# Mobile technology for rural climate resilience: The role of mobile operators in bridging the data gap

The GSMA represents the interests of mobile operators worldwide, uniting more than 750 operators with nearly 400 companies in the broader mobile ecosystem, including handset and device makers, software companies, equipment providers and internet companies, as well as organisations in adjacent industry sectors. The GSMA also produces the industry-leading MWC events held annually in Barcelona, Los Angeles and Shanghai, as well as the Mobile 360 Series of regional conferences.

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## GSMA AgriTech Programme

The GSMA AgriTech Programme works towards equitable and sustainable food chains that empower farmers and strengthen local economies. We bring together and support the mobile industry, agricultural sector stakeholders, innovators and investors in the AgriTech space to launch, improve and scale impactful and commercially viable digital solutions for smallholder farmers in the developing world.

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# Contents

# 1. Executive summary

Agriculture is highly dependent on regional climates, especially in developing countries where farming is largely rainfed. Smallholder farmers, responsible for the bulk of agricultural production in developing countries, are particularly vulnerable to changing weather patterns - given their reliance on natural resources and exclusion from social protection schemes. Climate change brings about variation in regional climate, ultimately affecting agriculture through changing rainfall patterns, drought, flooding and the geographical distribution of pests and diseases.

Building up climate resilience can enable smallholder farmers to withstand climate change while maintaining agricultural productivity. Although managing climate change in agriculture includes adaptation and mitigation approaches, this report will focus primarily on adaptation techniques. As the agricultural sector is impacted by climate variability, adaptation techniques can bring about better climate resilience amongst rural communities. However, climate resilience products are not widely available to smallholder farmers. Developing countries have historically struggled to provide climate resilience products such as weather forecasts and insurance against climate shocks. This is primarily due to a lack of sufficient weather stations, historical data and technical capacity to generate reliable climate resilience products for rural populations.

With ever increasing mobile penetration, mobile network operators (MNOs) can play a bigger role in developing and delivering services to strengthen the climate resilience of smallholder farmers. The pervasiveness of mobile has led to an uptake of agricultural value-added services (Agri VAS) amongst rural communities, resulting in weather forecasts becoming increasingly available via SMS.[1] The growth of mobile connectivity in rural areas is also creating more opportunities to use MNO assets to generate valuable data for climate resilience products, from user location data that support relevant, hyperlocal services, to actual weather data. A growing number and variety of objects are also being used as sensors to monitor environmental variables, opening new possibilities for Internet-of-Things (IoT) based weather products. Although not originally designed for this purpose, "virtual sensing" allows weather data to be collected from smartphones, connected cars and commercial microwave links (CMLs) used in mobile networks to transmit signals.[2]

By harnessing their own assets and data, MNOs can strengthen the value proposition for a broad suite of weather products that are especially relevant for farming communities. These include a variety of weather forecast products (daily, weekly, sub-seasonal and seasonal) and nowcast products, as short-time predictions for a period of up to six hours that are used in Early Warning Systems (EWS) for the prevention of weather-related disasters (Table 1).

MNOs can also help strengthen the value proposition of other climate resilience products, such as weather index insurance and decision agriculture. Weather index insurance protects farmers against severe weather or crop failure, and can help to manage the risks associated with adaptation to new or changing conditions, such as extreme rainfall that leads to crop loss. Decision agriculture, or data-driven agriculture, combines big data collected from multiple sources to complement farmers' knowledge and techniques and inform decisions about planting, growing, harvesting and transporting crops. Decision agriculture uses data from multiple sources (e.g. weather stations, satellites, and soil and crop sensors) and farm location data to optimise crop production down to the individual plant level.

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1. Tricarico, D. (2016). *Agricultural Value-added Services (Agri VAS) Toolkit 2.0*, GSMA mAgri.
2. ClimaCell. (2019). *Part 2: Virtual Sensing*. Available at https://www.climacell.co/virtual-sensing

Table 1

Source: GSMA AgriTech Programme

## Agriculture-specific climate resilience products for smallholder farmers

| WEATHER PRODUCTS | | CLIMATE SERVICE PRODUCTS | |
|---|---|---|---|
| WEATHER NOWCASTS | WEATHER FORECASTS | AGRICULTURAL INSURANCE | DECISION AGRICULTURE |
| 1-2 HOURS | DAILY | WEATHER INDEX INSURANCE | HYPERLOCAL WEATHER FORECASTS<br>AGRONOMIC ADVICE |
| EARLY WARNINGS | WEEKLY | CROP INSURANCE<br>YIELD INSURANCE | |
| | SUB-SEASONAL | | |
| | SEASONAL | | |

Ground-level measurements are an essential component of climate resilience products. Weather forecasts and nowcasts, for example, are generated from the analysis of ground, spatial and aerial observations. This analysis involves the use of algorithms, weather models and current and historical observational weather data. Accurate weather observations, both current and historical, are also crucial to weather index insurance products, which trigger payments to farmers based on low or excess observed rainfall compared with historical rainfall indexes. Weather monitoring infrastructure, such as radar and weather stations, or, alternatively, observations from satellites, must be available to provide ground-level weather measurements. However, National Hydrological and Meteorological Services (NHMSs) in developing countries too often lack the capacity to generate accurate ground-level measurements beyond a few areas, resulting in persistent gaps in local weather data.

Although satellite data has become cheaper, offers better quality and is more available to NHMS, its ability to show accurate and granular ground-level measurements remains limited. Additionally, in tropical and sub-tropical regions where many smallholder farmers live, variable local weather patterns can skew averages from satellite data.

An emerging alternative source for ground-level measurements, and a prominent virtual sensing technique, is the use of CMLs, a by-product of any mobile network. CMLs are ground-level radio connections used in mobile telecommunication networks globally. During rainfall, these microwave signals are attenuated, leading to changes in the signal strength between transmitting and receiving base stations. Using an algorithm, CML data can be analysed and converted into realistic and accurate rainfall measurements, effectively turning a mobile network into a virtual network of rain gauges. A series of pilot projects conducted by the GSMA, Wageningen University & Research and the Royal Netherlands Meteorological Institute (KNMI) with MNOs in Bangladesh, Nigeria and Sri Lanka confirmed that CMLs can be used to measure rainfall in tropical conditions. The pilots also uncovered specific challenges and requirements related to the use of CMLs in practice, such as the need to optimise the algorithms required to interpret and map CML data for each region.[3]

In addition to CMLs, MNOs can improve climate resilience products by co-locating IoT-enabled automated weather stations (AWSs) with their base stations and providing location data for the delivery of specific weather information. For example, UNDP's Climate Information for Resilient Development in Africa (CIRDA) initiative has worked on improving the capacity of African NHMSs including installing AWSs at MNO base stations. In one of its projects, CIRDA set up 11 AWSs at base stations in Liberia to improve weather forecasting in the country.[4]

3. The algorithm used to analyse CML data in the first GSMA-supported pilots in Bangladesh, Nigeria and Sri Lanka was optimised for use in the Netherlands. As a next step, GSMA plans to adjust the algorithm to the weather parameters of targeted tropical countries.

4. Benchwick, G., et al. (2016). *A new vision for weather and climate services in Africa.* UNDP.

With the necessary infrastructure already in place, MNOs have an opportunity to improve the quality of climate resilience products for smallholder farmers and rural communities, and open up new revenue streams. To use CML data in particular, MNOs will need to establish viable business models and partnerships with NHMSs and commercial weather companies. Once partnerships are in place, MNOs will have an important role to play in promoting climate resilience through improved weather and climate resilience products.

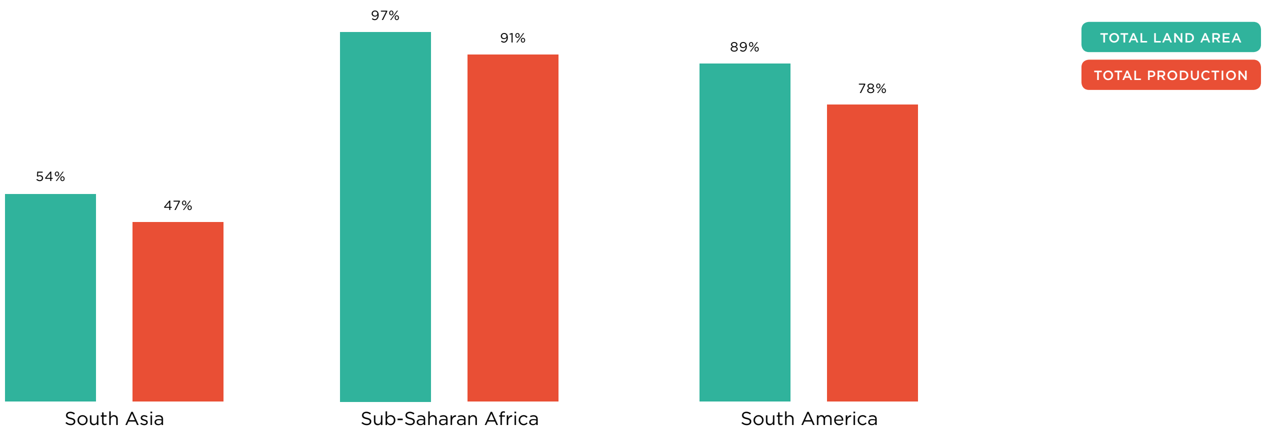
# 2. Introduction: Climate resilience in developing countries

Climate varies naturally over time, but the recent increase in variability is resulting in more extreme weather events and unpredictable weather patterns. These noticeable and drastic changes in the weather have led to climate change becoming a defining crisis. Climate change refers to "changes beyond the average atmospheric condition that are caused both by natural factors such as the orbit of earth's revolution, volcanic activities and crustal movements and by artificial factors such as the increase in the concentration of greenhouse gases and aerosol".[5]

Agriculture is a climate-dependent industry with varying regional ecosystem characteristics based on a region's climate.[6] Climate change disrupts agricultural ecosystems, leading to changes in agro-climatic elements, such as temperature, precipitation and sunlight, while also affecting arable and livestock agricultural production. In developing countries, agriculture is largely rainfed, especially in Sub-Saharan Africa. While countries in South Asia, such as Pakistan, have relatively better access to irrigation, their agriculture sectors still depend predominantly on rain (Figure 1). This is important considering the significant role of agriculture in developing economies. As of 2016, agriculture represented 32.3 per cent of GDP value in low-income countries and 16.7 per cent in lower-middle-income countries.

Figure 1 Source: IFRPI

## Rainfed agriculture as a percentage of total agricultural land and total agricultural production (2016)




5. Kim, C.G. (2012). *The Impact of Climate Change on the Agricultural Sector: Implications of the Agro- Industry for Low Carbon, Green Growth Strategy and Roadmap for the East Asian Region.*
6. Ibid.

Smallholder farmers are among the most vulnerable communities in developing countries and already cope with a variety of challenges, from poor natural resource management (especially water and land) to limited land tenure security, small farm sizes, lack of access to technology and up-to-date information, low market access and limited investment.[7] Climate change multiplies these risks for smallholder farmers, given their dependence on natural resources and lack of access to social protection systems and safety nets. Ultimately, the effects of climate change will disproportionately affect smallholder farmers and severely test their capacity for resilience.

## What is climate resilience and why is it important?

Climate resilience refers to "the capacity of a community or biological system to organise or adapt itself to stresses and changes by absorbing the changes and/or obstacles".[8] It is the ability of a community or biological system to withstand changes while maintaining its functions and structure. Resilience involves developing adaptation solutions and implementing actions to respond to the impacts of climate change that are already happening while also preparing for future impacts.

Climate hazards can have a profound impact on people and communities. With few social protections in agriculture-dependent economies, building climate resilience among smallholder farmers is a unique opportunity to secure livelihoods and reduce inequalities. There are several ways to address climate change for small-scale agriculture, including reinforcing on-farm capacity (both to enhance labour and agricultural productivity) and assets; diversifying on-farm and off-farm activities; building resilience through social protection systems; and understanding risks that can affect agriculture indirectly, such as growing populations, environmental degradation and economic protectionism.[9]

## Solutions to improve climate resilience

Climate resilience includes the use of specific solutions and techniques to adapt to changing climate trends. Weather and climate information is a prime example of an adaptation solution that is important for both urban and rural dwellers. The dissemination of accurate, granular weather forecasts to farmers offers a significant opportunity to support farming decisions. It is also possible to achieve adaptation through improved agricultural extension and advisory services that can lead farmers to adopt climate-smart technologies and practices. Adaptation techniques include the use of diversification strategies, such as agroforestry and intercropping, promoting conservation agriculture and sustainable mechanisation, the use of improved seed varieties and using water efficiently.[10]

Crop insurance, weather index insurance and livestock insurance have become key tools for strengthening the climate resilience of rural communities. Sustainable land management practices can improve soil carbon storage, encourage more efficient fertiliser use and improved water use (i.e. water harvesting or producing more crops with the same amount of water), and promote the use of fewer carbon-intensive inputs.[11]

However, not all these climate resilience products are accessible at scale to smallholder farmers in developing countries. Developing countries have historically faced challenges providing even basic services, such as weather forecasting, due to a lack of equipment (i.e. weather stations), historical data and technical capacity to generate weather information for urban and rural areas.

## The role of digital technology in climate resilience

The emergence of low-cost digital technologies has created an unprecedented opportunity for mass collection, aggregation and dissemination of

7. Lewis, P. and Adbel Monem, M. (2018). *Impacts of Climate Change on Farming Systems and Livelihoods in the Near East and North Africa.* Food and Agriculture Organisation of the United Nations (FAO).
8. Kim, C.G. (2012). *The Impact of Climate Change on the Agricultural Sector: Implications of the Agro- Industry for Low Carbon, Green Growth Strategy and Roadmap for the East Asian Region.*
9. Lewis, P. and Adbel Monem, M. (2018). *Impacts of Climate Change on Farming Systems and Livelihoods in the Near East and North Africa.* FAO.
10. Reno, C. (2019). *From theory to practice: Perspectives on climate-smart agriculture in India and Africa.* ORF Issue Brief, No. 290.
11. Ibid.

information and data at the farm level in developing economies. The cost of new technologies has been declining, opening access to innovative solutions, including those that support climate change adaptation in farming communities. Much of this innovation has come from the private sector, where specialised weather companies are now able to create and distribute weather forecasts. The role of the private sector is crucial in addressing some of the shortcomings of the NHMSs in generating the weather products that local communities need.

Technological improvements in weather monitoring and forecasting have emerged in recent years, in part driven by increased private sector participation (see figure 2).

Figure 2

Source: GSMA AgriTech Programme

## Technological improvements in weather monitoring and forecasting

| INFRASTRUCTURE | COMPUTING AND SOFTWARE | OUTPUTS |
|---|---|---|
| LOW-COST WEATHER SENSORS | IMPROVED CLOUD COMPUTING | REAL-TIME WEATHER DATA |
| ACCESSIBLE SATELLITE DATA | ADVANCED ANALYTICS AND MODELLING | LOCALISED AND SPECIFIC FORECASTS |
| UBIQUITOUS MOBILE COVERAGE | ENHANCED BIG DATA STORAGE | SEVERE WEATHER WARNINGS |
| IMPROVED NETWORK CONNECTIVITY | | ACCESSIBLE HISTORICAL DATA |

Technological advancements in infrastructure, computing and software for weather forecasting offer potential for more accurate weather information, especially in regions where established weather monitoring tools, such as weather stations and radar, are absent. Improved infrastructure includes the introduction and use of low-cost weather sensors. Organisations other than NHMSs, such as private weather companies and NGOs, are deploying low-cost weather stations for meteorological observations on the ground. For instance, the Trans-African Hydro-Meteorological Observatory (TAHMO)[12] has set up a network of co-located AWSs at schools across several African countries. Weather data collected by TAHMO's weather stations can be accessed via an API, a web portal and, for NHMSs, via a data-sharing agreement. As of 2018, TAHMO had deployed 478 stations in 18 countries across Sub-Saharan Africa.[13]

Satellite data has become more widely available for weather observations, filling in gaps from sparse ground measurements. For example, the Global Precipitation Measurement (GPM)[14] mission provides near real-time global weather observations of rain and snow to improve forecasting. A growing number of organisations are providing a range of satellite data sets for numerical weather predictions (NWPs). The US National Oceanic and Atmospheric Administration (NOAA), collects geo-observations through its satellites and offers access to rebroadcasts of its satellite data to NHMSs in developing countries. The NHMSs can access this data by purchasing a small

12. Trans-African Hydro-Meteorological Observatory: https://tahmo.org/
13. Mwangi, G. (2018). *TAHMO: Donor-funded projects in Africa.*
14. The Integrated Multi-Satellite Retrievals for GPM (IMERG) by NASA's Precipitation Processing System generate global precipitation data every half hour with a 6 hour latency from the time of data acquisition. Data from GPM IMERG is freely available to download at https://pmm.nasa.gov/gpm/imerg-global-image

antenna or computer for under USD 1,000.[15] Other organisations, such as the National Aeronautics and Space Administration (NASA) and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), have made significant volumes of satellite data sets available - many free of charge.[16]

As mobile connectivity continues to spread, there is also a growing opportunity to connect a variety of objects that generate weather data. "Virtual sensing" relies on connected objects not specifically designed to collect weather data to monitor environmental variables. Examples include the collection of weather data through smartphones or connected cars. Smartphones can assess atmospheric conditions by measuring data points like atmospheric pressure, temperature and humidity, while cars can provide intricate detail on rainfall when wipers are activated or on poor visibility using fog lamps.[17] Analysing and processing data from millions of smartphones could lead to real-time forecasts, which in turn could be sent to smartphone users as weather alerts or forecasts.[18] Developing countries may lack sufficient weather stations, but growing smartphone use across Sub-Saharan Africa and Asia could lead to better weather monitoring and predictions.

Progress in computing and software development has led to the use of affordable cloud computing and big data storage solutions. Developments in advanced data analytics and modelling has led to better data analysis and interpretation using open-source and proprietary software, as well as algorithms. This has made real-time or near real-time weather information available to support regular, accurate and localised weather information.

This report presents the emerging opportunity to use digital and mobile technology to improve climate resilience products for smallholder farmers in developing countries. This includes using data from MNOs to add value to existing products or to create new climate-smart solutions. In addition to generic weather forecasts, there is a need for solutions that can help farmers adapt to both gradual changes in weather patterns and to extreme weather events, such as droughts and floods. While weather information allows better decision making, insurance services and access to finance can enable farmers to invest in solutions that help them adapt to climate change.

## 2.1 How can smallholder farmers become climate resilient?

### The impact of climate change on smallholder farmers

For those whose livelihoods depend on agriculture and who are resource-constrained, climate risks add to the many challenges they face, making them even more vulnerable. These risks include failed harvests and falling yields, changes in pest and disease epidemiology, and asset loss and damage. Yields of subsistence crops, such as wheat, maize, rice and potatoes, can be reduced by erratic rainfall, rising temperatures and evapotranspiration stress.[19] The impact of climate variability can ultimately lead to the displacement of vulnerable populations and the loss of homes, assets and livelihoods.

### Existing climate resilience techniques

Table 2 shows a selection of adaption techniques for two interconnected parts of the value chain, production and support services.[20]

15. Phillips, J. (2018). *Freely shared satellite data improves weather forecasting.*
16. Gray, B., et al. (2018). *Feed the Future: Digital Farmer Profiles: Reimagining Smallholder Agriculture.*
17. ClimaCell. (2019). *Part 2: Virtual Sensing.* https://www.climacell.co/virtual-sensing
18. ScienceDaily. (2018). *Smartphones may be used to better predict the weather.*
19. Irish Aid and IIED. (2017). *Guidance note: Promoting climate-resilient agriculture in smallholder farming.*
20. Reno, C. (2019). *From theory to practice: Perspectives on climate-smart agriculture in India and Africa.* ORF Issue Brief, No. 290.

Table 2

Source: Reno, C. (2019). From theory to practice: Perspectives on climate-smart agriculture in India and Africa.

## A selection of climate resilience adaptation techniques

| VALUE CHAIN SEGMENT | ADAPTATION TECHNIQUES |
|---|---|
| Production | Conservation agriculture and sustainable mechanisation.<br>Diversification through agroforestry, intercropping or other diversification strategies.<br>Improved seed varieties that are adapted to climate change (e.g. drought resistant, heat tolerant and flood tolerant).<br>Irrigation (based on water availability). |
| Support services | Crop and livestock insurance for climate risk adaptation.<br>Agricultural extension services to increase adoption of climate-smart technologies by farmers.<br>Climate information services/climate models to support farming decisions, develop agricultural advisories and disseminate to farmers based on the seasonal weather forecasts. |

Digital solutions can play a role in climate adaptation at both the production and support services segments. Production-level examples include: SunCulture's solar-powered irrigation pump RainMaker2,[21] which improves water use by sending farmers personalised irrigation recommendations; and Access Agriculture's Agtube,[22] which promotes sustainable agriculture through training videos to farmers, pastoralists and rural businesses.

Examples at the support-services level include weather products, such as Orange Mali's Sandji[23] service, which provides users with localised daily, monthly or seasonal forecasts via SMS. In Kenya, ACRE Africa's Bima Pima[24] offers insurance for crop damage or poor harvests caused by drought or excess rainfall. In Zambia and Malawi, Pula[25] bundles agricultural inputs with satellite-based weather insurance and agronomic advisory to smallholder farmers to boost yields.

### Overcoming scale and barriers to adoption

Despite the promotion of best practices to create well-functioning and resilient agricultural value chains, there are still barriers to scaling and adopting adaptation techniques. For instance, any technology that requires specialised equipment or significant capital investment will have low adoption among poor rural households. Equally, agronomic advice sent to smallholder farmers via SMS relies on high literacy levels and network connectivity.

Adaptation to new and emerging risks requires access to knowledge, technology and finance. Digital technology and services can play a crucial role in scaling climate-smart solutions that support climate resilience. The use of digital information services to provide agronomic advice, for instance, can raise awareness of soil management and lead to changes in farming practices

21. SunCulture's Rainmaker: https://drive.google.com/file/d/1t9bjNGDJgdua0mDIJdUL9VdcqMicTKNt/view
22. Agtube: https://www.accessagriculture.org/agtube
23. Bouaré, Y. (2018). *Weather information by phone in Mali life-changing for farmers in Tèrèkungo and Parana.*
24. Bima Pima: http://acreafrica.com/bima-pima/
25. Pula: https://frp.org/finance-oriented/pula

based on a farm's location. Equally, remote or sensor-based pumps can support irrigation (depending on water availability) and make water use more efficient.

For example, Dialog Axiata has been offering comprehensive advice to farmers in Sri Lanka through its Govi Mithuru[26] (Farmer's Friend) Agri VAS since October 2015. Phone surveys and field work were carried out in 2017 amongst a number of its users to understand changes in farming behaviour. Many users identified the benefits brought about by the advice provided, with some noting an improvement in soil fertility and a lower reliance on chemical fertilisers.

While digital solutions can improve access to climate resilience knowledge and technology, finance is also a necessary component, both in terms of improving access to financial services for farmers and financing initiatives that help farmers become more climate resilient. A number of weather index and yield index insurance service providers have already launched pilot services across Sub-Saharan Africa and Asia. While microinsurance services can serve as a first step for smallholders to gain access to climate resilience-specific financial services, other offerings such as savings, credit, mobile money and even micro-pensions could be gradually introduced to improve farmers' ability to withstand climate-related shocks. Initiatives to promote climate resilience among smallholder farmers require risk capital to become sustainable. For instance, Pula's pilot in Zambia and Malawi aims to reach over 700,000 farmers by 2023. MasterCard Foundation's Fund for Rural Prosperity is supporting Pula's aim to scale their service beyond a pilot.[27]

## 2.2 How can mobile technology enhance climate resilience products for rural communities?

MNOs are uniquely placed to leverage their assets and data to develop and deliver localised, tailored products that address climate variability. Through partnerships, they can support innovative mobile solutions for climate resilience and provide comprehensive information and financial service bundles that can help farmers adapt to the effects of climate change.

In agriculture, mobile networks are used primarily as a communication and payments channel. Mobile is used to send agronomic advice and weather forecasts to smallholder farmers. Agronomic advice is often sent to farmers about the crops they grow, tailored to the location of their farms. Airtel Malawi's M'chikumbe Agri VAS, which can be accessed by dialling 212, allows farmers to access practical information about agriculture via interactive voice response (IVR) and SMS. Farmers are required to register for one of 15 crops, which enables them to access a menu with relevant crop information, as well as Airtel Money advice, market prices and weather information.[28]

Mobile technology can also be used to determine a user's location. User location data is important for value creation because it enables highly granular services, such as hyperlocal weather forecasts.[29] It is possible to obtain location data in a variety of ways, including using network-based call detail records (CDR), triangulation via base stations, GPS via smartphones and data collection at the point of user registration via SMS or apps. The most common way of capturing a user's location is still at registration when users sign up for a service, such as a weather advisory, and select their approximate location from a list. In markets with low smartphone penetration, there is a growing opportunity for MNOs to automate the collection of location data using Location Based Software (LBS).[30] Through this method, an MNO triangulates the cell ID that identifies each base station or the sector of a base station with a Location Area Code. It is then possible to identify the approximate location of the user.

26. Palmer, T. and Darabian, N. (2017). GSMA Govi Mithuru/Uzavar Tholan: A mobile agriculture service by Dialog, Sri Lanka.
27. Kisada, P. (2018). *Mastercard awards $2.8M to 3 companies from Uganda, Burundi & Malawi,* DigestAfrica.
28. Palmer, T. and Darabian, N. (2017). *M'chikumbe 212: A mobile agriculture service by Airtel Malawi.* GSMA mAgri Case Study.
29. Tricarico, D. and Darabian, N. (2016). *GSMA mAgri Weather forecasting and monitoring mobile solutions for climate resilience.*
30. Location technologies can be divided into handset-based technologies (GPS) with intelligence mainly in the handset; network-based technologies (Cell-ID, RF Pattern Matching and Uplink-Time Difference of Arrival, U-TDOA) with intelligence mainly in the network, as well as hybrid technologies (for instance Assisted-GPS and Observed Time Difference of Arrival, OTDOA) with intelligence in both the handset and the network.

For example, in Pakistan, Telenor has partnered with LMKT, an IBM partner, to provide hyperlocal hourly and daily weather forecasts to its rural customers as part of its Agri VAS Khushaal Zamindar. User locations are determined using LBS, and subscribers can receive forecasts free of charge by dialling 7272 and choosing their preferred format (SMS or outbound dialling) and language (Urdu, Punjabi and Saraiki) to receive alerts. Because of this partnership, Telenor now disseminates almost 6,000 unique forecasts daily to their users at a resolution of one square kilometre, in addition to agricultural and livestock advice. Such accessible, customised content has proved popular in rural communities, with the service now reaching over 7.5 million subscribers nationwide. Weather forecasts are now at the core of Telenor's content bundle.[31]

Mobile technology can also strengthen the delivery of digital weather index insurance services to farmers by becoming a distribution channel for microinsurance and by locating the farmer via LBS. Mobile money can play an important role by serving as a payment channel for premiums and for claim payouts. Well-known examples include ACRE Africa's Bima Pima[32] service in Kenya, which pays out for crop damage and poor harvests via mobile money, and EcoFarmer's Weather Indexed Insurance in Zimbabwe, which offers compensation for maize crop failure.

By leveraging LBS, weather companies can harness mobile technology and big data analytics to create hyperlocal forecasts. For insurers, LBS and mobile money are crucial in addressing common pain points for users, such as inaccurate farm location data and payment delays, and in reducing transaction costs. MNOs can also deploy a range of delivery channels to ensure that weather advisory and other services can reach rural communities with basic handsets. For example, in markets with low literacy levels, IVR or outbound voice dialling (OBD) is a more accessible format to convey weather information than text-heavy SMS or Unstructured Supplementary Service Data (USSD).

## 2.3 How can mobile technology address the ground-level weather data gap?

The creation of weather forecasts relies on the use of algorithms, weather models and current and historical observational data. Ground-level observations are particularly important. To obtain these, NHMSs use networks of weather stations, radar and stallite observations that measure the state of the weather on the ground and the lower atmosphere. However, NHMSs in developing countries lack the infrastructure to provide these measurements accurately. The availability of weather observations and historical rainfall data is also a crucial element in weather index insurance schemes, where payouts to farmers are triggered based on low or excess observed rainfall compared with historical rainfall indexes.

In developing countries, real-time and historical weather observational data are either difficult to obtain or simply do not exist. Where historical data does exist, it is often hard to find, understand and apply to decision making. Creating climate resilience products requires an understanding of historical climate and weather trends, which are used to model possible future trends. The challenge of accurately monitoring and predicting weather patterns is exacerbated in tropical countries where weather can be highly variable even within relatively small geographical areas.

Gaps in local weather data are an ongoing challenge in developing countries, which lack the necessary infrastructure to collect weather information beyond a few select areas. For example, the World Meteorological Organization (WMO) estimates there are only around 1,100 active weather stations in all of Africa – amounting to only one-eighth of the minimum density mandated by the WMO.[34,35] This sparse network has limited the ability of countries to predict high-impact weather events,

31. Telenor Group. (2018). *Sustainability Report.*
32. Bima Pima: http://acreafrica.com/bima-pima/
33. EcoFarmer: https://www.ecofarmer.co.zw/financial-services/ecofarmer-weather-indexed-insurance
34. Simmons, D. (2017). *How missing weather data is a 'life and death' issue.* BBC News.
35. WMO. (2014). *Integrated African strategy on meteorology (Weather and Climate services).*

and provide real-time, ground-level weather monitoring for nowcasting,[36] forecasting and insurance. In Africa, the average coverage area for a weather station is around 27,000 square kilometres. This level of coverage is inadequate to generate sufficient current data for weather monitoring, which needs at least 12,000 additional stations. To compare, Germany has around 290 weather stations, each covering an approximate area of 1,200 square kilometres.[37] Figure 3 shows the global distribution of ground-level weather observation stations, with Sub-Saharan Africa showing thin coverage compared to other regions.[38]

Figure 3

Source: Integrated Surface Dataset, NOAA

## Global distribution of surface observations[39]

Geostationary and polar-orbiting satellites have become increasingly important for ground-level measurements as they provide data that is subsequently used in weather forecasting models. Importantly, the vast majority of crop and weather insurance products available in Sub-Saharan Africa, such as WorldCover[40] and OKO,[41] rely almost entirely on satellite data for weather observations. Modern weather satellites carry sophisticated equipment that allows remote measurements of a variety of parameters, such as sea surface temperature, snow coverage, amount of water vapour, and wind speed and direction. Satellites also allow uniform global coverage, complementing gaps in ground-based networks.

Despite these advancements, satellites are still unable to provide accurate and granular ground measurements. In tropical countries especially, fluctuating local weather patterns can render satellite observations inaccurate and skew historical average weather data. One possible alternative to ground-level weather data is weather radar systems. Radar provides coverage of wide areas,

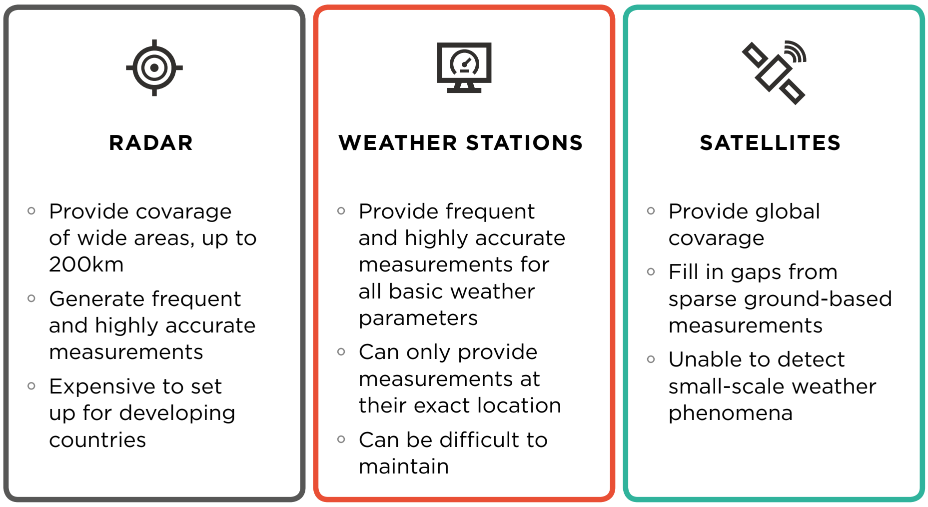
36. According to the World Meteorological Organisation, “nowcasting comprises the detailed description of the current weather along with forecasts obtained by extrapolation for a period of 0 to 6 hours ahead.” http://www.wmo.int/pages/prog/amp/pwsp/Nowcasting.htm
37. UNECA – African Climate Policy Centre. (2011). *An assessment of Africa’s climate observing networks and data, including strategies for rescuing of climate data.* Working paper 3.
38. Simmons, D. (2017). *How missing weather data is a ‘life and death’ issue.* BBC News.
39. Campbell Flatter, G. (2019). *Turning weather into opportunity: using weather-of-thing data to create pathways from poverty to prosperity.* ClimaCell – The MicroWeather Blog.
40. WorldCover: https://www.worldcovr.com/
41. OKO: https://www.oko.finance

up to 200 kilometres, and generates frequent and relatively accurate measurements. It has been vital in detecting the presence and locations of storms.[42] However, radar technology requires significant upfront investment and is expensive for developing countries. For instance, 122 Next Generation Weather Radar stations have been installed in the US since 1996 at a cost of USD 3.1 billion, and are currently undergoing costly upgrades to extend their lives from the minimum design age of 20 years to 35 years.[43]

Figure 4

Source: GSMA AgriTech Programme and Wageningen University

## Technologies for ground-level weather measurements




Given the lack of reliable ground-level measurements, MNOs have an opportunity to add significant value to a range of weather monitoring and forecasting services. Recently, MNOs have begun using CMLs as virtual weather sensors to monitor and map rainfall measurements. CMLs are close-to-the-ground radio connections used worldwide in cellular telecommunication backhaul networks. In telecommunications, backhauling refers to the connections and links between the core or backbone network and the small sub-networks at the edge of the network.

Along microwave links, radio signals propagate from a transmitting antenna at one base station to a receiving antenna at another base station. During rainfall, water absorbs and scatters these microwave signals, creating subtle changes to the signal strength between the transmitting cell phone towers. Using an algorithm, CML data can be analysed and converted into highly accurate rainfall measurements, effectively turning the mobile network into a virtual network of rain gauges. Commercial weather companies, such as ClimaCell,[44] and technology companies, such as Ericsson through its Weather Data Initiative,[45] have developed their own proprietary algorithms to analyse this data and develop weather-related services. An open source algorithm, known as RAINLINK, also exists as a result of a joint initiative between Wageningen University and KNMI.[46,47]

The use of CMLs for rainfall monitoring is a prominent example of so-called opportunistic or virtual sensing, as part of a broader ongoing trend where sensors are used to monitor environmental variables that they are not specifically designed to monitor. Rainfall

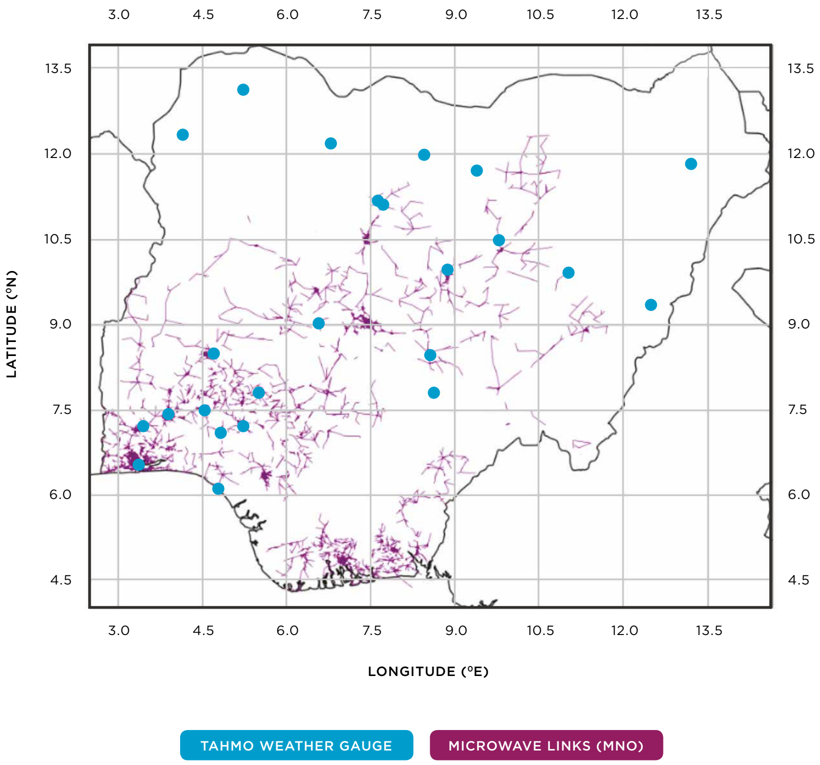
42. ETHW – Radar and Weather Forecasting. https://ethw.org/Radar_and_Weather_Forecasting
43. Pfeil, R. (2015). *U.S. Doppler Radar Stations Need $16.7 Million in Maintenance, Government Technology.*
44. Climacell: https://www.climacell.co/
45. The Weather Data Incubation Project – The Ericsson ONE Unit: https://www.ericsson.com/en/cases/2018/SMHI
46. RAINLINK Algorithm: https://github.com/overeem11/RAINLINK
47. Overeem, A., Leijnse, H. and Uijlenhoet R. (2016). *Retrieval algorithm for rainfall mapping from microwave links in a cellular communication network.*

retrieval via CMLs serves the twofold purpose of collecting rainfall data for real time monitoring and for the build-up of historical rainfall records. All these data points are crucial to a range of products, from weather nowcasts and forecasts to weather and crop insurance. Since MNOs already collect this data to monitor the stability of their networks, generating weather-specific observations incurs no additional infrastructure cost. With more than five million CMLs worldwide, the number of available rain gauges are easily outnumbered by CMLs - even areas without any gauges are covered by CMLs. Figure 5 below shows the distribution of weather gauges and CMLs in Nigeria.[48]

Figure 5

Source: Wageningen University

## Traditional weather gauges versus microwave links in Nigeria




48. Ericsson (2018). *Ericsson Microwave Outlook Report, 2018.*

# 3. The role of MNOs in improving climate resilience products

Through the use of mobile technology assets and data, MNOs are becoming an important private sector actor in the creation of a range of climate resilience products, from weather forecasts and nowcasts to agro-climatic advisory and weather and crop insurance.

The framework below (Table 3) shows the key steps in creating and disseminating weather information, as well as the assets that the public sector (NHMSs) and a wide array of specialised weather companies (e.g. IBM, Earth Networks, Foreca and Ignitia) deploy along these steps. Clearly, MNOs offer significant value in service delivery by leveraging their key assets such as coverage, connectivity and delivery channels. While the ubiquity of mobile makes it extremely relevant for service delivery, weather information providers also deliver forecasts through other channels, such as radio, TV and the internet. The use of mobile data for service creation is still nascent but offers great scope to drastically improve climate resilience products, starting from weather forecasts.

Table 3

Source: GSMA AgriTech Programme

## Steps to creating accurate, localised weather forecasts

| | SERVICE CREATION | | CONTEXTUA-LISATION | SERVICE DELIVERY | |
|---|---|---|---|---|---|
| | 1. COLLECT | 2. ANALYSE | 3. LOCATE | 4. BUNDLE | 5. DELIVER |
| **NHMS, private weather company** | ◦ Proprietary and open weather data<br>◦ Remote sensing data (satellite) | ◦ Data processing<br>◦ Weather models<br>◦ Specialised analysis | ◦ Integration with MNO data via APIs<br>◦ User registration<br>◦ GPS via apps | ◦ Customisation | ◦ Weather data API<br>◦ Web applications |
| **MNO value-add** | ◦ MNO data (CMLs)<br>◦ Co-location of AWS with base station or in the field<br>◦ Connectivity (cellular internet, WiFi, LPWAN) | | ◦ Network-based CDR<br>◦ Triangulation via LBS<br>◦ User registration (SIM registration, SMS, voice, field agents) | ◦ Content services (VAS)<br>◦ Financial services (Mobile money) | ◦ Coverage (GSM, 2G)<br>◦ Connectivity (3G, 4G)<br>◦ Delivery channels (USSD, SMS, IVR, OBD for 2G, rich media/ apps for 3G) |

Service creation involves two steps: collecting data and analysing data. Service delivery also involves two steps: bundling weather information and delivering it through a range of channels. Both service creation and service delivery utilise user locations as context for the types of service to be delivered. For service creation, this enables localised forecasts, while for service delivery this allows forecasts to be delivered to users based on their location.

### 1. Collect: Gathering and improving the quality of available weather data

While specialised weather providers are likely to have access to proprietary data sets or satellite data, MNOs can complement data collection by leveraging their CML data, installing weather stations on base stations or improving connectivity for weather sensors.

### 2. Analyse: Analysing data to create accurate forecasts

Specialist weather providers usually have supercomputers, data processing, analytical models and sophisticated algorithms to interpret and convert raw data into accurate forecasts. For example, ClimaCell uses real-time CML data from MNOs for its weather prediction system. Due to its highly specialised nature, MNOs do not analyse CML data, but rather rely on partnerships with companies for this analysis. However, MNOs may consider processing CML data in-house by adding value to the data before exposing it to third parties for further analysis and value addition.

### 3. Locate: Enabling the creation and delivery of specific weather information

MNOs can locate users in a variety of ways through network-based CDR, triangulation via LBS and user registration, which enables the creation and delivery of highly localised, farm-level forecasts based on user location.[49]

### 4. Bundle: Providing weather advisory with other value-added services

Product bundling is one of the key marketing assets that MNOs have developed over the years. In developing countries, MNOs can bundle value added services such as weather forecasts with other information services such as agronomic advisory. There is also an opportunity for cross product bundling when information is packaged with financial services (e.g. weather index insurance) to enhance the value proposition for customers. For example, Econet Wireless in Zimbabwe offers its farming customers a bundle that includes agricultural advisory and insurance.

### 5. Deliver: Distributing services via a range of channels

While specialised weather providers can deliver weather forecasts via APIs, web applications or other non-digital channels, MNOs can also deliver weather information via a selection of channels, such as USSD, SMS, IVR and OBD, depending on users' literacy levels and coverage. MNOs can also provide weather forecasts via smartphone apps to 3G users, like Ooreedoo in Myanmar, which provides farmers with agronomic advisory and a five-day weather forecast via its Site Pyo app.[50]

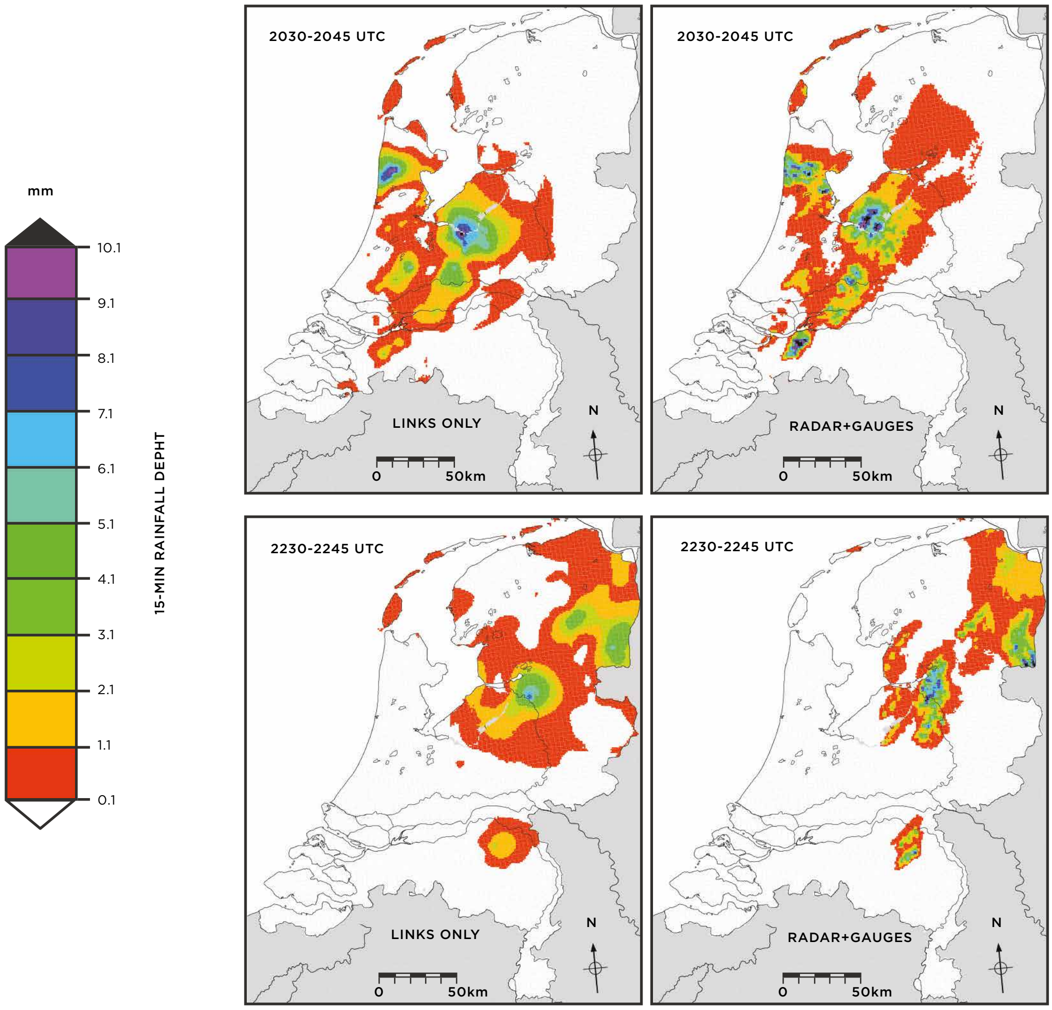
## 3.1 The opportunity for MNOs to use CML data

The use of CMLs to monitor and forecast rainfall is a service creation opportunity for climate resilience products - primarily weather forecasts and nowcasts, but also weather insurance. Early pilots in the Netherlands and Sweden have shown promising results.[51] In 2013, a joint project by Wageningen University and KNMI produced a nationwide rainfall map created using radio spectrum data from microwave links gathered from T-Mobile Netherlands' backhaul network (Figure 6). The initiative involved estimating data over a 12-day period across over 2,400 CMLs in the Netherlands and demonstrated the possibility of producing high-quality rainfall readings and maps from mobile networks.[52]

49. Tricarico, D. and Darabian, N. (2016). *GSMA mAgri Weather forecasting and monitoring: Mobile solutions for climate resilience.*
50. Palmer, T. and Darabian, N. (2017). *GSMA Site Pyo: A weather and agriculture app by Ooredoo Myanmar.*
51. The Economist. (2017). *Weather Forecasting: Counting Raindrops Using Mobile Phone Towers.*
52. Tricarico, D. and Darabian, N. (2016). *GSMA mAgri Weather forecasting and monitoring mobile solutions for climate resilience.*

Figure 6 Source: Wageningen University and KNMI

## Rainfall maps: comparison between radar and gauges, and CMLs during a rainfall event in the Netherlands[53]




In 2019, the GSMA's AgriTech Programme, through funding from the UK's Department for International Development, began a collaborative partnership with Wageningen University and KNMI to improve rainfall-monitoring services for agriculture and weather warnings in developing countries. The initiative involved the implementation of a proof of concept on CMLs for rainfall retrieval in Bangladesh, Nigeria and Sri Lanka. Working in partnership with MNOs in each of the three countries, the aim of the project was to understand the difference in rainfall estimates between three types of sensors: CMLs, weather stations and satellite data from the Global Precipitation Measurement (GPM) IMERG data product.[54] To obtain rainfall observations, the pilot projects used data from weather gauges operated by TAHMO in Nigeria and directly by the MNO in Sri Lanka. No data from weather gauges was available for the Bangladesh pilot, which instead relied on comparisons with satellite data.

The pilot involved the use of the open-source RAINLINK algorithm[55] developed and made publicly available by Wageningen University and KNMI. MNOs in each country provided specific types of data on the microwave

53. Overeem, A., Leijnse, H. and Uijlenhoet, R. (2013). *Rainfall maps from cellular communication networks: Proceedings of the National Academy of Sciences*, 110 (8), 2741–2745.
54. The Integrated Multi-Satellite Retrievals for GPM (IMERG) by NASA's Precipitation Processing System generate global precipitation data every half hour with a 6 hour latency from the time of data acquisition. Data from GPM IMERG is freely available to download at https://pmm.nasa.gov/gpm/imerg-global-image
55. RAINLINK: https://github.com/overeem11/RAINLINK

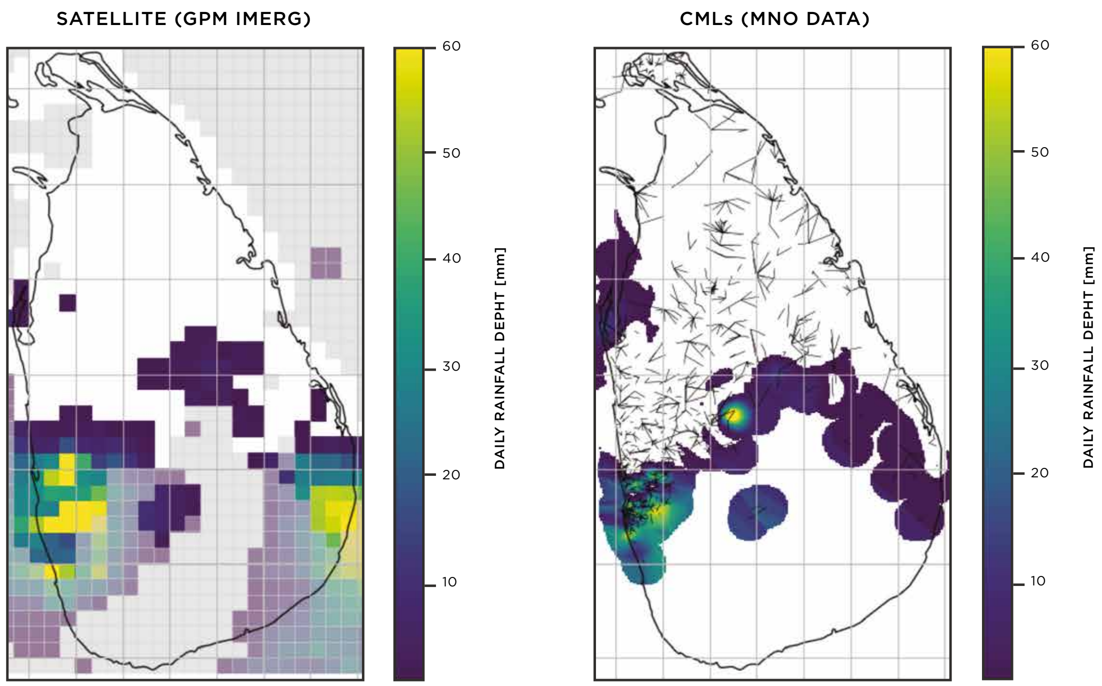
links, such as link frequency, the latitude and longitude of links, altitude and link lengths. This data was then processed through a series of steps, including classifying links during rainfall and dry periods, determining reference levels and identifying any outliers before being used to populate rainfall-monitoring maps.

Assessments based on the results of the pilots showed that CML data is a viable and realistic method of detecting rainfall in tropical environments. CMLs can provide granular detail on the spatial and temporal evolution of rain showers, resulting in space-time rain maps that offer superior resolution compared with satellite data (Figure 7). The pilots found that CMLs' path measurements and higher network density can bring about more representative rainfall measurements – compared to rain gauges. One reason for this is the lack of an effective network of rain gauges in the countries profiled. While CML data offers average rainfall measurements over a pathway, rain gauges can still offer greater accuracy for the points where they are located. This demonstrates that CMLs can be most impactful in the developing countries, where the network of rain gauges is the weakest.

Figure 7

Source: Wageningen University and KNMI

## Rainfall maps: comparison between satellite and CMLs during a rainfall event in Sri Lanka



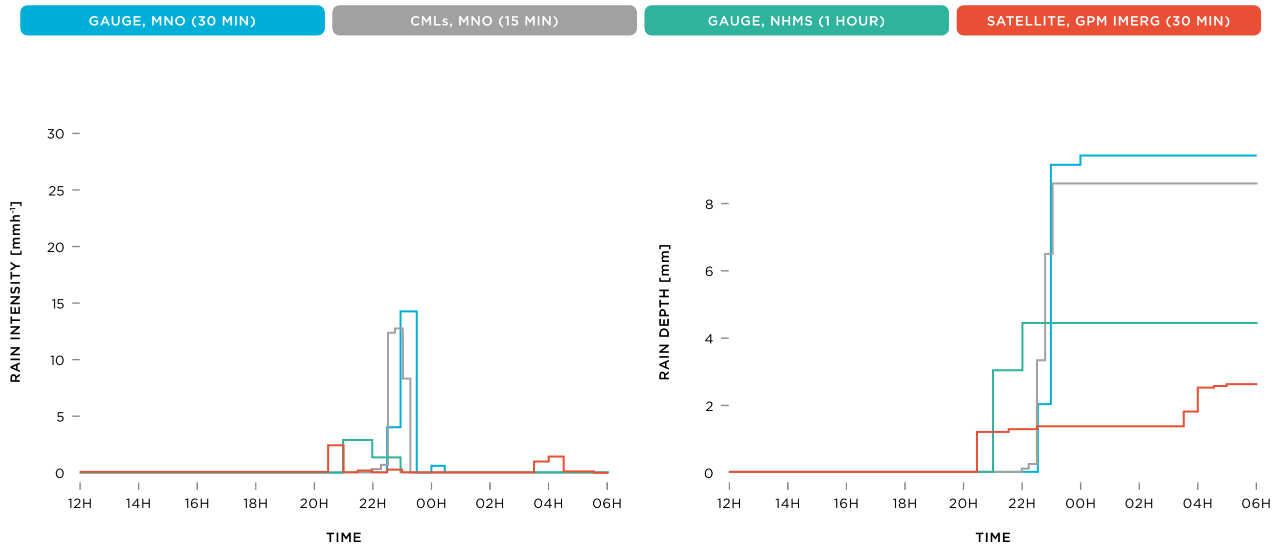

These GSMA-led projects also revealed differences in correspondence between satellite data, rain gauges and CMLs – making it difficult to determine the ground truth in some cases (Figure 8). However, it is important to note that the algorithm used for these pilots had been initially developed for use in the temperate climate of the Netherlands. While rainfall attenuates microwave signals, so do other phenomena, such as atmospheric density (temperature and pressure), composition (for example due to localised emissions from factories or farms), humidity, mist, fog and cloud cover. This makes the algorithm locally dependent. It is possible to overcome this challenge by analysing local weather data over a longer period and using disdrometer[56] data representative of local climate to understand specific attenuation. As a next step, this GSMA-led initiative plans to optimise the algorithm to the weather parameters of targeted tropical and subtropical countries.

56. A disdrometer is an instrument used to measure the drop size distribution and velocity of falling hydrometeors, such as rain, graupel, and hail.

Overall, the results of the pilots were promising and showed that CML data could be used to monitor rainfall more accurately than satellite data. The results showed that it is possible to use CMLs as an alternative or complementary source of rainfall monitoring in developing countries. Merging CML-based rainfall estimates with satellite data and rain gauge readings could produce a much more complete ground-level picture.

Figure 8 Source: Wageningen University and KNMI

## Comparison of rainfall intensity and depth during a rainfall event in Colombo, Sri Lanka




There is an opportunity for MNOs to collaborate with commercial weather companies or with insurance providers interested in CML data for rainfall retrieval. To date, most weather index insurance products have relied heavily on satellite data to measure rainfall and could benefit from additional data sets that offer more granularity. For example, ACRE Africa's Bima Pima microinsurance service in Kenya uses publicly available satellite data from NOAA — the sole data source used to determine whether crop failure has occurred due to drought or excess rain and whether a farmer is due compensation. Satellite data measurements are available in a 10 km by 10 km resolution, showing a lack of granularity – compared to CML-based weather maps, which can offer a 1 km by 1 km resolution.[57]

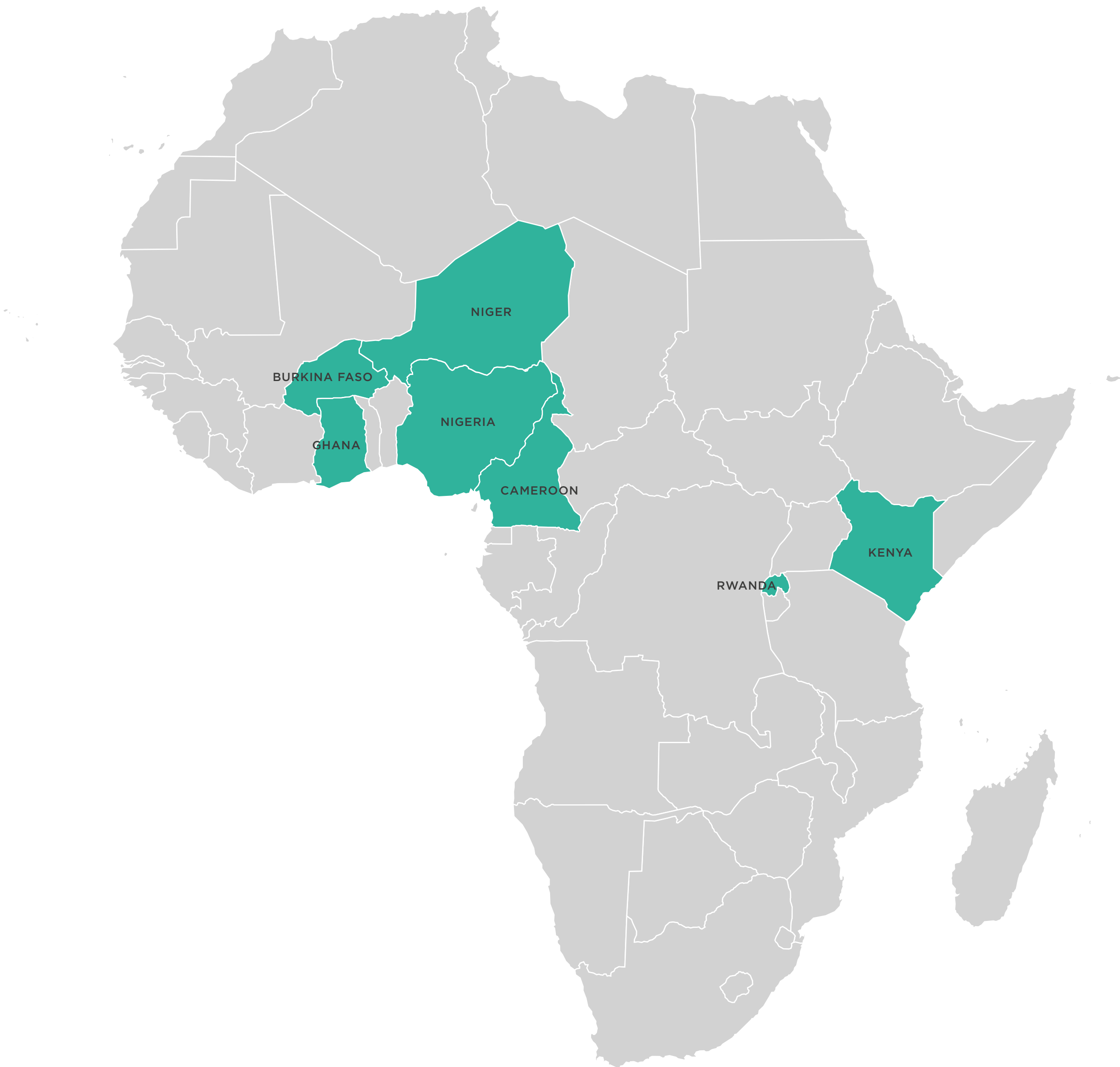
There is also an opportunity for MNOs to foster public-private partnerships with local NHMSs. Most NHMSs in developing countries lack sufficient ground-based measurement equipment and would benefit from low-cost solutions that enhance their ability to carry out specialised analysis. In some countries, a challenge to public-private partnerships is the notion of weather information as a public service, which may inhibit third-party organisations like MNOs from sharing or distributing weather data or information.[58] In such markets, collaborating with local NHMSs would be the only way for MNOs to use or share their data to generate weather advisory services. Several pilots on the applicability of CML data for rainfall retrieval have already been conducted, particularly in Sub-Saharan Africa where infrastructure for ground-level weather observations is most lacking (Figure 9).

57. ACRE Africa – BIMA PIMA Terms and Conditions. https://acreafrica.com/bima-pima/
58. Usher, J., et al. (2018). *Climate Information Services Market Assessment and Business Model Review.*

Figure 9

Source: GSMA AgriTech Programme

## Sub-Saharan African countries piloting rainfall estimation via CMLs



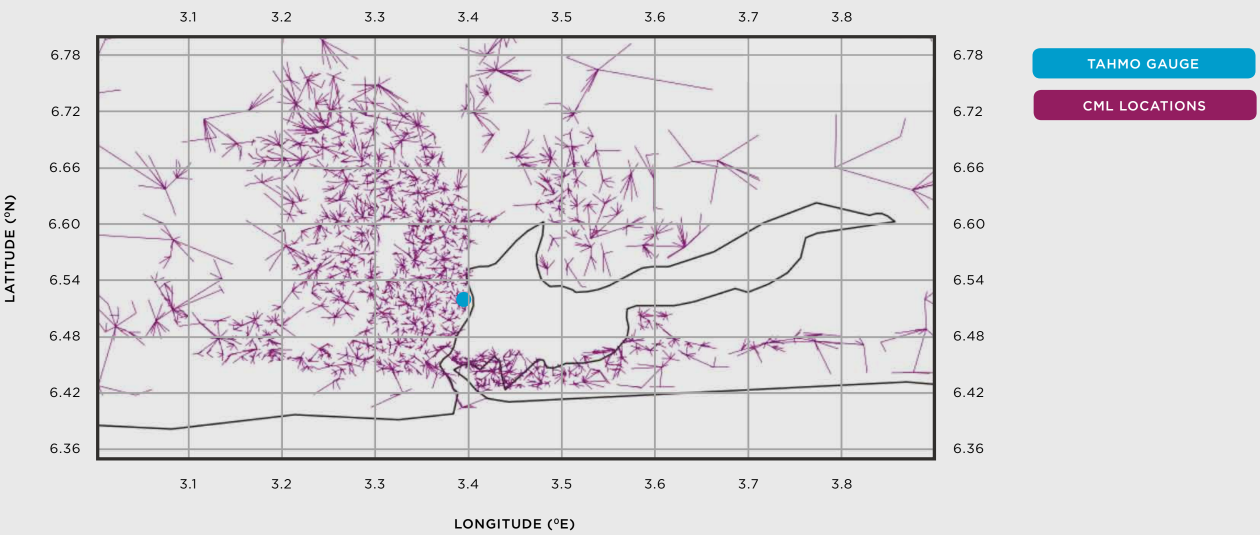
## Spotlight: Using commercial microwave links to estimate rainfall in Nigeria

In 2019, in partnership with the GSMA AgriTech Programme, Wageningen University and KNMI conducted CML data analysis for several regions in Nigeria using data provided by a Nigerian MNO. The analysis looked at rainfall estimates for the same regions and times as observed by satellite and measured by ground-level TAHMO weather gauges.

Figure 10

Source: Wageningen University and KNMI

### Density of CMLs vs gauges in the Lagos area




In the Lagos region, there are very few rain gauges available, and only one weather gauge operated by TAHMO. However, there is a high density of CMLs across the area (Figure 10). CML data analysis on a rainfall event on 6 March 2019 showed a difference in the intensity and depth of rainfall measured by CML attenuation, the TAHMO gauge and the GPM IMERG satellite (Figure 11). While CMLs and the TAHMO gauge show higher rainfall intensity and depth than the satellite data, the TAHMO gauge's rainfall readings show that the rainfall started two hours earlier than the CML data showed. CML data also showed an overestimation of rainfall intensity and depth compared to the TAHMO gauge and satellite data. One likely reason for this is the algorithm used, whose parameters are not yet optimised for use in Nigeria.[59] However, this analysis demonstrated that rainfall could be realistically detected by CMLs.

59. The algorithm currently uses parameters that were optimised for the Netherlands. It has not yet been adapted to the tropical and subtropical weather conditions experienced in Nigeria.

Figure 11 Source: Wageningen University and KNMI

## Comparison of rainfall intensity and depth during a rainfall event in Lagos, Nigeria

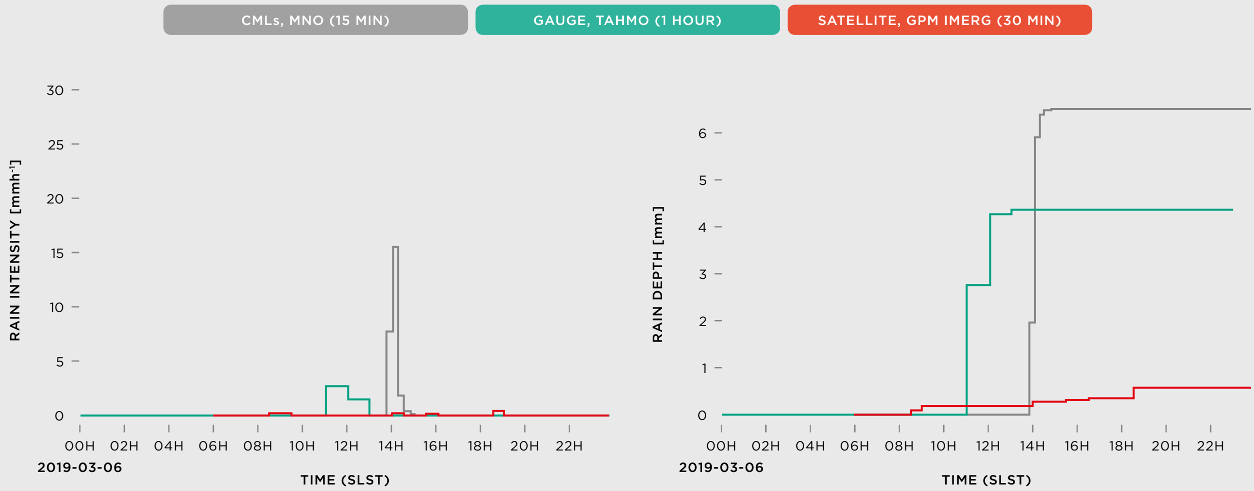
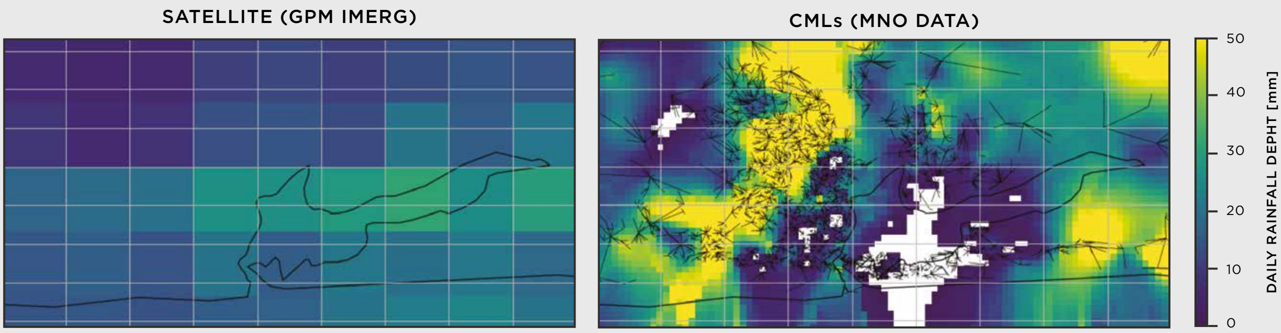



Figure 12 shows that CML-based observations produced superior spatial observation maps than satellite data, showing more accuracy and granularity. While CML analysis in developing countries is still nascent, the approach is a cost-effective and already-available alternative to traditional weather observation tools.

Figure 12 Source: Wageningen University and KNMI

## Rainfall maps: comparison between satellite and CMLs during a rainfall event in Lagos, Nigeria




The use of CMLs for rainfall observation still has limitations as not all areas of a country may be sufficiently covered by mobile networks. Satellite data clearly remains important for ground-level observations. However, CML data has emerged as an important complementary data set for Nigeria, where weather radar and functioning weather stations are lacking.

# 3.2 The challenges of using CML data

While CML data is readily available globally, there are some challenges in using CMLs for climate resilience products - both in terms of the operational model used to extract and compute the data and the overarching business model.

From an operational standpoint, extracting CML data in real time can put additional strain on an MNO's network, which could slow down its servers and impair its ability to perform core operations. However, CML data retrieval is not a cumbersome process and is possible by running a software script. The cost of writing a bespoke script will depend on the network equipment an operator uses, but once developed the software can be run by an MNO's network engineers. Such complexities may have limited the use of CMLs in commercial products to date, despite its high potential end value and the possibility of monetising such data.

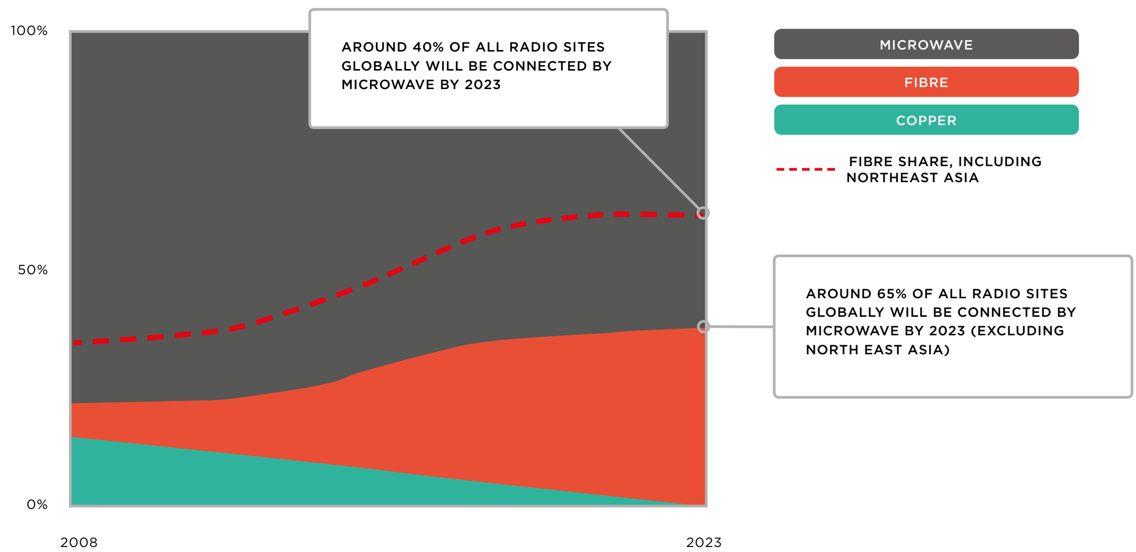
While private weather companies have developed proprietary algorithms to interpret CMLs and convert this data into weather products[60] in developed markets, few viable business models have yet emerged in developing countries. While this may be due to a lack of awareness about this opportunity among MNOs, launching a CML-based weather product requires resources, investment and technical expertise, particularly in converting CML data to comprehensible weather information. For MNOs interested in exploring this opportunity, a partnership with a specialised company with the technical ability to interpret CML data is vital.

Despite awareness and interest from WMO, no guidelines exist on the standards and quality of CML data. However, it is possible to validate CML-based estimates against data from official rain gauges and weather radar station that meet WMO guidelines. Another potential challenge is the declining availability of CMLs as the use of fibre increases for backhauling mobile traffic (Figure 13). Nonetheless, this trend is more prevalent in developed countries and urban areas. In developing countries, microwave links will remain a prevalent backhaul technology, especially for rural areas where no alternative is available.[61]

Figure 13

Source: Ericsson

## Global backhaul media distribution[62]




60. For example, ClimaCell offers nowcasts for a range of industries, such as aviation, construction, insurance, sports and transport. ClimaCell also provides historical weather data, road risk scores and urban weather forecasts for developed and emerging markets
61. GSMA. (2019). *Mobile Backhaul: An Overview.* https://www.gsma.com/futurenetworks/wiki/mobile-backhaul-an-overview/
62. Ericsson. (2018). *Ericsson Microwave Outlook Report, 2018.*

By providing real-time observational data, MNOs can add significant value to a range of products, including weather monitoring and forecasting, nowcasting and insurance. In turn, these products can strengthen the climate resilience of the broader agricultural sector and open new opportunities for revenue generation beyond the dissemination of weather advisory via mobile. The challenge for MNOs in this case is to determine whether they want to become data companies.

## 3.3 Additional opportunities for MNOs: Location-based service creation and delivery

In addition to the use of CMLs, there are other opportunities for MNOs to use their technology assets to provide ground-level weather observations and enhance climate resilience products. These include co-locating AWSs owned by specialised weather forecasters at MNO base stations or MNOs deploying their own AWSs at their base stations. These options are more capital intensive for MNOs than opportunistic sensing using existing CMLs because they require varying degrees of infrastructural upgrades. Nonetheless, the point-level observations generated from AWSs are extremely valuable in improving climate resilience products - particularly weather forecasts. Co-locating IoT-enabled weather stations on or near base stations can open new business-to-business (B2B) and business-to-government (B2G) revenue streams for MNOs, with agribusinesses, insurance companies and NHMSs interested in data from AWSs.

To capitalise on this opportunity, Dialog Axiata in Sri Lanka has partnered with Earth Networks and Ideamart to launch a weather solution called WeatherGuru.[63,64] Under this initiative, weather data is collected from 35 AWSs across the country (as of 2018) and fed into Dialog Axiata's IoT platform. This data is then combined with thermal maps, radar and satellite data and uses proprietary algorithms to generate hourly, daily and 10-day forecasts. These forecasts, as well as real-time weather data and alerts, are accessible via APIs on Ideamart, Dialog Axiata's developer platform, enabling developers and enterprise users to create customised weather applications that can also leverage Dialog Axiata's SMS, USSD, location and IVR APIs. Any applications built using the platform can be monetised via a 70:30 revenue share in favour of the developer.[65]

In opening new enterprise revenue opportunities, Dialog Axiata also intends to use enhanced forecasts from WeatherGuru to strengthen their consumer Agri VAS offering. This includes providing the 600,000 farmers that use its Govi Mithuru Agri VAS with a two-day weather forecast, as well as actionable agronomic advice tailored to the crops they grow. This example shows that MNOs can play a key a role in delivering weather products to consumers, either by bundling weather forecasts with other value-added services or by pushing content directly to users.

Co-locating AWSs with or near base station sites can be beneficial to both MNOs and NHMSs. Co-location offers access to the base station's power source and locational security. MNOs can carry out maintenance and transfer data through the connectivity provided by the base station. Although co-located AWSs could be highly reliable, in some instances base station sites may not be at suitable locations for weather observations.[66] However, given the pervasiveness of mobile networks, co-location presents an opportunity to deploy AWSs securely and efficiently. MNOs can benefit from such an arrangement through a revenue share model with the AWSs operator.

While the cost of weather instruments has dropped, co-locating AWSs with base stations can be capital intensive. For instance, while a weather company may own the AWSs itself, the MNO it has partnered with

63. WeatherGuru: https://weather.ideamart.io/
64. Daily Financial Times (Sri Lanka) (14 December 2018). *Dialog and Ideamart partner Earth Networks to launch revolutionary aggregate weather solution.*
65. Bayen, M. (2016). *APIs: A bridge between mobile operators and start-ups in emerging markets. GSMA.*
66. Benchwick, G., et al. (2016). *A new vision for weather and climate services in Africa.* UNDP.

would be responsible for bearing the cost of powering and securing the AWSs. Although the cost of installing, operating and maintaining a network of AWSs depends on the nature of the partnership between the MNO and the weather company, the price involved is a key reason as to why co-location has not yet scaled significantly.

Another important MNO asset for service creation and delivery is location data, which offers MNOs or third parties the opportunity to deliver location-specific services. A mobile user's location is determined automatically via a smartphone's GPS or via LBS through the triangulation of cell IDs. Location data enables customisation of information services (i.e. weather forecasts, agronomic advisory) to the farm level. For financial service providers, it is a key data point that allows risk assessment at the farm level. For example, a smallholder farmer's approximate location could enable a weather information provider to send hyperlocal, farm-level forecasts. For an insurance company, the ability to obtain accurate, automatic location data can greatly improve and eventually scale weather index insurance, which largely relies on often inaccurate user registration data, at best at district or regional level.

It is fundamental to highlight that the use of LBS involves the collection and use of personal user data, which would require users' explicit consent. Any company that collects location data would need to ensure that their users have sufficient awareness and knowledge of who requires and stores their data, how their data is used, who they share it with and what impact this might have on consenting users.

# 4. Future roadmap

## 4.1 Developing business models for CML data usage

For mobile technology to bridge the weather data gap, NHMSs, commercial weather companies and MNOs must form partnerships to complement existing infrastructure, generate new data and eventually improve weather forecasts, nowcasts and other climate resilience products. An early challenge involves identifying business and operating models that can support viable public-private partnerships for data generation, supply and sharing. A well-known partnership example is the WMO-backed Weather Enterprise, an international framework that aims to stimulate and facilitate access and exchange for both public and private sources of data.[67] The Enterprise aims to identify business models for the sustainability of public and private data services, and encourage cooperation between the public and private sectors.

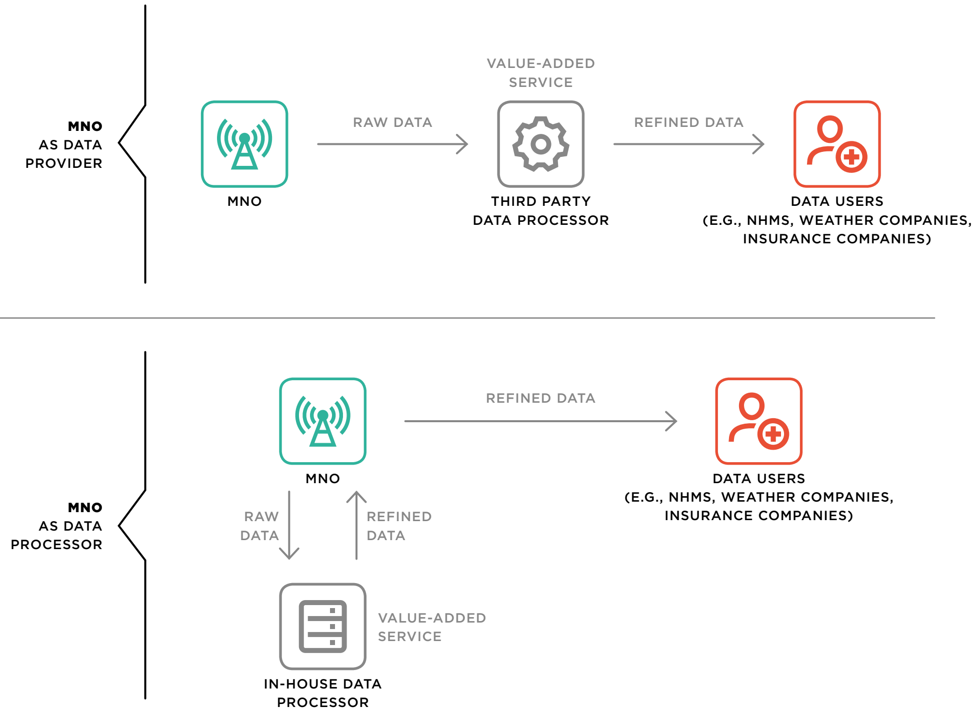
MNOs can adopt a variety of different business and operating models, notably as a data provider or as a data processor (Figure 14). In the first model, the MNO can generate revenue by sharing its raw CML data with a third-party data processor, which could in turn offer refined data to a NHMS or a commercial company that would use it to improve its existing products. Examples include companies offering generic weather forecasts for the consumer market; companies offering enterprise products that target sectors such as aviation, construction or agriculture (i.e. specialised nowcasts); or insurance companies that could use the data to improve their own products. Alternatively, the third-party data processor could provide the refined data to a public-sector organisation such as the NHMS, which would use it to improve its rainfall observations and the quality of its products.

Under the second model, an MNO serving as a big data provider adds value to its raw data by processing it internally before passing it to third parties such as NHMSs and commercial companies. MNOs can also use the refined data to augment its own range of value-added services (i.e. Agri VAS), without having to rely on a third-party intermediary.

67. Thorpe, A. (2016). *The Weather Enterprise: A Global Public-Private Partnership*. World Meteorological Organisation Bulletin, Vol. 65 (2).

Figure 14 Source: GSMA

## MNO business models for CML data sharing and use




Both models offer revenue potential for MNOs. While the second model – with the MNO as a data processor - requires up-front investment to set up in-house processing capacity, it also presents an opportunity for MNOs to extract higher value from ready-to-use data.

Analysis carried out by the GSMA shows that the revenue opportunity for MNOs is significant. The revenue potential for MNOs in developing countries can be estimated by applying an adapted version of a pre-existing revenue model for CML data sharing used in Europe and North America. A basic model, based on a fixed fee per square kilometre of available CML data per year, can estimate annual revenue potential for MNOs based on their network area coverage. For Nigeria, assuming available CML data for as low as 30 per cent of network landmass coverage and as high as 30 per cent, the revenue potential could range from USD 0.55 million to USD 3.23 million per year.[68]

Table 4 Source: GSMA AgriTech Programme

## MNO as a CML data provider - Potential revenue per area coverage per year in Nigeria

| COUNTRY AREA COVERAGE | PRICE PER SQUARE KILOMETRE PER YEAR | | |
|---|---|---|---|
| | USD 2 / YEAR | USD 5 / YEAR | USD 7 / YEAR |
| 30% | USD 0.55 MILLION | USD 1.39 MILLION | USD 1.94 MILLION |
| 40% | USD 0.74 MILLION | USD 1.85 MILLION | USD 2.59 MILLION |
| 50% | USD 0.92 MILLION | USD 2.31 MILLION | USD 3.23 MILLION |

68. This estimate assumes a data sharing annual fee for Nigeria between USD 2 and USD 7 per square KM. GSMA has taken as a reference USD 10 per year per square KM applied in European markets.

## 4.2 Bundling financial services and agro-climatic advisory

While MNOs have made progress in offering agro-climatic advisory to farmers, providing content on its own may not be sufficient for farmers to adapt to climate change. Building resilience requires the ability to withstand and recover from changing climatic patterns. MNOs can help to build smallholder farmers' climate resilience by offering digital financial services and enabling climate-smart investments at farm level. As a further step, MNOs can provide additional value to rural customers through cross-product bundling. Examples include the packaging of multiple digital financial services, such as weather index insurance and credit, and the bundling of financial services with information services.

Access to financial services is an essential part of the climate change response. Financial inclusion is vital to improving the resilience of smallholder farmers, most of whom lack access to financial services and instead save by investing in livestock or housing. However, these savings are immediately eroded when a flood or drought occurs. The financial needs of farmers vary across households, but a range of financial tools, including climate finance solutions, can empower all types of smallholders to become climate resilient.

The use of CML data, in particular, can strengthen both information and financial services, such as weather index services - ultimately improving the quality of bundles targeting smallholder farmers. In a pilot that bundled agricultural credit with rainfall insurance, Safaricom in Kenya tested the use of CML data in Machakos County.[69] The use of CMLs, which can be plotted in one by one kilometre grids, has the potential to offer precise weather observations, especially in Kenya where Safaricom has significant nationwide coverage, and other weather index insurance services. Such bundles have the potential to improve economic welfare and support food security and resilience among vulnerable communities. Accurate weather data can help drive a shift toward a wider range of climate smart financial services, such as credit based on lending risks involved or credit blended with insurance.

## 4.3 From hyperlocal weather forecasts to decision agriculture

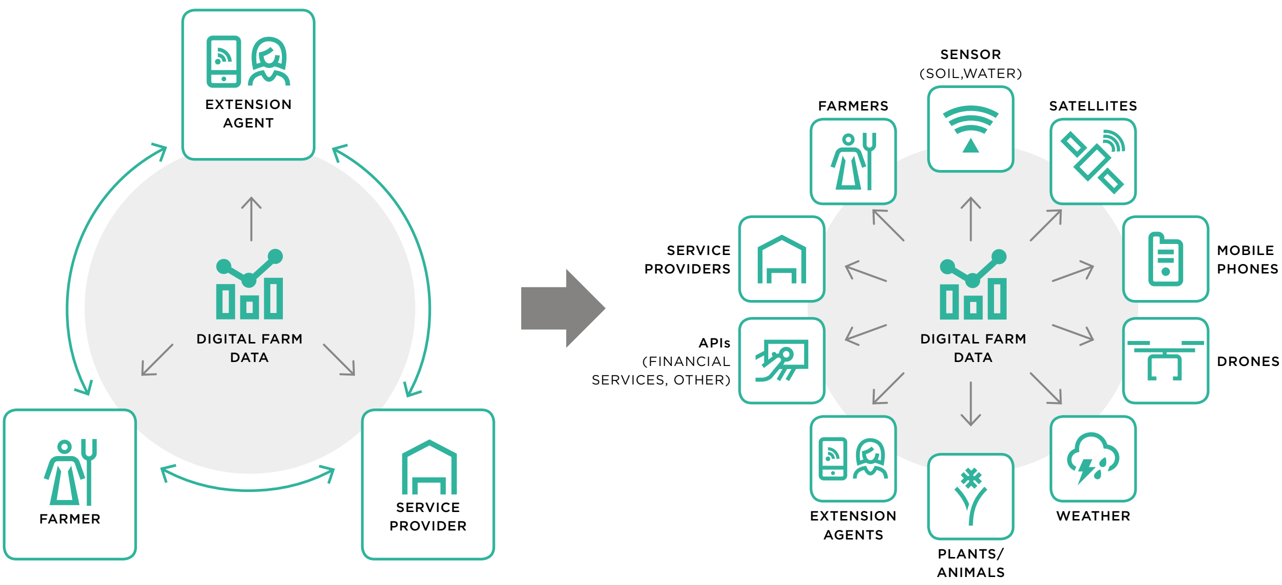
Hyperlocal weather forecasts, created with the use of mobile data and delivered through mobile technology, can provide a vital data source for decision agriculture. Data sources for decision agriculture include weather sensors (e.g. temperature, water and soil sensors), satellite, radar modelling, crop production statistics and farmers themselves (Figure 15), among others. Decision agriculture has the potential to transform agriculture as farmers become one of many data sources and just one of its many users.

69. Liu, Y. (2018). *Using Commercial Microwave Links to Monitor Rainfalls for Agriculture.*

Figure 15

Source: Grameen Foundation and USAID

## Evolution from current smallholder farming to data-driven agriculture




aWhere, a specialist weather information provider, has developed a model that uses farm information, such as daily rainfall, temperature, soil type and disease risk, as well as satellite data, to develop a set of agronomic business rules.[70] An example of one of its rules is shown below:

"**IF** *growth stage => stage 2* **AND** *soil type = sandy-silt* **AND** *rainfall minus normal <= 10 mm* **AND** *(forecast rainfall more than 10 mm* **AND** *less than 35 mm)* **AND** *(modelled disease pressure risk < medium OR no observed disease)* **THEN**"

By combining available and relevant weather and agricultural information, these rules can then be used to provide specific and dynamic agro-climatic advisory to farmers based on their location. The use of CMLs could enable the integration of highly granular rainfall data into decision agriculture datasets, while the use of LBS could determine accurate farmer locations, which are critical to the entire value proposition of decision agriculture services. Such granular intelligence is not only critical for decision making at farm level, but can be important to national policy for countries that rely heavily on agriculture.

While aWhere collects and analyses billions of data points to create an agronomic database, the use of these data platforms may be beyond the reach of ordinary smallholder farmers. Farmers in developing countries face barriers to accessing these types of services, including the cost of subscription and the lack of an appropriate access method (e.g. smartphone). However, information service providers, such as Esoko in Ghana and iShamba in Kenya, have collaborated with aWhere to disseminate weather updates, agronomic advisory and market prices via SMS to around 100,000 farmers in Ghana and over 250,000 smallholder farmers in Kenya.[71]

Another prominent example of decision agriculture is Microsoft's artificial intelligence-based system designed to help farmers in India increase their yields. Known as the Sowing App, the solution was piloted in one district in Andhra Pradesh (Figure 16).[72] The app provides farmers with advice on the best time to sow based on weather conditions, soil and other indicators. Microsoft also rolled out a Personalised Village Advisory Dashboard for 4,000 farmers across 106 villages in Andhra Pradesh. The dashboard offers village-specific insights on soil health, fertiliser recommendations and seven-day weather forecasts.

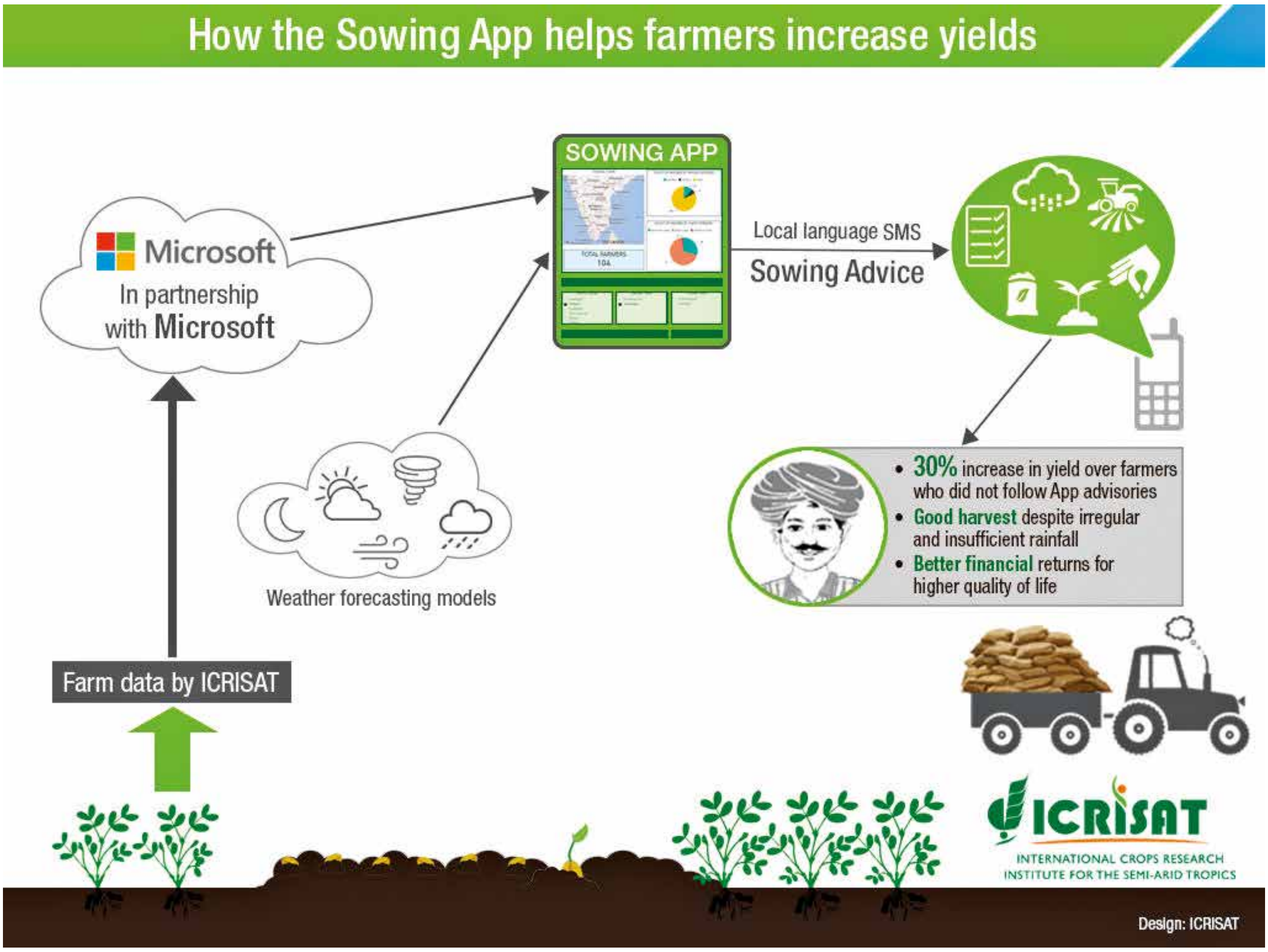
70. *GSMA mAgri internal presentation*
71. FAO e-agriculture (2018). *aWhere: Providing weather-based tips for smallholder farmers.*
72. Microsoft Asia News Centre. (2017). *Steward for the environment: Prashant Gupta.*

Microsoft partnered with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the Andhra Pradesh government to launch this solution, with the main objective to support groundnut farmers adapt to drought.[73] Farmers can access information and updates on sowing via SMS sent to basic mobile phones. From an initial pilot covering 175 farmers in 2016, the app was then scaled to 13 districts in Andhra Pradesh in 2017.[74]

Figure 16

Source: ICRISAT

## An example of a decision agriculture service[75]




Providing timely and accurate weather and climate change information to smallholder farmers can lead to the adoption of climate-smart agricultural practices. Bundling weather information with accompanying agronomic advice can be an important intervention to address information gaps and enable better decision making. By adapting to climate change, farmers can improve productivity through strategic crop planting, minimising environmental impacts and maximising yields in the process.

73. Ibid.
74. Microsoft News Centre India (2017). *Microsoft and ICRISAT's Intelligent Cloud pilot for Agriculture in Andhra Pradesh increase crop yield for farmers.*
75. FAO e-agriculture News (2017). *How the Sowing App helps farmers increase yields.*

# 5. Recommendations

### MNOs have the potential to strengthen rural climate resilience

Historically, MNOs have played a role in digitising disaster response and recovery initiatives (e.g. early warning systems, water-level monitoring and alerts). However, this report highlights the pivotal role MNOs can play in climate adaptation, particularly for rural and vulnerable communities.

### Mobile is much more than a channel for disseminating weather information

Mobile technology is often narrowly understood as a channel for third-party content. However, the growth in the number of Agri VAS and enterprise solutions that are digitising agricultural value chains show that MNOs have the potential to launch new services through partnerships and by leveraging their key assets (e.g. mobile money). Given the huge potential of CMLs in rainfall retrieval, MNOs can create additional value through their data. By sharing this data with NHMSs, private weather companies or insurance providers, MNOs have an opportunity to create new business models and add to their existing value propositions.

### MNOs must continue to build on the promising positive results of CML pilots

While CML pilots in the Netherlands and Sweden have shown positive results, early promising pilots in developing countries, particularly in tropical regions, still require additional effort. For instance, the algorithms used during initial pilots were based on successful tests in developed countries. These algorithms need to be adapted to local weather patterns and conditions in developing countries to better understand the accuracy and utility of CMLs compared to weather stations and satellite data. Investment from donors or private investors are required at this stage to further develop and validate algorithms for areas most in need of accurate weather information.

### MNO assets can lower the cost of weather data collection and improve service delivery

MNOs are in a position to expand weather station coverage through their own networks of base stations. Co-locating AWSs at MNO base stations offers NHMSs a way to improve their observational capacity through a “light-touch” approach, with such an initiative serving as an additional revenue-generating avenue for MNOs in the process. Additionally, by knowing a user’s location, mobile can deliver location-specific weather information.

### Partnerships and business models need to be established to monetise CMLs

To date, MNOs have allowed their CML data to be used for pilots and tests at no cost. However, as the value of this data becomes apparent, MNOs will have an invaluable opportunity to monetise the use of their CML data. While this report has explored a number of possible business models, how CMLs is ultimately used will depend on the nature of partnerships between MNOs, third-party data processors and customers of processed data.

### Weather index insurance services can benefit from the use of CML data

Weather index insurance services have often struggled to take off due to the difficulties of proving that crop failure or poor harvests were caused by severe weather or disasters, as well as the high transaction costs of serving smallholders in a traditional delivery model. Although satellite data has become more available and cheaper to access than in the past, weather index insurance providers can benefit by using CMLs to monitor weather patterns and pay claims automatically. MNOs, particularly those with mobile money services, also have the potential to offer their own weather index insurance with mobile money platforms facilitating quick claim payouts.

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