CASE STUDY

Exploring opportunities for climate services in Papua New Guinea with Digicel

GSMA

GSMA AgriTech Programme

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Contents

Executive summary

Agriculture is a source of livelihood for more than 85 per cent of the population in Papua New Guinea (PNG), but this vital sector is vulnerable to the impacts of climate change. It is expected that in a warming climate, extreme El Niño and La Niña events will become more frequent and intense, presenting significant challenges to agricultural activities. Accurate and timely information services, including weather observations, weather forecasts and climate predictions, will be crucial to anticipate and mitigate impacts on food security and support long-term adaptation to climate change.

Meteorological observations enable the provision of these services, and mobile networks provide an opportunity to collect valuable ground-level rainfall observations. By using data from the commercial microwave links (CMLs) that form part of these networks, existing mobile infrastructure can generate high-resolution, near real-time rainfall observations in areas covered by mobile backhaul networks. These observations are comparable to weather radar data. In PNG, the national weather service currently operates approximately 25 manual weather stations and rainfall radar is not available. CML data therefore has the potential to enable innovative new weather services, including rainfall nowcasting, agricultural intelligence and weather index insurance, to strengthen the climate resilience of smallholder farmers and other agricultural stakeholders.

In 2020, Digicel, the largest mobile network operator (MNO) in PNG, partnered with the GSMA on a two-year project funded by Australia's Department of Foreign Affairs and Trade (DFAT) to 1) validate the use of CML data for rainfall estimation in PNG; and 2) assess potential uses for rainfall observations in weather and climate services for smallholder agriculture.

During the project period, Digicel shared CML data covering a nine-month period and approximately 500 link paths, representing all usable links in their network. Reference rainfall data was sourced from weather stations in PNG, and the Global Precipitation Measurement (GPM) mission satellite rainfall service. The CML data was converted into rainfall estimates using the RAINLINK algorithm[1] and compared against weather station and satellite reference data by a technical consortium consisting of Wageningen University and Research (WUR), the Royal Dutch Meteorological Office (KNMI) and the Delft University of Technology (TU Delft). In areas where many short links were available, the analysis revealed a strong correlation between rainfall estimates and weather and satellite data, but a weak correlation in areas with long links (>10 km) or exceptionally intense rainfall amounts. Furthermore, due to the topography and population distribution of PNG, CML network coverage was limited (five to 10 per cent of total area) and fragmented across population centres.

While CML data can add value to a variety of services in PNG, the relative scarcity of weather and digital agriculture service providers in the country means that rainfall nowcasting and flood and landslide early warnings are currently the most relevant use cases.

Rainfall nowcasting provides high-resolution forecasts up to six hours in advance. They are based on high-resolution rainfall observations (typically radar) that are extrapolated into the future using physics- or machine learning-based approaches. CML rainfall data is a key enabler of nowcasts as they provide sufficiently high resolution and are available in near real-time. Nowcasts enable farmers to anticipate and mitigate the effects of severe rainfall events, and are relevant to other weather-sensitive sectors, such as aviation and maritime. For nowcasting services to be developed in PNG, CML data coverage would need to be expanded through integration with satellite rainfall data. This would enable rainfall events to be anticipated outside CML coverage areas.

1 The RAINLINK algorithm enables the mapping of rainfall observations from microwave links in a cellular communication network.

Flood and landslide early warnings integrate observational data with weather forecasts and topographic information to assess the risk of floods and landslides. When a risk threshold is reached, warnings are sent out to affected communities. Due to the presence of mobile networks in the more populated areas of PNG, CML data can provide coverage in areas where flood and landslide events would have the greatest impact. While rainfall data is a key input, other data sources, including water levels in waterways and topographic features, are also required and determine whether it is feasible to provide services effectively.

The highlands of PNG frequently experience inland flooding and landslides, with floods and landslides reported in Central, Morobe and Chimbu provinces over the past two years. These events cause damage to property and infrastructure, displace people from their homes and can lead to fatalities. Early warnings would allow people in affected areas to anticipate risk and take preventative actions to minimise losses.

CML data has shown potential to add value to rainfall nowcasting and flood and landslide early warnings, which will be critical to improving the climate resilience of at-risk communities and weather-dependent sectors, such as agriculture.

RECOMMENDATIONS

In the short to medium term, we recommend the following activities to develop the technical approach and explore opportunities for service provision:

Undertake additional technical work to tailor CML rainfall observation to the long links and intense rainfall characteristic of PNG;

Develop a data service that provides near real-time CML rainfall observations to third parties; and

Conduct research to understand how to maximise the opportunities from the integration of CML and satellite precipitation data;

Assess the opportunities to provide rainfall nowcasting and flood and landslide early warnings, specifically collaborations with government agencies, such as the PNG National Disaster Centre or PNG National Weather Service (NWS).

Introduction

Agriculture is the cornerstone of Papua New Guinea (PNG). While its contribution to the economy has fallen to 17 per cent of GDP,[2] it provides a livelihood for more than 85 per cent of the population.[3] This crucial sector is facing several challenges due to the country's rugged terrain and poor infrastructure, the predominance of informal value chains and increasing threats from climate change.

The climate of PNG is strongly influenced by the El Niño-Southern Oscillation (ENSO), which can result in two distinct weather patterns.[4] The warm phase of ENSO, or El Niño, pushes rainfall to the eastern Pacific, resulting in significant drought conditions in PNG. The reduced cloud cover also causes low temperatures to drop, resulting in highland areas experiencing frost during night-time. During La Niña, the cool phase of ENSO, rainfall is concentrated in the western Pacific, resulting in extreme rainfall events, flooding and landslides in PNG. It is expected that in a warming climate, extreme El Niño and La Niña events will become both more frequent and intense.

Both scenarios present significant challenges to agricultural activities. During the most recent El Niño event in 2015, droughts caused widespread food shortages, leading to increased deaths from famine and malnutrition. Strong El Niño events affect the production of sweet potato and sago,[5] both staple crops for villagers in PNG.[6] Repeated highland frosts completely disrupt agricultural production and affect uncultivated edible species. Droughts increase the occurrence of wildfires that can damage crops and cause loss of livestock. Agricultural challenges caused by excessive rainfall during La Niña events are more difficult to identify since rainfall events are highly localised, the impacts are delayed and there are many mediating factors.

In this context, accurate and timely information services, including weather observations, weather forecasts and (sub-)seasonal climate predictions, are critical to anticipate and mitigate impacts on food security and enable long-term adaptation to climate change. Meteorological observations are essential to the provision of such services, but ground-level weather data is scarce in PNG. The National Weather Service (NWS)[7] operates an observation network of approximately 25 manual weather stations, insufficient to cover the large area and many microclimates of PNG. The PNG Remote Sensing Centre (RSC)[8] provides a third-party network of automated weather stations (AWS) that have been operating for the past 10 years and currently includes 37 across the country.

Mobile networks provide an opportunity to augment ground-level data with data from commercial microwave links (CMLs). Discussed in more detail in chapter 2, this approach enables existing mobile infrastructure to provide high-resolution, near real-time rainfall observations that are comparable to weather radar data in areas that are covered by mobile backhaul networks. This presents an opportunity to significantly increase rainfall observation coverage in PNG and develop and improve weather services.

Since 2019, the GSMA has conducted feasibility studies on the use of CML data for rainfall observation in three markets,[9] and a landscaping study of opportunities for digital agriculture in PNG.[10] Drawing on the lessons of these studies, the Australian Department of Foreign Affairs and Trade (DFAT) funded a two-year project led by the GSMA AgriTech programme to pursue digital agriculture opportunities in PNG. The project included a proof-of-concept study to validate the use of CML data for rainfall estimation in PNG and an assessment of how this data might be used in weather and climate services for smallholder agriculture.

This report, aimed at mobile network operators (MNOs) and weather and climate service providers, summarises the findings of this work to illustrate the operational aspects of implementing CML rainfall observation services. The study highlights the opportunities of CML-based rainfall observations to improve weather and climate services, with a focus on PNG.

2 World Bank. (n.d.). "Agriculture, forestry, and fishing, value added (% of GDP) – Papua New Guinea". World Bank Data.
3 See: agriculture.gov.pg
4 Kuleshov, Y. et al. (2019). Climate Risk and Early Warning Systems (CREWS) for Papua New Guinea.
5 Sago is a starch extracted from the pith, or spongy core tissue, of various tropical palm stems. It is a major staple food for the lowland peoples of New Guinea and the Maluku Islands.
6 Bourke, R. M. and Harwood, T. (2009). Food and Agriculture in Papua New Guinea.
7 See: pngmet.gov.pg
8 See: pngclimate.net
9 GSMA. (2019). Mobile technology for rural climate resilience: The role of mobile operators in bridging the data gap.
10 GSMA. (2019). Landscaping New Opportunities for Digital Agriculture in Papua New Guinea.

1
Using mobile networks for rainfall observation

Existing mobile infrastructure presents a unique opportunity for near real-time rainfall observation. To observe rainfall using mobile networks, specialised algorithms use data from CMLs typically used to monitor network health.

CMLs are close-to-the ground radio connections used worldwide in cellular networks to connect mobile base stations to the wider network where cabled connections are not viable.[11] The signal strength of CMLs is routinely monitored by MNOs for network management. This monitoring data can be used for rainfall observation due to the physical characteristics of the radio signals used.

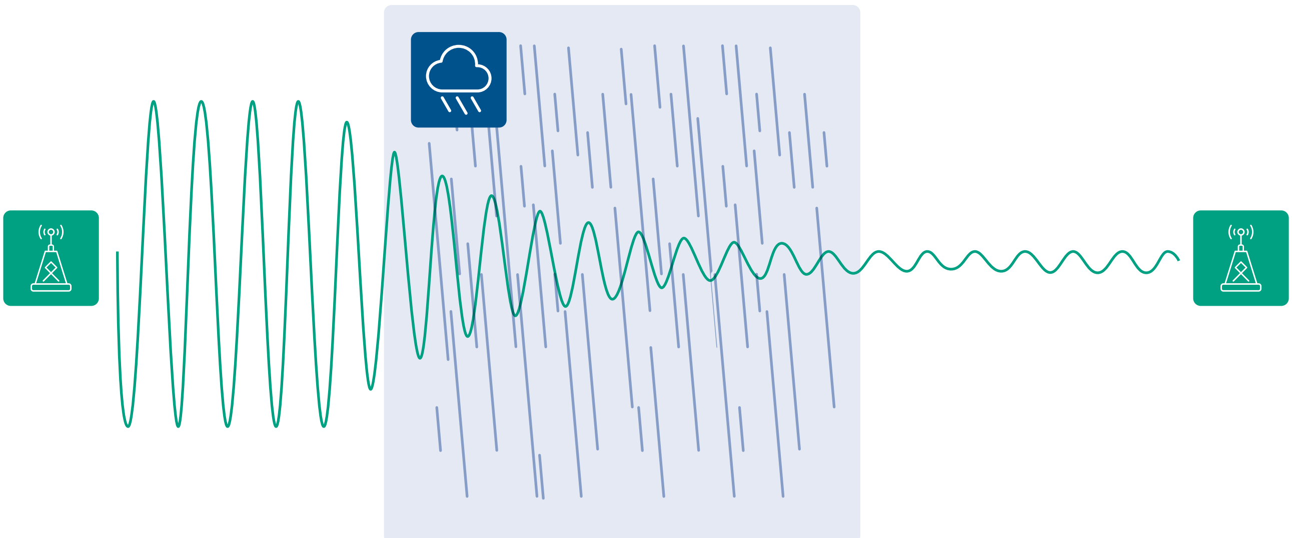
It is estimated that by 2023, around 65 per cent of radio sites in the world will be connected by microwave links (excluding Northeast Asia).[12] Since most countries in Sub-Saharan Africa, South Asia and Southeast Asia have mobile networks covering more than 86 per cent of the population,[13] there is a significant opportunity to use CMLs as virtual weather sensors to monitor and map rainfall.

1.1 Principles of CML rainfall estimation

Along microwave links, radio signals propagate from a transmitting antenna at one mobile base station to a receiving antenna at another base station. The radio signals rely on frequencies that are disrupted by rainfall. As it rains, water absorbs and scatters these microwave signals, reducing the signal strength at the receiving tower. By comparing the signal levels during rain to those representative of dry weather, the CML data can be converted into highly accurate rainfall measurements (Figure 1). Using these principles, each CML in a mobile network can function as a rain gauge, each providing observations of rainfall intensity every 15 minutes or less. Once rainfall intensities have been calculated for all CMLs in a network, the values are interpolated onto a spatial grid of 1–2 km to provide a uniform distribution of observations in the coverage area.

Figure 1

Principles of rainfall observation using CML data



Source: GSMA

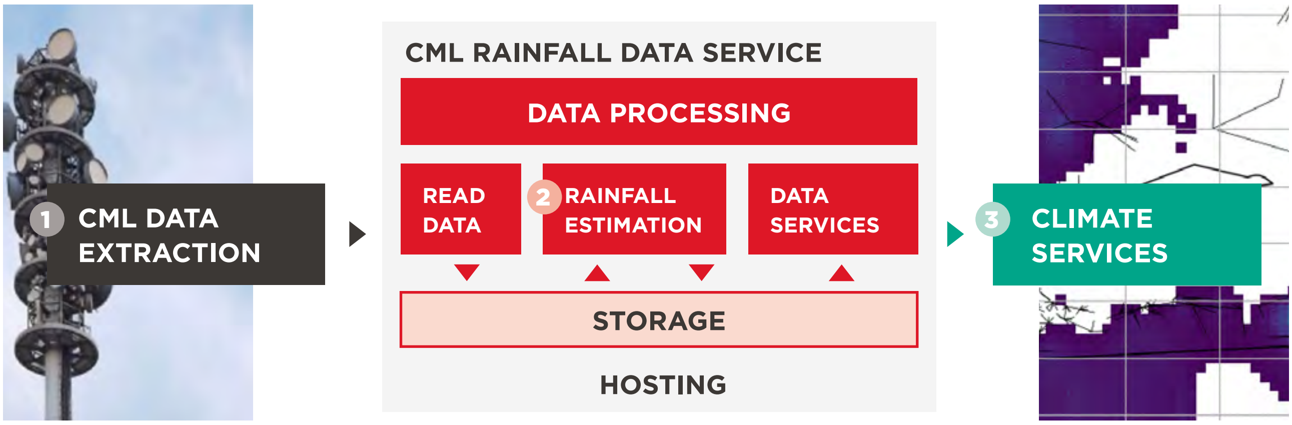
11 GSMA. (2019). Mobile Backhaul: An Overview.
12 Ibid.
13 Indicator 9.c.1: Proportion of population covered by at least a 2G mobile network (percent); GSMA Network Coverage Maps: gsma.com/coverage/

1.2 CML rainfall observation software

To implement CML rainfall observation services, a layer of software needs to be added to existing mobile infrastructure to enable the necessary data analysis and management. Figure 2 outlines the basic elements required to produce CML rainfall observations.

Figure 2

CML rainfall data service outline[14]



Source: GSMA

1. Data is acquired from CMLs through network management software, data loggers or dedicated software services. For example, the open source pySNMPdaq service has been used to collect CML data directly from base stations, regardless of the mobile network manufacturer.

2. There have been various approaches to converting CML data into rainfall estimates. For example, RAINLINK is an open source R package that can be used for this conversion. This package was developed by researchers at the Royal Dutch Meteorological Office (KNMI) and Wageningen University and Research (WUR) based on an extensive set of radar, weather station and CML data sourced from the Netherlands.[15]

3. Once the rainfall data is available, various services can be used to make data available to end users. The most basic have one or more application programming interfaces (APIs) that allow users to request and receive data in pre-defined formats. Other data services can include map-based visualisations that allow users to view data in real time.

14 Adapted from: GSMA. (2021). Digital Innovation for Climate-Resilient Agriculture.
15 Overeem, A. et al. (2016). "Retrieval algorithm for rainfall mapping from microwave links in a cellular communication network." Atmospheric Measurement Techniques, 9, pp. 2425–2444.

1.3 Evidence for the accuracy of CML rainfall observations

Recent studies have evaluated rainfall observations produced from CML data in tropical climates.[16] The typical lack of ground-level observations simultaneously validates the importance of the approach and hinders extensive validation of the data produced. Despite these limitations, promising results have been found in comparisons of weather station and satellite data.

Ongoing collaborations between WUR, KNMI, TU Delft and the GSMA with MTN Nigeria and Dialog Axiata Sri Lanka have yielded some of the most extensive validation studies of CML rainfall estimation in tropical climates.

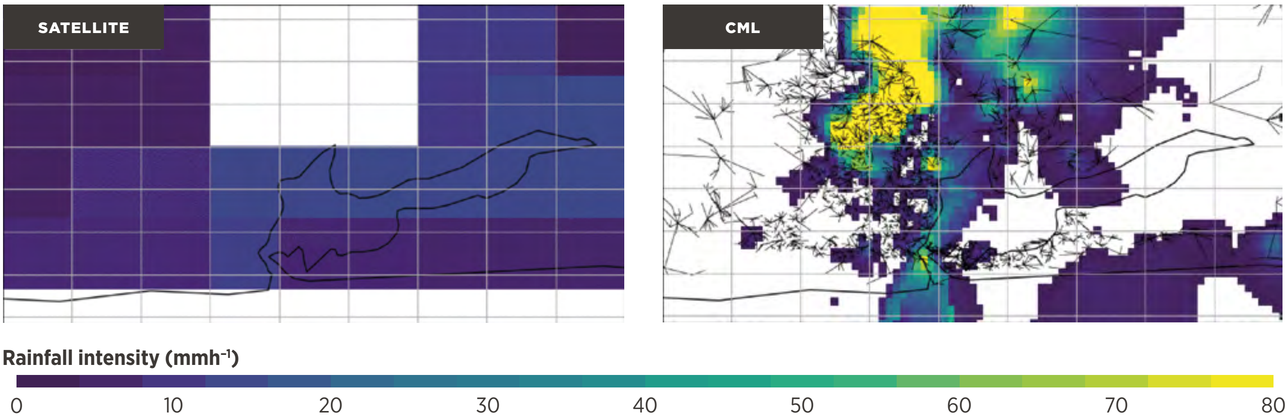
In Sri Lanka, CML-derived rainfall data from 2,418 link paths were compared with data from 23 weather stations operated by the Sri Lanka Met Office over a three-month period. The results show a very high correlation (r^2=0.79) between the daily rainfall amounts measured by both sources.[17]

Figure 3

Comparing satellite and CML rainfall observations

Rainfall intensity map for Lagos, 6th March 2019 from GPM IMERG data

Rainfall intensity map for Lagos, 6th March 2019 from MTN Nigeria's CML data



Source: GSMA

In Nigeria, CML rainfall observations were compared to rainfall data produced by the Global Precipitation Measurement (GPM) mission, which uses a constellation of satellites to produce precipitation rates for the world every 30 minutes at approximately 10 km resolution.[18] This data is available six hours after the rainfall event. A rainfall event over Lagos, Nigeria was compared using these two data sources (Figure 3). In addition to improved spatial resolution (1 km vs 10 km) and temporal resolution (15 minutes vs 30 minutes), the CML data also showed a greater range of rainfall intensity, indicated by the yellow areas of high intensity.

The findings from this work indicate that CML data can consistently provide accurate rainfall observations. Given the coverage of CML networks, this approach provides an opportunity to greatly extend the area covered by existing ground-level weather sensors. The typically high network density and near real-time availability of CML data can improve both spatial and temporal resolution compared to available remote-sensing sources. For most low- and middle-income countries (LMICs), CML data is a valuable complementary data source, offering similar benefits as rainfall radar, which is typically not available.

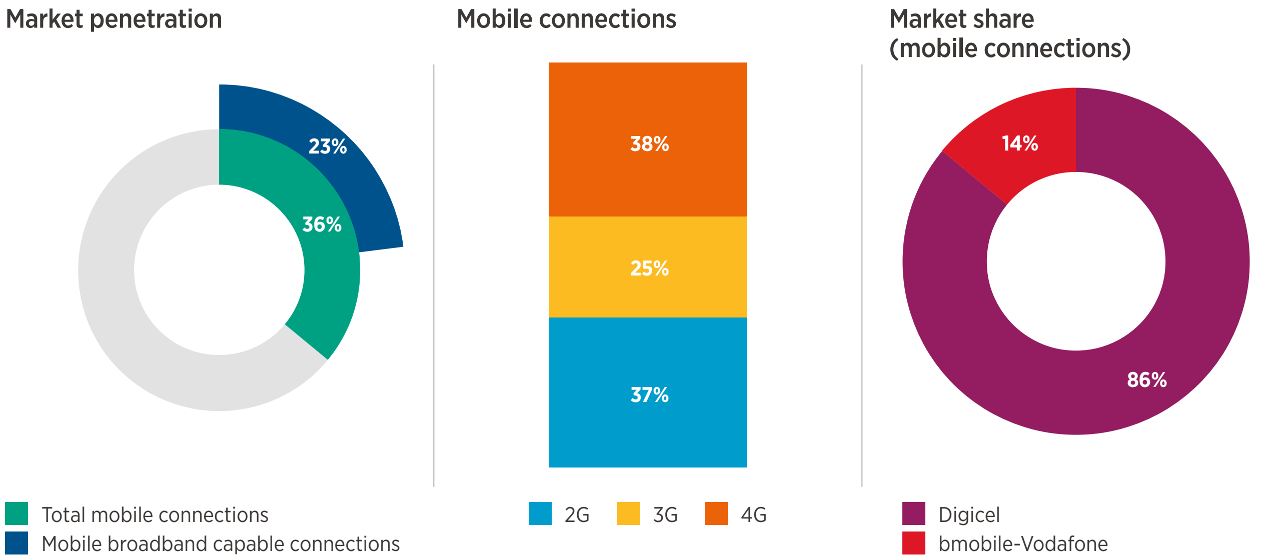
16 Overeem, A. et al. (2021). "Tropical rainfall monitoring with commercial microwave links in Sri Lanka." Environmental Research Letters, 16.
17 Ibid.
18 NASA's Global Precipitation Measurement mission (GPM): gpm.nasa.gov/missions/GPM

2
Developing CML-enabled climate services with Digicel

Digicel is Papua New Guinea's largest MNO, with more than 86 per cent of total mobile connections in the country as of the end of 2021.[19] The remaining connections are controlled by bmobile-Vodafone, which has focussed most of their commercial activity on urban areas.

Figure 4

Mobile connectivity in PNG, end of 2021



Source: GSMA

Digicel is by far the largest MNO in rural areas and has the most extensive network coverage in the market. Digicel provides a suite of communications and collaboration solutions for the consumer and enterprise markets. They do not currently offer value-added services for specific industry verticals.

19 See: https://data.gsmaintelligence.com/data/operator-metrics

2.1 Opportunities for climate services

CML rainfall data has the potential to enable or improve a variety of climate services relevant to agriculture and other industry sectors.[20] Figure 5 outlines the various services that CML data can support and the categories of agricultural users (e.g. smallholder farmers, agribusinesses) that could be targeted. It is important to note that while agricultural applications are extremely relevant given the importance of the sector to the economy, CML data can improve a variety of services for other sectors as well. For example, improved weather services, such as weather forecasts and rainfall nowcasts, and flood and landside early warnings will benefit the general population as well as weather-sensitive sectors of the economy, including aviation, transport, public services and extractive industries.

Figure 5

Opportunities for service enhancement using CML data

Service	CML value-add		Agricultural users	Other sectors	
Weather nowcasting	Service enabler		Smallholder farmers, agribusinesses, extension agencies	Aviation Public services	Extractive industries Logistics
Weather and climate forecasting		Improved accuracy and resolution	Smallholder farmers, agribusinesses, extension agencies, policymakers	Aviation Public services	Extractive industries Logistics
Early warnings and alerts	Service enabler	Improved accuracy and resolution	Smallholder farmers, agribusinesses, extension agencies	Public services Mainstream media	Humanitarian
Agricultural intelligence		Improved accuracy and resolution	Agribusinesses, commodity traders, policymakers, input providers, financial service providers		
Climate-smart agri advisory		Improved accuracy and resolution (indirect)	Smallholder farmers, extension agencies, cooperatives, agribusinesses		
Precision agriculture		Improved accuracy and resolution	Smallholder farmers, agribusinesses		
Agricultural insurance	Service enabler	Improved accuracy and resolution (indirect)	Smallholder farmers, agribusinesses, input providers, government agencies		
Agricultural credit		Improved accuracy and resolution	Smallholder farmers, agribusinesses, input providers, government agencies		

■ Weather and climate services ■ Early warnings and alerts ■ Data-driven agricultural advisory services ■ Digital financial services

Source: GSMA

In PNG, Digicel recognises the opportunity to use their mobile network to develop better climate services. For Digicel, participation in the project is strategic given that they aim to explore the potential of CML-enabled services to provide previously unavailable data and innovative services to new sectors. It also allows Digicel to provide data services to third parties that will complement their basic enterprise offering of data and connectivity. By maximising the impact of their CML data through staged investments, Digicel can keep the option open to develop sector-specific services in the future.

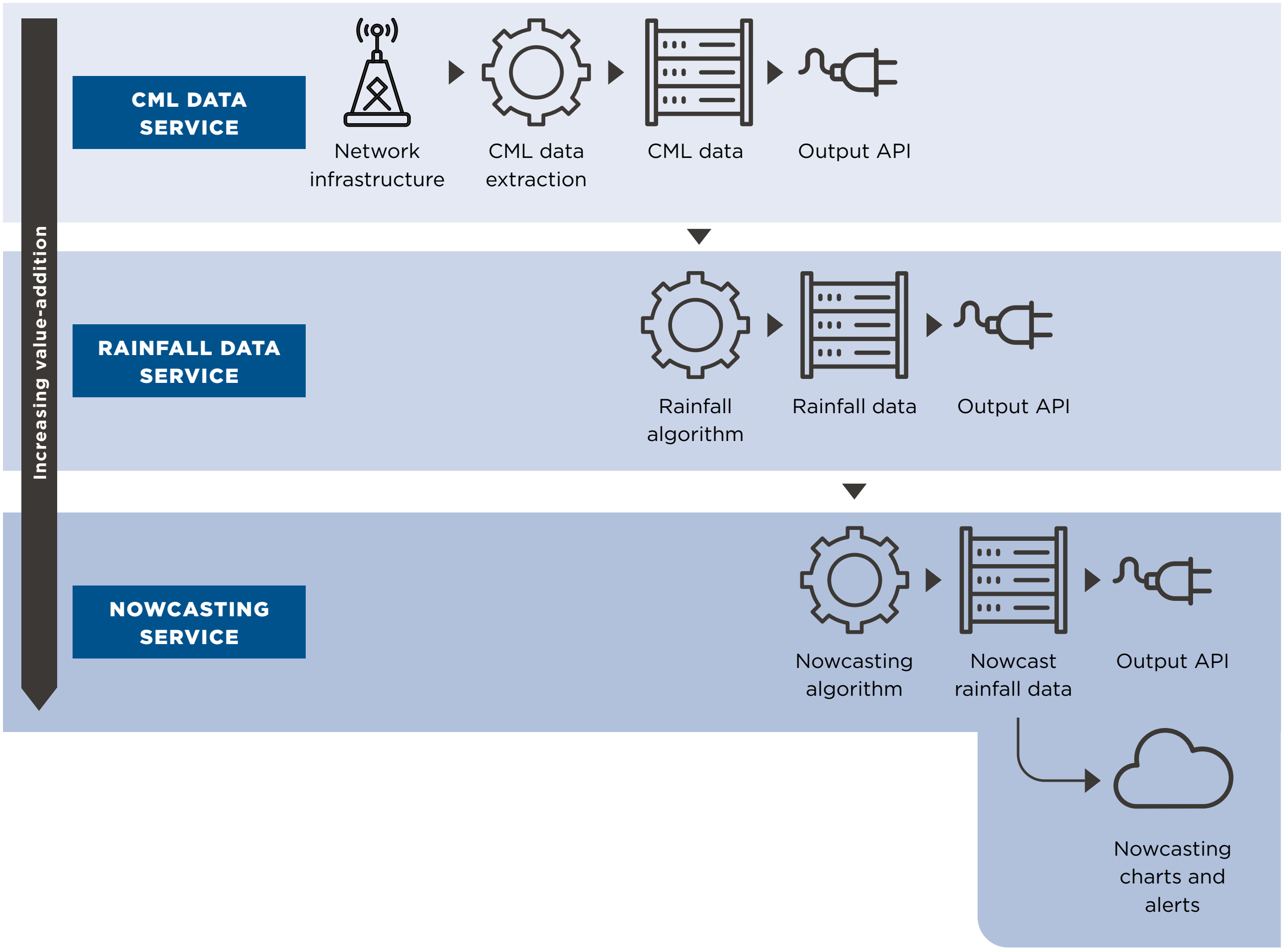
20 GSMA. (2021). Digital Innovation for Climate-Resilient Agriculture.

2.2 Opportunities for data sharing

In the provision of CML rainfall data, an MNO can take on one of many roles depending on the additional processing they are willing to perform (Figure 6).

Figure 6

Building enterprise services based on CML data



Source: GSMA

At the most basic level, an MNO can operationalise the extraction of CML data from their network and provide access to one or more third parties, which would then convert the data into rainfall observations. Another option is for the MNO to process the data in-house and provide rainfall data as a service. Finally, an MNO can process the rainfall data to create rainfall nowcasts, which require minimal additional data and infrastructure to set up.

As the MNO enhances the value of CML data through data processing, there is a greater opportunity to serve a larger base of interested data users, from specialist organisations that can process raw CML data, to multisector and mainstream audiences that can use rainfall nowcasts. Deciding where to position oneself is therefore an assessment of the trade-off between additional investment in processing and the potential returns from reaching a wider audience.

Given Digicel's position (as outlined in the previous section), they have opted to start with the low-cost data-as-a-service approach. As the applicability of CML rainfall data for services in PNG is validated, and they develop a better understanding of the demand, they will decide whether to pursue service creation.

3
Implementing CML rainfall observation with Digicel

The technical work covered by the DFAT-funded engagement aimed to validate the provision of CML-derived rainfall estimates from the Digicel network. A variety of physical, human and intellectual resources were required for this project and are described in this chapter.

The technical partners were a research consortium formed by the GSMA AgriTech programme comprised of WUR, KNMI and TU Delft. The Digicel network team extracted the CML data from Digicel's network. The research consortium then converted the CML data into rainfall observations using the open source package RAINLINK, and then validated the approach by comparing the rainfall observations to reference rainfall data from weather stations and satellites. The rainfall calculation algorithm was optimised using reference data from PNG.

This work had two main objectives:

- To confirm the validity of the CML rainfall estimation approach for PNG by comparing CML-derived rainfall observation with reference datasets from weather stations and satellites; and
- To customise the rainfall estimation algorithm to the PNG climate by integrating data on the physical characteristics of rainfall in PNG.

Figure 7

Resources used to validate rainfall observation using CML data

PHYSICAL RESOURCES

- Mobile backhaul network, including base stations and CML devices
- Network management software (NMS)

HUMAN RESOURCES

- Network team to configure NMS to enable CML data extraction
- Technical consortium team to convert CML data, conduct validation study and optimise conversion algorithm

INTELLECTUAL RESOURCES

- CML data covering study period of nine months
- RAINLINK algorithm for conversion of CML data into rainfall observations
- Rainfall observation data from weather stations and remote sensing

Source: GSMA

3.1 Accessing CML data in the mobile network

Achieving the objectives of this research required Digicel's network team to take practical steps to extract the necessary data from their mobile network.

Physical resources: the MNO network

During the study period, Digicel's mobile network used CML device hardware from three manufacturers. Extraction of CML data from two of these manufacturers was not feasible due to a lack of links (as hardware was being upgraded) or links that were too long for rainfall estimation because of the distance between towers. PNG has a complex topography that includes many small islands and dispersed population clusters where links of 40 to 160 km bridge areas of connectivity.

CML data was accessed using the NMS of the hardware manufacturer, Huawei, whose links were suitable for the purposes of the project. Following a previously planned migration to an upgraded NMS, Huawei's Network Cloud Engine (NCE), data from all Huawei links could be extracted for each 15-minute interval. Subsequently, the extraction of the data to an internal server was automated using NCE, allowing rolling storage of seven days of CML data. The resulting datasets were manually transferred to the server of the KNMI once a week.

The shared datasets consisted of a set of meta-data, including the locations of transmitting and receiving towers and microwave frequencies used by the links, which was manually extracted and shared. The CML performance data, providing transmitted and received signal levels for all Huawei links at 15-minute intervals, was shared on a weekly basis with the research consortium supporting the pilot project.

Human resources: configuration of NMS and data sharing

Setting up the NMS to back up the CML data took approximately one day of the network team's capacity, including several rounds of iterations with the research consortium. During the data collection period, monitoring the process and uploading the data to the KNMI server took approximately 30 minutes a week.

3.2 Observing rainfall using CML data

Following successful extraction and sharing of the CML dataset with the research consortium, the CML data was converted into rainfall estimates using the RAINLINK algorithm. To enable a comparison, rainfall data was sourced from weather stations and satellite sources, and a comparison of the two datasets was conducted to validate the approach.

Intellectual resources: converting CML data into rainfall estimates

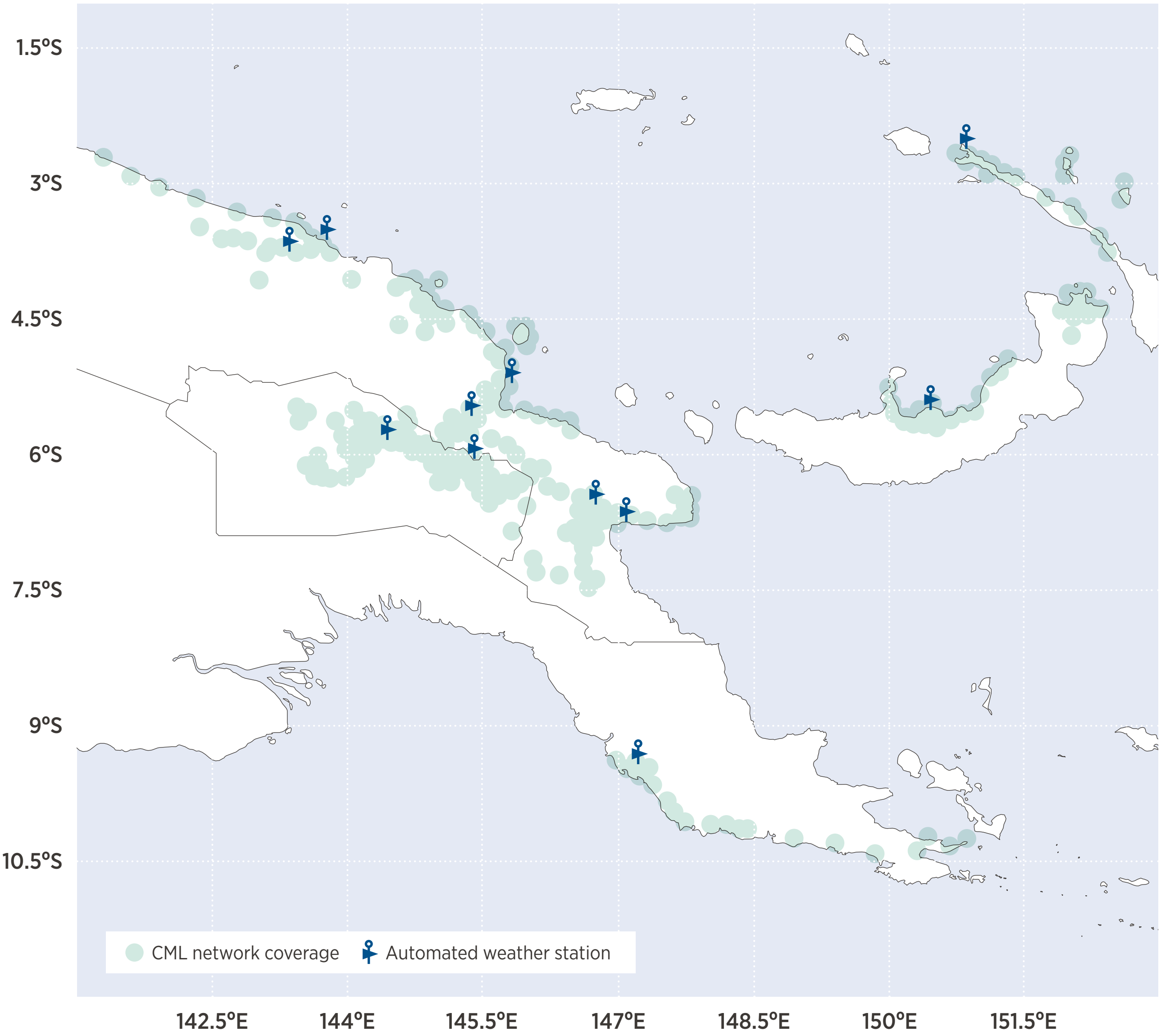
The RAINLINK algorithm was used to process the extracted CML data into rainfall observations. It followed four simple steps: 1) pre-processing of the CML data to remove unsuitable links; 2) classification of periods with and without rainfall; 3) calculation of rainfall intensity along CML paths during rainfall periods; and 4) interpolation of CML path rainfall intensities to create a gridded map of rainfall observations at a resolution of 4 km^2.

Intellectual resources: reference rainfall data

Weather station data was sourced from the PNG RSC using publicly available daily data. Of the 37 stations providing rainfall data for PNG, 11 stations were situated close enough to the CMLs to provide a direct comparison (Figure 8).

Figure 8

CML coverage and reference weather stations in PNG



Source: GSMA

The GPM[21] mission is an international mission co-led by the US National Aeronautics and Space Administration (NASA) and Japan's Aerospace Exploration Agency (JAXA) to advance precipitation estimation from space. It provides rainfall maps at a resolution of 30 minutes and grid size of 25 km^2. Its satellites have a daily overpass rate, meaning that individual locations are not continuously covered, but data is refreshed every 24 hours. Data from real-time products is provided approximately six hours after observation. Over the study period, several rainfall events were captured by both the CML and GPM data and used to make visual comparisons.

21 NASA's Global Precipitation Measurement mission (GPM): https://gpm.nasa.gov/

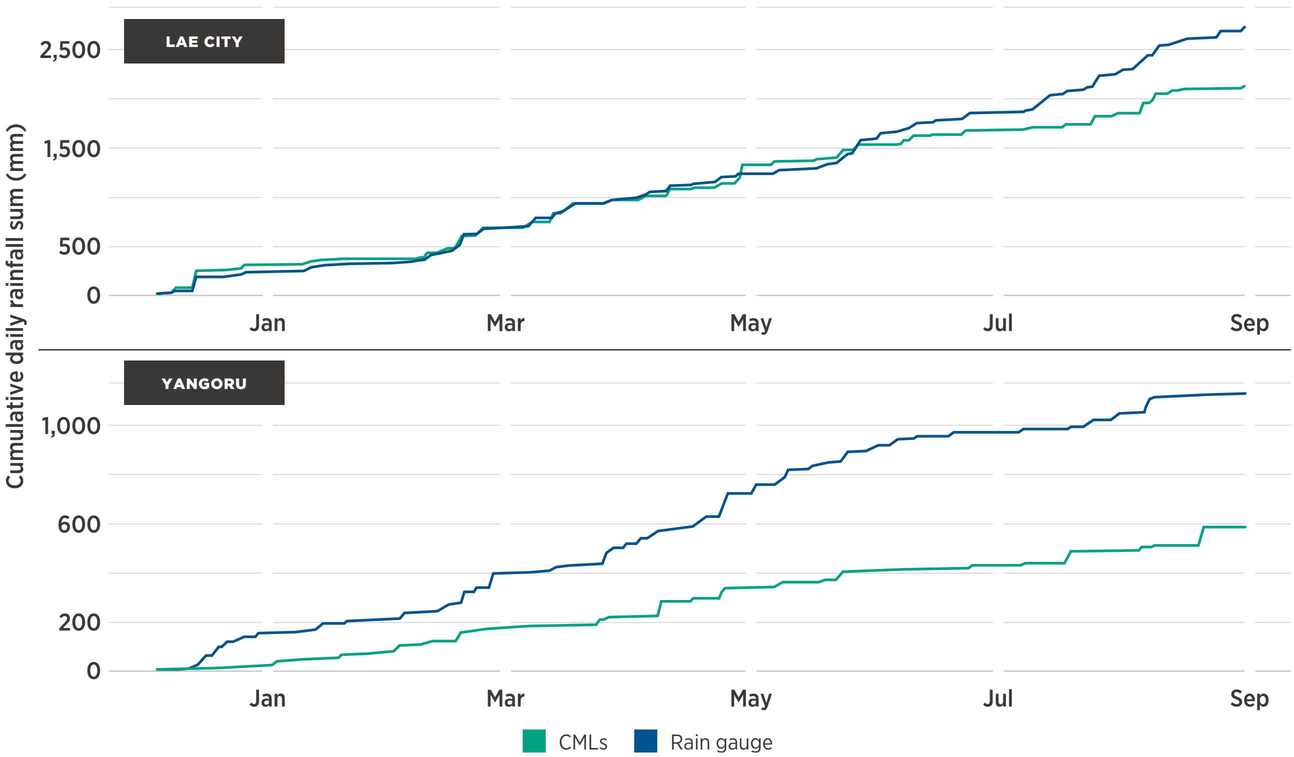
3.3 Validating CML rainfall observation in PNG

Data availability

Like most mobile networks, the Digicel network in PNG closely mirrors population density distribution, with dense networks covering urban centres and main roads that become sparser in rural regions. Steep mountain ranges and islands isolate population centres. As a result, the mobile network is fragmented into pockets of connectivity, and much of the surface area is not covered by a mobile signal. CML network coverage (Figure 8), as a subset of the wider mobile network, also follows this pattern.

Figure 9

Cumulative rainfall data comparisons



Source: GSMA

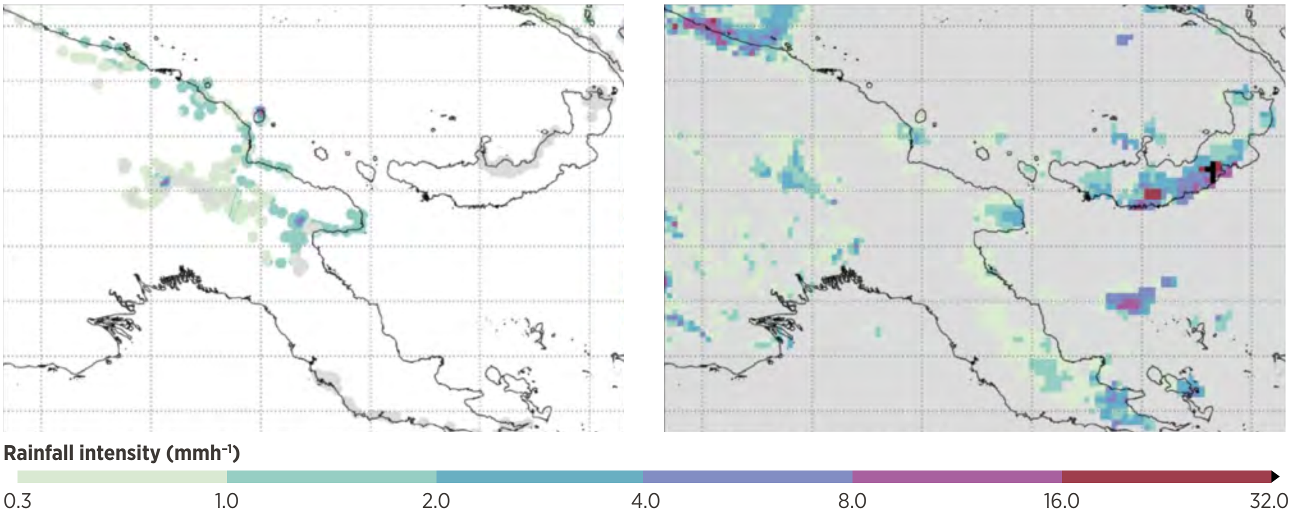
Comparison of rainfall data sources

Although the CML data compared closely with rain gauges in several locations, such as Lae City (Figure 9), the CML data generally underestimated the levels of rainfall recorded by rain gauges, as seen in Yangoru (Figure 9). This underestimate was exaggerated in locations with exceptionally heavy rainfall or in locations with relatively long links using low frequencies. For reference, the links used in Lae City have an average length of 3.5 km, while the links in Yangoru are 13.5 km, on average. The availability of reference data was further limited as several rain gauges were found to be faulty and had stopped recording data. Comparisons with satellite data (Figure 10) were generally favourable with visual agreement of overall rainfall trends. However, 24-hour satellite overpasses limit the amount of data available since rainfall events also need to occur within that window. Therefore, fewer comparison cases could be found.

Figure 10

Comparison with satellite data

CML 2020/12/21 03:00–03:15 | IMERG-f 2020/12/21 03:00–03:30



Source: GSMA

3.4 Improving CML rainfall observation in PNG

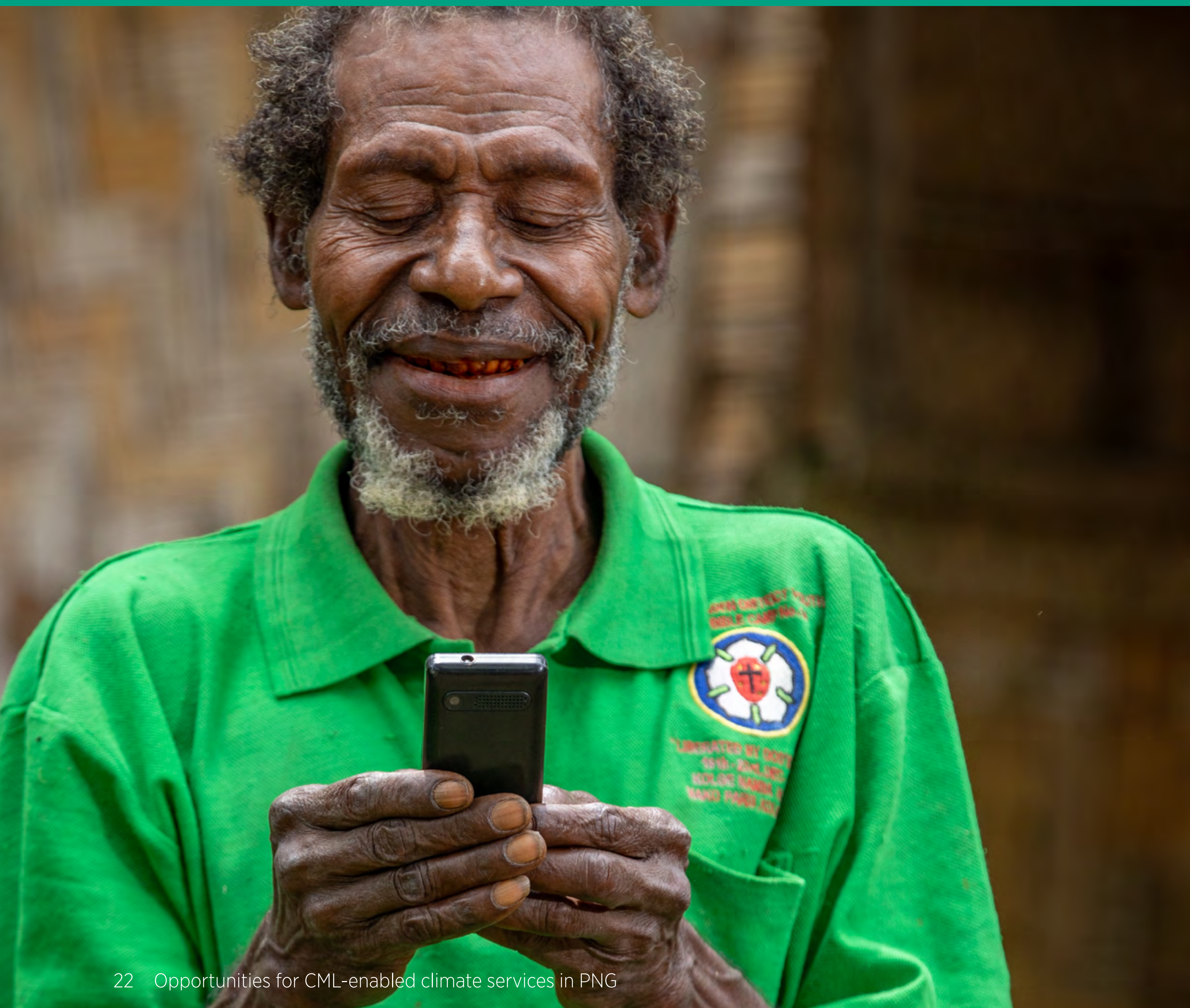
CML has strong potential to fill gaps in rainfall observation in PNG and could be optimised if some additional measures are taken. To address the underestimation of rainfall events, the rainfall calculation algorithm must be optimised to account for the heavy tropical rainfall experienced in PNG. This can be done using data on the physical characteristics of rainfall to adjust the parameters that determine rainfall quantity. The research consortium has located such a dataset and will be carrying out the optimisation as a next step in the project.

In addition to improving the accuracy of CML rainfall observations, integration with satellite data can expand the limited geographic coverage provided by CML data. By identifying relevant satellite data rainfall sources (that provide coverage for the entire country and are available continuously and in near real-time) and integrating them with CML data, there are opportunities to use the strengths of one source to alleviate the shortcomings of the other. Most importantly, CML rainfall coverage is limited to network infrastructure at the ground level, and satellite data would extend coverage to the entire country and surrounding areas. Satellite data could also help to triangulate observations from individual links, thereby extending coverage to the entire CML network without filtering out isolated links.

Conversely, CML rainfall data would provide higher resolution rainfall observations in areas of coverage where population density is also higher and, therefore, likely to be of more interest. CML data can also provide training or validation data for models that use satellite imagery for rainfall observation. Satellite observations do not measure rainfall directly; rather, they use data on cloud cover (including colour, altitude, temperature) to infer rainfall events and intensity. CML rainfall observations would provide additional input to train and optimise these models, improving rainfall data beyond the coverage of CML data.

Given the current lack of weather observations in PNG, merging CML and satellite rainfall data is a major opportunity for innovation and improvement in weather and climate services.

4
Opportunities for CML-enabled climate services in PNG



The agritech ecosystem in PNG is in an early stage, with few digital solutions providers active in the market. The Fresh Produce Development Agency (FPDA), a government agency supporting horticulture and fresh produce, provides one of the few digital advisory services: the Fresh-produce Advisory Resources and Market Information Service (FARMIS).[22]

While the development of agricultural insurance services is currently being supported by UNCDF under the STREIT[23] programme, few such services exist, let alone able to integrate CML data. No private agrometeorological[24] services were found in PNG, and the NWS is currently involved in an extensive capacity building programme with the Australian Bureau of Meteorology. As such, while CML data provides opportunities for many use cases, the most promising for PNG are rainfall nowcasting and flood and landslide early warning services. In both cases, minimal additional data is required to develop the service and delivery is possible through mobile channels alone.

4.1 Rainfall nowcasting

What is it and how does it work?

Rainfall nowcasting provides high-resolution rainfall forecasts up to six hours in advance. Rainfall nowcasts are based on high-resolution rainfall observations (typically radar) that are spatially extrapolated into the future using physics-based models or machine-learning approaches. The services are typically provided as dynamic maps that visualise the movement of predicted rainfall events, either as early warnings or as data services that can be integrated in other applications.

How does it address challenges in PNG?

Rainfall nowcasts enable users to anticipate and mitigate the risk of severe weather events. Nowcasts enable farmers to anticipate potentially damaging rainfall and take mitigating actions depending on the crops grown, stage of the cropping cycle and agricultural practices used. For example, heavy rainfall would typically delay planting or expedite harvesting of seasonal crops. Fishers can use heavy rainfall warnings to plan their activities and avoid severe weather. Nowcasting services are also relevant to mainstream audiences and across weather-sensitive sectors, such as transport, aviation, maritime, emergency services and energy management.

How can CML add value?

CML rainfall data is a key enabler for weather nowcasting services in LMICs since it is typically the only real-time data source with sufficient resolution available.[25] In countries where network coverage is relatively small compared to land area, like PNG, merging CML with satellite rainfall data (as described in section 3.4) is necessary to fill coverage gaps.

22 FARMIS: https://farmis.fpda.com.pg/
23 FAO. (n.d.). "FAO in Papua New Guinea".
24 Agrometeorological information services use scientific input from meteorology coupled with agricultural information to create information packages tailored to farmers.
25 Imhoff, R.O. et al. (2020). "Rainfall nowcasting using commercial microwave links". Geophysical Research Letters.

Developing CML rainfall nowcasting services

The development of CML-enabled nowcasting services requires an MNO, such as Digicel, to provide the CML data, and to partner with technical experts that develop the nowcasting models and implement them in an operational service. The service could then be distributed to users by the MNO as a value-added service (VAS) or through existing providers of digital agricultural advisory. Providing attractive VAS to the rural sector has been shown to increase market share and reduce churn for MNOs.[26] In the case of Digicel, VAS could encourage mobile penetration among rural communities in PNG. A partnership with an agricultural advisory service provider would provide access to an existing user base, and rainfall early warnings would be provided to the service partner on a subscription basis.

OVERVIEW OF CML NOWCASTING SERVICE

Agricultural services
Heavy rainfall early warnings

Technical partners
Nowcasting service provider
(e.g. HKV, Weather Impact, Hyds)

Service delivery
MNO (e.g. Digicel)
Government agency (e.g. Fresh Produce Development Agency, National Maritime Safety Authority), agribusiness (e.g. Olam), agritech (e.g. Farmforce)

Additional sectors
Mass media, maritime, aviation, emergency services, energy management

4.2 Flood and landslide early warnings

What are they and how do they work?

Flood and landslide early warnings integrate observational data (e.g. precipitation amounts, waterway levels) with weather forecasts and topographic information to assess the risk of floods and landslides. This information is typically provided as dynamic maps highlighting the levels of risk across the covered area. When a risk threshold is reached, warnings can be sent out to affected communities. Mobile communications are an ideal dissemination channel as they can reach all mobile phones in a given area with interactive voice calls or SMS through cell broadcast.[27]

How do they address challenges in PNG?

The highlands of PNG frequently experience inland flooding and landslides, with floods and landslides reported in Central, Morobe and Chimbu provinces over the past two years.[28] These events cause damage to property and infrastructure, displace people from their homes and can lead to fatalities. Early warnings allow people in affected areas to anticipate risk and take preventative actions to minimise losses. Disaster response agencies can use the same services to identify affected areas and mobilise aid earlier.

26 GSMA. (2015). "Case Study: Vodafone Turkey Farmers' Club".
27 GSMA. (2015). Disaster Response: DEWN – Dialog's Disaster and Emergency Warning Network.
28 FloodList: https://floodlist.com/tag/papua-new-guinea

How can CML add value?

Rainfall data is a key input for flood and landslide modelling. CML rainfall observations are unique in PNG as they provide high-resolution data for covered areas and near real-time availability. Due to the presence of mobile networks in the more populated areas of PNG, CML data can provide coverage in areas where flood and landslide events would have the greatest impact. By merging CML with satellite rainfall data, this coverage can be extended to more remote areas. While rainfall data is a key input, other data sources, including water levels in waterways and topographic features, are also required and will determine whether it is feasible to provide services effectively.

Developing CML-enabled early warning systems

Developing early warning systems will require partnerships with technical experts that can source the necessary data and carry out the modelling, which can be either private consultancies or public agencies. Warnings can be transmitted through the MNO network, using SMS or interactive voice response (IVR) in combination with cell broadcast.[29] Partnerships with relevant public agencies in PNG would enable warnings to be provided as a public service, with the MNO providing the rainfall data on a subscription basis or as part of a corporate social responsibility (CSR) initiative. The same service can be tailored to specific sectors and monetised under a subscription model.

OVERVIEW OF FLOOD AND LANDSLIDE EARLY WARNINGS

Agricultural services

Flood and landslide early warnings

Technical partners

Flood and landslide service provider (e.g. HKV, JBA risk management)

Service delivery

MNO (e.g. Digicel)
NWS, Department of Agriculture and Livestock (DAL)

Additional sectors

Mass media, transport, emergency services, energy management, humanitarian

29 Cell broadcast is a method of targeting all mobile phone users in a given area.

5 Recommendations for future activities

CML data has shown potential to add value to rainfall nowcasting and flood and landslide early warnings, services critical to improving the climate resilience of at-risk communities and weather-sensitive sectors, such as agriculture.

In the long term, CML rainfall data can contribute to agri-intelligence services, climate-smart agricultural advisory services and agricultural index insurance services as these industries grow and mature.

In the short- to medium-term, we recommend the following activities to develop the technical approach and explore opportunities for service provision.

TECHNICAL WORK

- The CML rainfall observation approach is sensitive to both the type of rainfall and the characteristics of the CML network. Additional work should be conducted to tailor rainfall observation to the specific measurement context. This is especially relevant in PNG due to its exceptionally heavy rainfall, many microclimates and unique CML network structure.
- The integration of satellite and CML data is an untapped opportunity to realise synergies between the two datasets. Satellite data can be used to fill gaps in CML data coverage and provide a reference point to verify observed rainfall events in areas with few links. CML data can increase the resolution of satellite rainfall data in coverage areas and provide a training dataset to optimise satellite rainfall observation models. Additional research is needed to unlock these synergies.
- Development of CML-enabled climate services requires a near real-time data service that processes CML data into rainfall estimates and makes them accessible through APIs. This service can be hosted by the MNO or a third party receiving the CML data. Additional software will need to be implemented within the MNO's network to access the relevant CML data and make this available to the near real-time service.

COMMERCIAL WORK

- More work is needed to assess the opportunity for rainfall nowcasting and flood and landslide early warnings. To maximise the potential of these services to increase the resilience of vulnerable communities to weather hazards, they can be provided as public services through relevant public organisations. Opportunities for collaboration between Digicel and the PNG National Disaster Centre and PNG NWS should be sought in the provision of these services. Areas of interest would be coastal areas with high levels of maritime activity, such as the Torres Strait, or areas with high levels of agriculture activity such as Morobe Province.

GLOSSARY

Agribusiness
Formal buyers, traders or exporters of agricultural produce, as well as input suppliers.

Agricultural value chain
The actors and activities that bring a basic agricultural product from production in the field to final consumption, with value added to the product at each stage. The value chain can involve processing, packaging, storage, transport and distribution, and can be formal or informal depending on the strength of the relationship between farmers and buyers.

Agritech
A company providing technology-based solutions to increase efficiency, transparency and profitability in agriculture. In this report, we refer to agritech companies or agritechs as the providers of digital agriculture services. Fintech companies providing digital financial services to farmers or other players in the ecosystem are also included in this category.

Agrometeorological information services
Information packages tailored to farmers using weather and climate data and forecasts coupled with agricultural information.

Algorithm
A sequence of well-defined instructions used to solve a problem or perform a computation.

Application programming interface (API)
A software program that makes it possible for the application programs of different organisations to speak a common technical language, interact and share data and functionality.

Automated weather station (AWS)
A system of integrated components that automatically measure, record and sometimes transmit weather data, most commonly: temperature, wind speed, wind direction, precipitation, humidity, solar radiation and atmospheric pressure.

CML devices
Electronic devices that use microwave radio signals to transmit and receive data wirelessly.

Commercial microwave links (CMLs)
Close-to-the ground radio connections used worldwide in cellular networks to connect mobile base stations to the wider network where cabled connections are not viable.

Mobile backhaul network
The connections between the base stations and the core of a mobile network.

Mobile network
A communications network spread over a land area and connected wirelessly by transceivers at fixed locations known as base stations.

Rainfall/precipitation nowcasting
High-resolution forecasts of rainfall made up to six hours in advance using high-resolution rainfall observations (typically radar) that are extrapolated into the future using physics- or machine learning-based approaches.

Smallholder farmers
Farmers in LMICs who produce crops or livestock on two-hectare plots of land or less.

Spatial interpolation
The process of using points with known values to estimate values at other points.

(Mobile) value-added services (VAS)
Services that complement a mobile network operator's core voice, SMS and data connectivity services.

Weather radar
A detection system that uses radio waves to locate precipitation, calculate its motion and estimate its type (rain, snow, hail, etc.)

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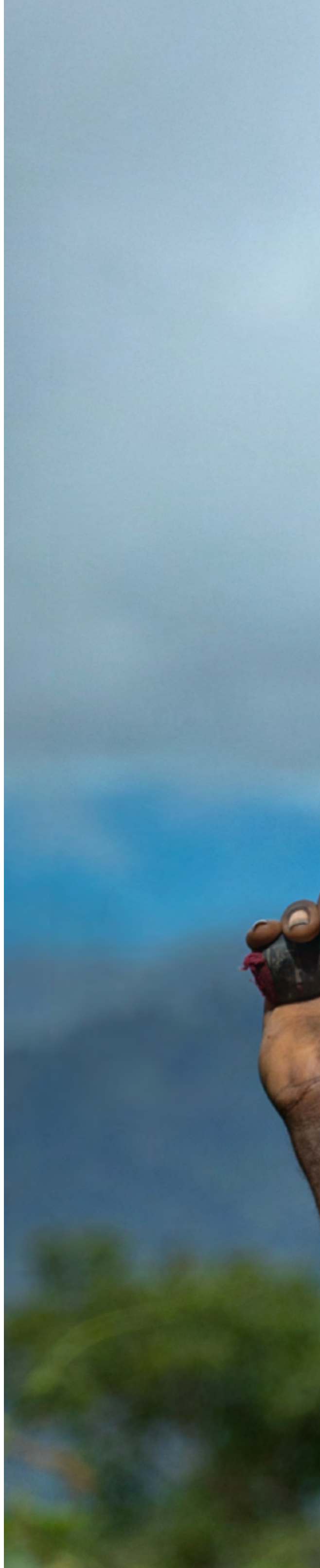

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