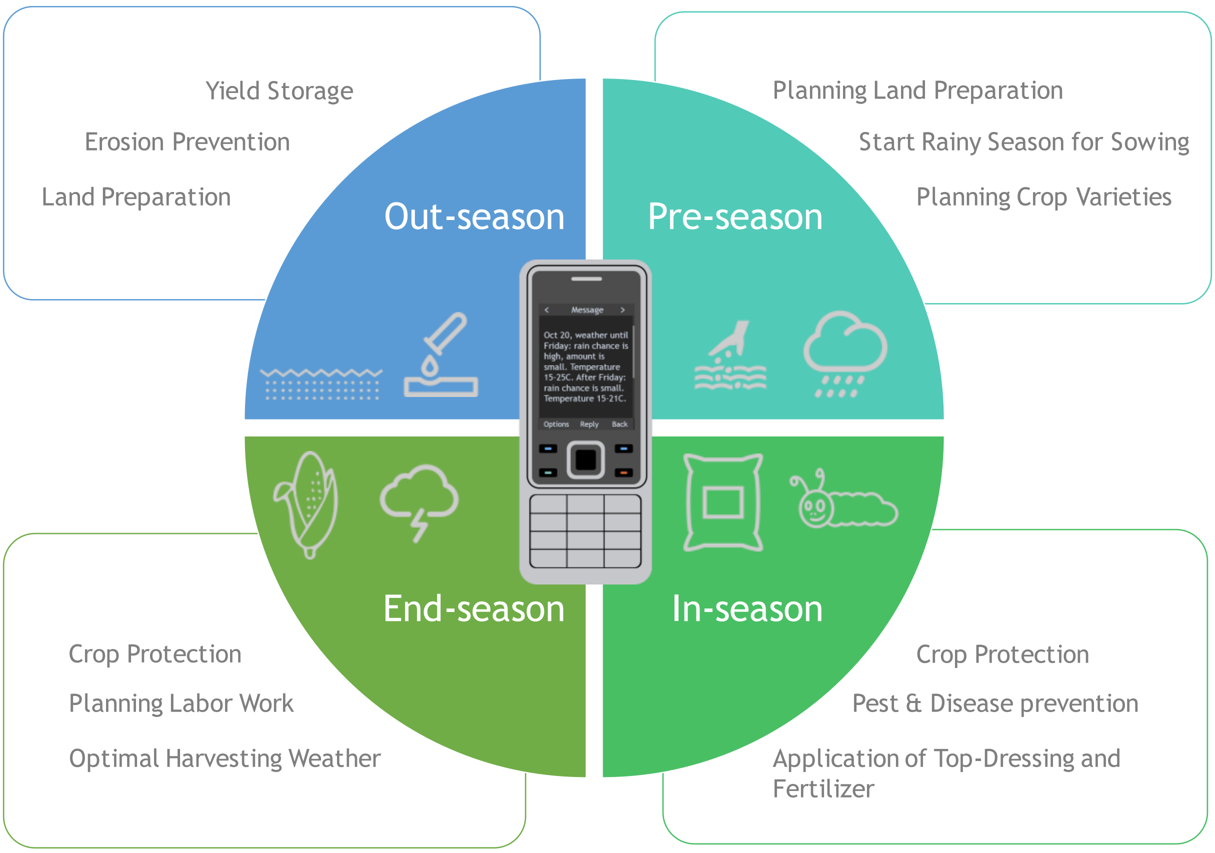

Figure 2: Farm-management schedules and actions related to weather help to optimise farmers' productivity.

Seasonal planning and monitoring

In addition to forecasts, knowledge on fields' current status and the weather in the upcoming season is highly valuable to small-scale farmers. Satellite measurements can be used to monitor local weather and the crop status. In areas where ground measurements are scarce [17, 18], satellite images with full-coverage information can help. More and more high-quality satellite images are available for free and ready to be used for farmer-support services, such as for predicting crop yields and for selecting the most suitable crops [19].

Seasonal weather forecasts can be of added value for the agricultural sector, providing they are sufficiently reliable. Based on seasonal outlooks, farmers can decide to use a drought-resistant crop in dry seasons, or a short-cycle crop when rains are delayed. Meanwhile, warehouses can better estimate storage and transportation capacity, while traders can more accurately estimate expected shortages or surpluses. These stakeholders can also be informed about anomalies expected in rainfall patterns in, for example, El Niño or La Niña years.

Forecasting the weather on seasonal timescales is more sensitive to uncertainties than forecasting for the next few days. One of the reasons for this is that seasonal patterns depend on the status of the global climate system, including the oceans. As these processes are slow and depend on very large-scale connections, they are more difficult to model. Seasonal forecasts are more reliable in tropical regions than in the mid-latitudes. As models are improving, we expect an increase in seasonal forecasting information and services benefiting the agricultural sector. However, the benefits for small-scale farmers may be limited.

The first problem is that seasonal forecasts are often impossible to summarise in a single, unambiguous message. Estimating the usefulness of a seasonal forecast requires expert knowledge about the forecasting uncertainties, and more advanced communication methods than a simple text message. The second problem is that the risks for small-scale farmers of following an incorrect forecast are relatively high. Caution is therefore needed to ensure farmers do not make crucial decisions based on incorrect seasonal forecasts in, for example, El Niño-neutral years.

Case study 1: Satellite-based farm-management advisories in Kenya

CropMon is an advisory service for small-scale farmers in Kenya. The service provides text messages to farmers via feature phones. These messages contain information on:

- Weather forecasts, e.g. rainfall, temperature.
- The actual condition of crops in the fields.
- The limiting factor when crop development is lower than expected.
- Farm-management advice on how to reduce the impact of the limiting factor.

As the position of each farmer's field is registered in a database, the service can be location-specific. This enables tailored information to be provided. To determine the limiting factor, the service takes account of weather conditions, soil fertility, water supply and other status variables. This information is based on satellite measurements and local soil analysis in the fields. The CropMon approach provides services to farmers cultivating various crops, including coffee, maize, grass, wheat and sugar cane, through four local partner organisations. These organisations have established networks of farmers and are able to spread the technology and ensure fast adoption by users and efficient expansion of the numbers of users.

Figure 3. CropMon service in Kenya provides farmers with field-level information. Their fields are registered, based on GPS coordinates, via the local extension officer's smartphone. This picture was taken during a 'training of trainers', where the extension officers are practising registering a farmer on their smartphone. Photo: Peter Mwangi.

Quality of weather forecasts

Weather forecasts are valuable for users only if they prove to be reliable. The quality of weather forecasts in Africa has been studied less intensively than the quality of these forecasts in the mid-latitudes. Studying the performance of models in Africa is hampered by a general lack of ground measurements. In addition, short-range weather forecasting is more difficult in the tropics than in the mid-latitudes because tropical rainfall is characterised by highly localised convective showers. However, weather forecasts are always uncertain to some extent. And recognising this uncertainty is the first step towards dealing with it. In this section we discuss the benefits of ensemble weather models, and the challenges of downscaling and validation with only limited data.

Ensemble weather forecasting

Ensemble weather prediction models can play an important role in the process of gaining trust and optimising decision-making. In an ensemble forecast, the forecasting model is run multiple times, with a varying set of initial conditions and model stochastics. This variation is imposed in such a way that the resulting spread of model outcomes represents the uncertainty in the forecast. This enables the forecaster to distinguish different scenarios of future weather and to determine the likelihood of a future event [20].

Ensemble models are more suitable for decision-making than forecasts with only one, 'deterministic' outcome [21, 22]. Examples in the water-management sector have already shown the benefits of using ensemble weather forecasts to reduce damage and losses due to flooding [23, 24]. However, even though global ensemble models have already been operational for 25 years, their use is not very widespread. Indeed, most free weather information apps on smartphones are based on deterministic forecasts.

The best-known global ensemble weather models are the American Global Forecasting System (GFS) and the model of the European Centre for Medium-range Weather Forecasting (ECMWF) [25, 26]. Some national meteorological agencies run their own national ensemble forecasting models. However, the huge computational demands imposed by running ensemble models mean the number of these models is currently limited.

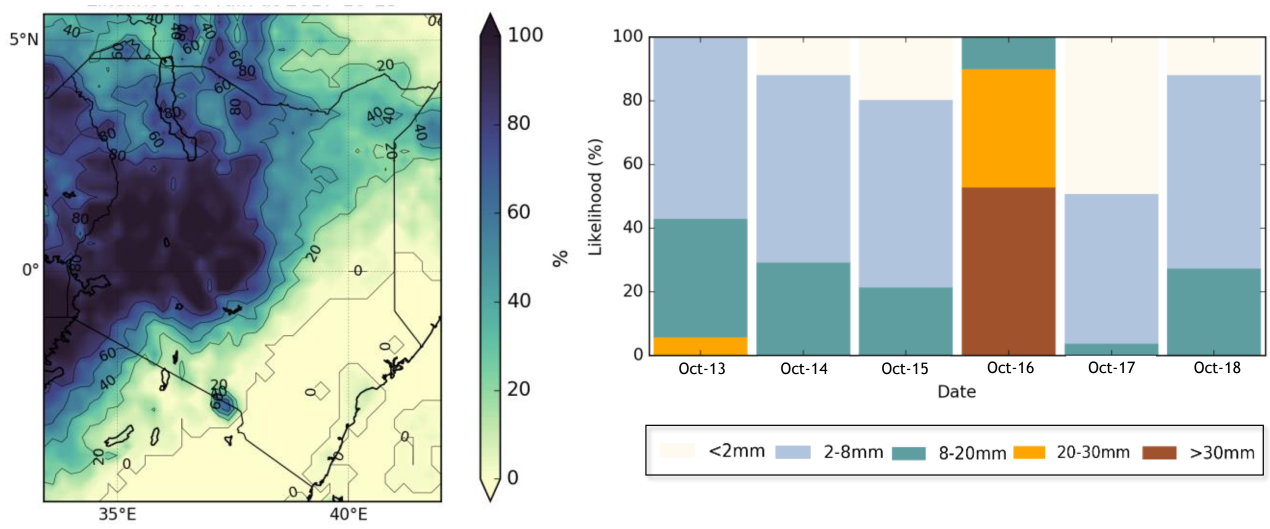

Figure 4. Ensemble weather models show the likelihood of weather conditions in time and space. Left: Likelihood of rain over Kenya for 13 October 2017. Dark blue colours indicate a high likelihood of rainfall. Right: Probability distribution of rainfall for the second week of October for a location of coffee farmers close to Mount Kenya. For 16 October, very high rainfall is expected. Data provided by the operational ECMWF model.

Scarcity of ground measurements

Statistical data techniques can be applied to reduce the uncertainty in weather forecasts. Calibration or statistical post-processing can provide substantial additional information, compared to the raw forecasts, if sufficient ground stations are available [27]. In general, however, the availability of weather stations in Africa is insufficient to produce such advanced model output statistics. The paucity of data throughout Africa, even from synoptic meteorological stations, consequently results in a poorer quality of forecasts in those regions.

A dense network of observations contributes to a better initialisation of weather model simulations, improved understanding of climate patterns and weather variability, more reliable early warning systems and improved validation of weather models. Weather stations are often successfully installed in *ad hoc* projects, but less attention is paid to subsequently maintaining such stations. Unfortunately, we currently lack the required numbers of meteorological stations, and this hampers efforts to improve forecasts, as well as the ability to downscale their results. The World Meteorological Organization estimates a need for an additional 4,000-5,000 basic meteorological observation stations in Africa [28] in order to significantly improve the situation.

Case study 2: User validation of local weather service, Northern Ethiopia

The weather forecasts in this case are based on the model of the European Centre for Medium-range Weather Forecasting (ECMWF), which is regarded as one of the best global weather forecasting models available. During the case study, the model output was compared to measurements from ground stations maintained by the national Ethiopian weather service (NMA). For the test sites, the forecasts based on the ECMWF model proved to have 80-90% accuracy for rainfall in the next three days [33], and were therefore regarded as very informative for small-scale farmers.

During the summer season of 2017, 1500 sesame farmers who joined the project pilot in Northern Ethiopia received a twice-weekly weather forecast (based on the ECMWF model) by text message in their local language. The participants regarded the messages as "having a significant effect on the performance of their farm activities". Rainfall forecasts proved to be the most valuable source of information for these farmers, more so than temperature and wind forecasts. Of all the pilot farmers interviewed during the study, 96% reported the short-term rainfall forecasts to be accurate. They stressed that the information should be provided in a straightforward and easy-to-understand message [34].

Figure 5. Melisew Misker Belay, an employee of the Benefit - Sesame Business Network, interviews one of the few female farmers in front of her house. She was one of the sesame farmers in Northern Ethiopia who received a weather forecast by mobile phone. The farmers involved were interviewed to evaluate the service and improve it for the next season. Photo: Benefit - Sesame Business Network.

Future of mobile weather services

All the key ingredients for mobile weather information services on the African continent are available, while weather forecasting models are improving and growing numbers of small-scale farmers now have access to a mobile phone, either their own or one owned by an extension worker or a community.

Weather Impact has recently been involved in five projects in East and Southern Africa providing weather information to thousands of farmers via various communication channels. In this section we share the lessons learned and the main drivers for success.

Case study 3: A value chain of public-private partners in South-Africa

The objective of the Rain for Africa project is to compile the best available weather and climate data and to make them easily accessible for food producers, the national weather service and other potential users of meteorological information in South Africa. The project aims to make data available at an affordable price for each user. The sustainability of the project results is being achieved through an innovative partnership of public weather and water institutes, agronomic value chain stakeholders and the private sector in the role of 'added value provider'.

National weather services can provide the best weather information and data, but delivering commercial services is not their core activity. Added value providers are consequently needed to make tailored weather services for end-users. The backbone of the service in this case is HydroNET, an international ICT platform, on which the project services are being developed [35]. The project has co-created an innovative business model, where commercial players ensure financial sustainability, and where small-scale farmers can access the platform free of charge in return for sharing their personal and local weather observations. One of the main reasons why international platforms such as HydroNET can ensure long-term and reliable delivery of weather services is that they are based on ICT cloud technology, where all users can share the funding needed to sustain the operational information streams.

Five critical success factors

Location-specific and reliable forecasts

Providing high-quality forecasts is essential; in other words, forecasts should be credible and reliable. Weather forecasts are always uncertain to some extent; the challenge is to estimate, understand and reduce the forecasting uncertainty as much as possible, and then to help users deal with the remaining uncertainties. Using the best available ensemble weather forecasting models and applying appropriate data techniques and statistics enable us to reduce the uncertainty in the forecasts to a minimum.

By targeting farmers at their location, service providers can ensure farmers receive the most appropriate message for their area. If a farmer is illiterate or unable to read a map, it is impossible to pinpoint the farm's location. To register such farmers, telephone GPS locations therefore have to be used. This is not always possible with basic mobile phones, however. Alternatively, extension workers can go into the field to register the farmer. Even though this is labour-intensive work, it can be justified by the improved reliability of a local forecast compared to a regional forecast.

Information and technology tailored to user needs

For scheduling purposes, rainfall forecasts covering at least one week ahead are the top priority for most farmers. Temperature, wind and humidity may also be important, given that some crops are sensitive to specific weather conditions. The ripening of sesame, for example, is very sensitive to strong winds, while coffee is highly sensitive to heat waves. It is important to tailor the type of information to the crop the farmer is growing and to the type of farm-management measures available to the farmer.

Providing information in the local language is also important, but translating messages into indigenous languages can be challenging, particularly in countries where numerous national languages or dialects exist. In Ethiopia, for example, more than 80 different languages are spoken. Translating messages from English into indigenous languages may pose problems since the meaning of a word may differ from one region to another. Reliable translations need to be made by local experts who are familiar with the language or dialect, the farmers, the use of common symbols and the local weather jargon.

Mobile phones are the primary devices we use for communicating with small-scale farmers. These phones allow the basic data transfers needed to convey the message and to request information, both for the farmer and for the service. In Table 1 (page 5), we have listed the various technologies available, together with their advantages and limitations. In summary, weather information should be targeted to farmers' needs and be:

- specific to their crops and farm-management activities;
- provided in the local language;
- accessible via available channels and easy-to-use technology.

Service embedded in existing local networks

Users' trust in a weather information service stands or falls with the availability of extension workers or agronomic experts. Such experts have the lead in engaging farmers for the service and supporting them in their continued involvement. People from local networks should be from the same culture and speak the right language. Farmer networks are indispensable for reaching large numbers of end-users, while cooperatives and unions can also promote the services among their members.

In our experience, dedicated workshops are needed to inform farmers of the service, to engage them in designing the local service process and to register them for participation. When the service is finally operational, extension officers can help farmers to learn to interpret messages and to make weather-smart decisions.

National weather services need to approve the service

National weather services are the local authority for providing weather information and weather alerts. Local legislation and regulations often do not allow parties other than the national weather service to provide weather forecasts. Approval by the national entity is often essential, therefore, for setting up a sustainable and trustworthy weather service. Including national weather services in the information chain allows an unambiguous series of messages to be issued and prevents confusion being caused by having to follow different weather information sources.

The network of long-term, ground-based observations maintained by the national weather service is often another important source of information. These national weather services also have a unique role to play in monitoring and archiving these weather observations. A relatively new source of valuable information is crowdsourced monitoring of meteorological variables, such as the WMO-compliant Tahmo stations [29] and other crowd platforms [30, 31]. Although arranging to collaborate with national weather services can be time-consuming, it is definitely important for achieving reliable and sustainable weather forecasting [32].

Involving the right business partners

Reaching large numbers of users willing to pay for the forecasting services in rural communities with high poverty rates is challenging. If the aim is to make an operational weather service sustainable into the longer-term future, it is essential to keep focusing on the long-term business perspective, right from the start. Long-term objectives for sustainable services can be achieved by setting up business lines in various ways, either directly in the form of paid services for farmers, or indirectly via stakeholders. Commercial parties can play a role in financing such services; for example, through advertisements of their products.

Weather- and climate-resilient farming in Africa

The years to come are expected to witness an increase in weather services for small-scale farmers in Africa. Specific farm advisories are a logical follow-on from conventional general weather forecasts and can include, for example, planting advice based on monitored and forecasted rainfall, or spraying advice when weather is favourable for the development of fungal diseases. Weather services can be provided in many ways, ranging from basic mobile-phone services for small-scale farmers to advanced web-based information sources for commercial enterprises. High-quality services to support small-scale farmers in the field can be developed in close partnership with all stakeholders.

This paper aims to provide inspiration for setting up such partnerships. Let’s collaborate to increase the food production of small-scale African farmers and to make them more weather- and climate-resilient!

Weather Impact

About us

This paper was written by Weather Impact to share our experience of mobile weather services for small-scale farmers. Weather Impact is performing various projects in Africa with the aim of improving both local food production and the livelihoods of farmers. Weather Impact's mission is to provide agronomical organisations with the weather and climate information they need to optimise food production and food quality, to reduce the use of scarce inputs, to reduce costs and to improve environmental and human wellbeing.

Weather Impact provides real-time data analysis to support optimal decision-making for African crop growers, producers and traders. If you are interested in cooperating with us, go to www.weatherimpact.com or contact us via info@weatherimpact.com.

This paper discusses research and development case studies from the following G4AW projects (www.g4aw.spaceoffice.nl/en/):

- CropMon, Kenya
  Partners: *Soil Cares Research, Sugar Research Institute, Coffee Management Services, Equity Group Foundation, Cereal Growers Association, Soil Cares Limited, NEO, Weather Impact. YouTube: https://youtu.be/hciFDU0m5dk*
- CommonSense, Ethiopia
  Partners: *Wageningen Environmental Research, Apposit, Ministry of Agriculture of Ethiopia, Airbus Defence and Space Netherlands, ExoTalent, Busaa Gonofaa, SFPI, HARBU, ICCO/Terrafina, Weather Impact, National Meteorological Agency Ethiopia, Benefit - Sesame Business Network.*
- Rain 4 Africa (R4A), South Africa
  Partners: *Agricultural Research Council, South African Weather Service, Royal Netherlands Meteorological Institute, HydroLogic, eLEAF, Weather Impact, Wine Job, Water Authority Drents Overijsselse Delta.*

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